Technical Memorandum Report

Greater Lawrence Sanitary District

Organics to Energy Feasibility Study

June 2013

CDM Smith

Table of Contents

Technical Memorandum No. 1 - Project Project Information ..... TM 1-1

1.1 Facility Background ..... TM 1-1
1.1.1 Treatment Facility History ..... TM 1-1
1.1.2 Anaerobic Digestion Facility History ..... TM 1-2
1.2 Project Goals ..... TM 1-3
1.2.1 Study Background ..... TM 1-3
1.2.2 General Scope of Work ..... TM 1-3
1.3 Massachusetts Clean Energy Center (MassCEC) Grant ..... TM 1-4
1.4 Study Organization ..... TM 1-4

Technical Memorandum No. 2 - Description of Existing Facilities and Operations Issues ..... TM 2-1

2.1 Sludge Thickening ..... TM 2-1
2.1.1 Gravity Thickeners ..... TM 2-1
2.1.2 Gravity Belt Thickeners ..... TM 2-4
2.2 Sludge Digestion ..... TM 2-5
2.2.1 Effective Tank Volume ..... TM 2-5
2.2.2 Design P Parameters and Operating Results ..... TM 2-5
2.2.3 Ancillary Digestion Equipment ..... TM 2-7
2.2.4 Digester Foaming ..... TM 2-8
2.3 Sludge Dewatering ..... TM 2-9
2.4 Thermal Drying ..... TM 2-10
2.5 Odor Control ..... TM 2-10
2.6 Biogas Utilization ..... TM 2-11
2.6.1 Production and Metering ..... TM 2-12
2.6.2 Biogas Safety Equipment ..... TM 2-13
2.6.3 Foam, Moisture and Sediment Removal ..... TM 2-14
2.6.4 Biogas Treatment ..... TM 2-14

Technical Memorandum No. 3 - Sludge and Biogas Production Estimates ..... TM 3-1

3.1 Summary of Current Operational Data ..... TM 3-1
3.2 Year 2025 Expected Production ..... TM 3-1
3.3 Estimate of Available Capacity Available for Outside Waste ..... TM 3-2
3.4 Future Potential Biogas Production ..... TM 3-5
3.5 Current and Future Energy Balance ..... TM 3-8
3.5.1 Current Energy Use ..... TM 3-8
3.5.2 Future Projected Energy Balance ..... TM 3-10

Technical Memorandum No. 4 - Outside Wastes Evaluation ..... TM 4-1

4.1 Types of Outside Wasters ..... TM 4-2
4.2 Industry Experience with Co-Digestion ..... TM 4-4
4.2.1 National Experience with Co-Digestion TM4-4
4.2.2 Regional Experience with Co-Digestion ..... TM 4-6
4.3 Ongoing Waste Characterization and Co-Digestion Studies ..... TM 4-8

4.4 Private Sector Role in Co-Digestion at GLSD ..... TM 4-9
4.4.1 Preprocessing Facilities TM4-9
4.4.2 Private Hauler Contractual Considerations ..... TM 4-10

Technical Memorandum No. 5 - Digestion, Co-Digestion and Biogas Utilization Improvements TM 5-1

5.1 Digestion Pretreatment and Receiving ..... TM 5-2
5.2 Digester Modifications ..... TM 5-4
5.3 Foam Containment ..... TM 5-6
5.4 Biogas Utilization Options ..... TM 5-7
5.4.1 Biogas Quantities Available for Cogeneration ..... TM 5-7
5.4.2 Cogeneration Technology Alternatives ..... TM 5-9
5.4.3 Cogeneration Technology Selection and Sizing ..... TM 5-11
5.4.4 Biogas Treatment Systems ..... TM 5-12
5.4.5 Biogas Storage Systems ..... TM 5-15
5.5 Downstream Considerations ..... TM 5-17
5.5.1 Dewatering and Drying Implications ..... TM 5-17
5.5.2 Side Stream Considerations ..... TM 5-17
5.6 Summary of Impacts to Existing System ..... TM 5-18

Technical Memorandum No. 6 - Regulatory and Permitting Trends and Issues ..... TM 6-1

6.1 Regulatory Trends ..... TM 6-1
6.1.1 National Regulatory Trends ..... TM 6-1
6.1.2 State Regulatory Trends ..... TM 6-2
6.1.3 Local Regulatory Trends ..... TM 6-4
6.2 Anticipated Permitting Requirements ..... TM 6-5
6.2.1 MassDEP and Board of Health Approvals ..... TM 6-5
6.2.2 Air Quality Permitting ..... TM 6-5
6.2.3 Wetland Resources ..... TM 6-6
6.2.4 Planning and Zoning ..... TM 6-6
6.2.5 Local Building Permits ..... TM 6-7
6.2.6 Flood Protection ..... TM 6-7
6.2.7 Stormwater ..... TM 6-7
6.2.8 Other Potential Permits ..... TM 6-7

Technical Memorandum No. 7 - Recommended Improvements for Further Consideration ..... TM 7-1

7.0 Recommended Improvements for Further Consideration ..... TM 7-1
7.1 Summary of Impacts and Improvements ..... TM 7-1
7.2 Conceptual Life Cycle Costs and Energy Benefits ..... TM 7-3
7.2.1 Capital Cost Estimates ..... TM 7-3
7.2.2 Operation and Maintenance Costs ..... TM 7-5
7.2.3 Combined Heat and Power Energy Benefits ..... TM 7-7
7.3 Summary of Financial Analysis ..... TM 7-14
7.4 Demonstration Testing ..... TM 7-15

List of Figures

Figure 2-1 Existing Biosolids Treatment Train Schematic ..... TM 2-2
Figure 3-1 GLSD Codigestion Evaluation - Conceptual Existing Heat Balance ..... TM 3-9
Figure 4-1 Permitted Food Residuals Processors throughout MA *(courtesy of MassDEP)* TM4-3
Figure 5-1 Existing and Future Potential GLSD Digestion Facility Layout ..... TM 5-5
Figure 5-2 Gutter Containment System Section Schematic ..... TM 5-6
Figure 5-3 GE Jenbacher 850 kW IC Engine ..... TM 5-11
Figure 5-4 Representative Siloxane Treatment Vessels ..... TM 5-13
Figure 5-5 Representative Biogas Booster System ..... TM 5-14
Figure 5-6 Typical Gas Membrane Storage System *(Figure Courtesy of WesTech)* ..... TM 5-15

List of Tables

Table 2-1 Design and Current Gravity Thickener Loading Rates ..... TM 2-2
Table 2-2 Design and Current Gravity Belt Thickener (GBT) Loading Rates ..... TM 2-4
Table 2-3 Design and Current Anaerobic Digester Loading Rates ..... TM 2-6
Table 2-4 Design and Current Gravity Belt Thickener (GBT) Loading Rates ..... TM 2-9
Table 2-5 Biofilter Design Air Flow Rates Table 5-1 Insert Table title Here ..... TM 2-11
Table 2-6 Biogas Production and Utilization ..... TM 2-13
Table 3-1 2025 Projected Population and Average Solids Loading ..... TM 3-2
Table 3-2 Current, Future and Excess Digestion Capacity ..... TM 3-4
Table 3-3 Current Biogas Production ..... TM 3-6
Table 3-4 Theoretical Potential Biogas Production - With System Growth and SSO Acceptance ..... TM 3-6
Table 3-5 Theoretical Potential Biogas Production - Without System Growth and With SSO Acceptance ..... TM 3-7
Table 3-6 Theoretical Potential Biogas Production - Without System Growth, With SSO Acceptance and With 4th Digester ..... TM 3-7
Table 3-7 Current and Future Energy Balance ..... TM 3-8
Table 4-1 Survey of Source Separated Organics Generators ..... TM 4-3
Table 4-2 Generator Size Distribution ..... TM 4-3
Table 4-3 New England WWTF with Anaerobic Digesters ..... TM 4-7
Table 5-1 Energy Available for CHP ..... TM 5-8
Table 5-2 Reciprocating Engine Selection ..... TM 5-12
Table 5-3 Siloxane Treatment Skid Sizing ..... TM 5-14
Table 5-4 Estimated Additional Biogas Storage Requirements ..... TM 5-16
Table 5-5 Potential Impact of SSO on Secondary Aeration ..... TM 5-18
Table 5-6 Summary of Co-Digestion Alternatives Impacts ..... TM 5-19
Table 6-1 U.S. EPA Emissions Standards for Stationary Digester Gas Engines ..... TM 6-6
Table 7-1 Summary of Co-Digestion Process Parameters ..... TM 7-2
Table 7-2 Summary of Co-Digestion Capital Improvements and Operational Impacts ..... TM 7-2
Table 7-3 Potential Impact of SSO on Downstream Solids Treatment Costs ..... TM 7-6
Table 7-4 Future With System Growth and Without Additional Biogas Storage TM7-8
Table 7-5 Future with System Growth and With Additional Biogas Storage ..... TM 7-9
Table 7-6 Future Without System Growth and Without Additional Biogas Storage ..... TM 7-10

Table 7-7 Future Without System Growth and With Additional Biogas Storage .... TM 7-11
Table 7-8 Future Without System Growth, Without Additional Biogas Storage and With 4th Digester .... TM 7-12
Table 7-9 Future Without System Growth, With Additional Biogas Storage and With 4th Digester .... TM 7-13
Table 7-10 GLSD Co-Digestion Financial Feasibility Summary .... TM 7-15

Greater Lawrence Sanitary District Organics to Energy Feasibility Study

Executive Summary

Introduction and Background

MassDEP has proposed a ban on the disposal of source separated organics (SSO) in landfills and incinerations for commercial wastes. Regulations resulting from this ban are expected to be implemented in mid-2014, at which time, approximately 1,000 wet tons per day (wtpd) of SSO would be diverted from landfills and incinerators state-wide to recycling facilities such as anaerobic digestion or composting facilities.

Acceptance of additional organic loading to the Greater Lawrence Sanitary District (GLSD) anaerobic digesters would result in the production of additional digester gas. This gas could then be utilized as an energy source though the use of a biogas fired Combined Heat and Power (CHP) system. The ability to accept new organics for treatment would also provide a new source of revenue to support the operation of the District. This study was completed to provide the GLSD a better understanding of the costs, risks and benefits of accepting additional source separated organic (SSO) materials prior to committing to any such program.

Existing Facilities and Operations Issues

The GLSD solids treatment train currently consists of thickening, anaerobic digestion, dewatering and thermal drying processes. As part of the current study, the design capacity and current utilization of these existing systems was evaluated for its ability to accept organic waste. The following summarizes the findings of this evaluation:

- Primary Sludge Thickening: Primary sludge from the primary clarifiers is pumped to one of four 45-foot gravity thickeners which are original to the facility. Based on recent data, the thickeners appear to be loaded at a maximum of approximately 7.6 lbs/sf/day which is well under the industry recommended design criteria of 20 Ibs/sf/day.

- Waste Activated Sludge Thickening: Waste activated sludge (WAS) from the secondary treatment train is conveyed to one of two gravity belt thickeners (GBTs) installed in 2002. The current average and maximum loading to a single GBT is approximately 420 and 550 gpm, which is well within recommended operating ranges for this type of equipment.

- Digestion Tanks: The 2002 solids train upgrade included the installation of three anaerobic digestion tanks with dimensions of 85-feet diameter and 38.5-feet sidewall depth which equates to a total storage volume of 4.9 million gallons (MG) for all three tanks. As detailed further below, the digestion process is believed to be currently loaded at 85-percent capacity with the ability to accept an average of 28,000 gallons of additional outside waste per day.

- Dewatering: The existing system utilizes 2 (1 duty 1 standby) horizontal solid bowl style centrifuges. The units are currently operated at a feed rate of 180 gpm (within the design average) and exhibit an average solids capture of approximately 83%. Though the District is currently attempting to improve capture efficiency through operational adjustments, the system contains adequate capacity to process additional digestate from the digestion process.

- Thermal Drying: The thermal drying facility contains a processing capacity of 38 dry tons per day. Recent operations records indicate an average daily processing of 13 dry tons per day, showing that significant excess capacity exists for waste processing.

Acceptance Scenarios and Recommended Improvements

The GLSD anaerobic digestion facility currently accepts an average of 164,000 gal/day of primary and waste activated sludge. Based on the capacity of the existing digestion system, the facility is capable of processing an average of 192,000 gal/day. As a result of the potential desire to reserve some of this capacity for future growth within the service area, as well as the possibility of constructing a 4th anaerobic digester at the site, this study evaluated three scenarios to represent the bounds for SSO acceptance volumes. In general, the SSO acceptance alternatives included the following:

Available Capacity With Growth

Under this alternative, the current excess digestion capacity would be utilized for SSO acceptance (18,500 gal/day) with the exception of a small portion of the capacity (9,500 gal/day) that would be reserved for future growth within the municipal collection system. Under these conditions, the overall digestion process would not change substantially as this additional volume represents less than 10% of the future/full design loading to the digestion system. With the exception of foam control, it is likely that only limited infrastructure improvements would be required to accept and process this waste. However, this alternative is likely to yield an increase in biogas production on the order of 50% above current levels. As a result, substantial investment in biogas utilization systems would be required to harness this resource.

Available Capacity Without System Growth

The second alternative has assumed that all existing available capacity would be utilized for SSO processing. Under this assumption, the capacity available to outside wasters would equate to approximately 28,000 gal/day which represents approximately 15% of the total processing capacity. Similar to the previous alternative, the significant improvements required to process this waste while realizing the benefit of the expected 70% increase in biogas production would include foam control and biogas utilization systems.

Available Capacity Without System Growth and With 4th Digester

This alternative evaluates the maximum theoretical amount that might be accepted at the GLSD facility utilizing the current digestion complex layout. This further assumes that the 4th anaerobic digester tank along with the required ancillary equipment were to be constructed in the area reserved for future anaerobic digestion facility expansion. Under this scenario, the total system capacity would be increased to approximately 256,000 gal/day while the existing municipal load (at its current level) would only utilize 64% of this capacity. The remaining capacity would be capable of processing approximately 92,000 gal/day. In addition to the above process considerations, significant facility upgrades would be required to handle the 230% increase in biogas production and downstream dewatering and drying modifications may be required to handle the 100% increase in post digestion solids that would result. It should also be noted that this quantity of SSO (140,000 tons per year) equates to approximately 40% of the total SSO wastes projected by MassDEP to be diverted from landfills and incinerations state-wide in 2020.

Table ES-1 summarizes some of the key expected process performance values under average annual conditions associated with each of these options. Table ES-2 provides an overview of the capital improvements recommended and operational impacts under each scenario.

	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
SSO Quantity Received (gal/day)	18,000	28,000	92,000
SSO Quantity Received (dry lb/day)	20,000	30,000	100,000
Additional Biogas Produced (cf/day)	190,000	288,000	946,000
Net Available Biogas for Cogeneration (cf/day)	146,000	213,000	682,000
Net Electrical Production w/out Biogas Storage (kW)	600	731	2,029
Net Electrical Production w/Biogas Storage (kW)	707	868	2,409
Excess Heat from Cogeneration w/out Biogas Storage (MMBtu/hr)	(1.00)	(0.43)	3.95
Excess Heat from Cogeneration w/out Biogas Storage (MMBtu/hr)	(0.53)	0.16	5.59
Increase in Process Oxygen Requirement from Side Stream (%)	1.4%	2.2%	7.4%
Increase in Solids to Downstream Dewatering and Drying (DT/day)	3	5	15

Table ES-1
Summary of Co-Digestion Process Parameters

Capital Improvement	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Digester cleaning and foam control	√	√	√
External draft tube leak issue resolution	√	√	√
Biogas metering and monitoring repairs	√	√	√
Additional outside waste receiving station			√
New outside waste blending tank and mixing system	√	√	√
New high pressure digester feed pumps	√	√	√
New anaerobic digester tank (1.4 MG)			√
New ancillary digestion equipment (HEX, pumps, mixers)			√
Upgraded biogas collection, flare and safety equipment			√
Biogas storage system	O	O	O
New biogas siloxane treatment	√	√	√
New cogeneration engines	√	√	√
Operational Impacts			
Increase in load to dewatering and drying	√	√	√
Increased secondary aeration	√	√	√
Biogas utilization system maintenance	√	√	√
Additional staffing for receiving operations			√

O = Optional

Table ES-2
Summary of Co-Digestion Capital Improvements and Operational Impacts

Conceptual Life Cycle Costs and Energy Benefits

To compare relative costs and benefits of the alternatives, estimates of probable project cost were developed for each of the improvements noted in Table ES-2. In addition, the associated operations costs impacts were quantified. All capital costs include a 25% allowance for project contingencies and an additional 25% for engineering of the associated improvements. As summarized in Table ES-3, the total annual net cost of implementing co-digestion is estimated to range from $385K to $1.05M before accounting for tipping fee revenues. At these costs and assumed SSO quantities, the break-even tipping fee would equate to between $0.02 and $0.07 per gallon (or $6 to $16 per wet ton received). These potential fees are in line and slightly less than fees charged at other facilities and less than what is currently charged for outside waste receiving at GLSD (currently $0.05 to $0.10 per gallon depending on material and source). For comparison, other New England wastewater treatment facilities accepting wastes directly to digesters typically charge between $0.05 and $0.10 per gallon – similar to GLSD.

It is also important to note that discussions with national private haulers during the course of this study indicated that tipping fees for organic waste in other parts of the country are commonly in the range of $30 to $40 per wet ton. As shown in Table ES-3, if this rate were to be charged for SSOs at GLSD, the net annual revenue would equate to an estimated surplus between $380K to $3.4M. As an additional point of comparison, Table ES-3 also includes the estimated total electrical production from the CHP system as a percentage of total current plant-wide power use.

As shown in Table ES-3, the largest of the waste acceptance options (construction of a 4th digester) brings with it the largest potential annual surplus along with the largest offset of plant power consumption. However, due to the significant capital cost required for the 4th digester, the “Future Without System Growth and With Additional Biogas Storage” option which maximizes the use of existing infrastructure yields a comparable breakeven tip fee. As a result of this, along with the inherent risk related to waste availability and the expected variability in the market for this material in the Commonwealth over the coming few years, it is likely in the District’s best interest to pursue a co-digestion option which maximizes the existing infrastructure while adding biogas storage and cogeneration facilities. This path would not preclude the future development of the 4th digester in the event the organic waste market was to prove to be a viable, long-term source of revenue.

Demonstration Testing

The co-digestion of wastewater solids and other organic wastes is not common in the U.S. However, it is an expanding practice that has been proven successful by several large wastewater utilities that have taken in compatible outside wastes and co-digested them with wastewater solids to significantly increase digester gas production. GLSD is considering co-digestion at its facility and, as shown in this study, could realize a significant economic and environmental benefit through implementing a co-digestion program dependent on the market-driven tip fee that could be charged for outside organic waste. As a next step in implementation of this program, it is recommended that pilot testing be performed to determine the co-digestibility of organic waste at the GLSD facility though limited receipt and introduction of organic waste into the GLSD digestion system.

	Annual Cost Excluding Tip Fee	Annual SSO Received (gal/day)	Break Even Tip Fee ($/gal)	Break Even Tip Fee ($/WT)	Annual Surplus @ $30/WT Tip Fee	Plant-Wide Power Offset from CHP
Future With System Growth Without Additional Biogas Storage	$442,000	18,000	$0.067	$16.13	$380,000	26%
Future with System Growth With Additional Biogas Storage	$385,000	18,000	$0.059	$14.05	$437,000	30%
Future Without System Growth Without Additional Biogas Storage	$398,000	28,000	$0.039	$9.33	$881,000	31%
Future Without System Growth With Additional Biogas Storage	**$273,000**	**28,000**	**$0.027**	**$6.40**	**$1,010,000**	**37%**
Future Without System Growth, Without Additional Biogas Storage With 4th Digester	$1,050,000	92,000	$0.031	$7.50	$3,150,000	87%
Future Without System Growth, With Additional Biogas Storage With 4th Digester	$777,000	92,000	$0.023	$5.55	$3,420,000	104%

* Negative values in above table indicate financial credit

Table ES-3

GLSD Co-Digestion Financial Feasibility Summary

Technical Memorandum No. 2

From: *Benjamin R. Mosher, P.E., BCEE*

Date: *November 2, 2012*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Description of Existing Facilities and Operations Issues*

2.0 Description of Existing Facilities and Operations Issues

As discussed within Technical Memorandum (TM) No. 1, the GLSD solids treatment train currently consists of thickening, anaerobic digestion, dewatering and thermal drying processes. The sequence of these stages is shown in Figure 2-1. The purpose of this memorandum is to document the design capacity and current operations/utilization of these existing systems. The design capacity of the systems discussed herein is based upon information obtained from work completed during the 2002 solids train upgrade while the assessment of current operations is based on discussions with GLSD staff as well as 12-months of plant operations data during the period between September 2011 and August 2012.

2.1 Sludge Thickening

Under normal operating conditions, the primary sludge from the primary clarifiers is pumped to one of four gravity thickeners while the waste activated sludge (WAS) from the secondary treatment train is conveyed to one of two gravity belt thickeners. In addition, the District has the ability to convey WAS to the primary clarifiers where it is co-settled with the primary sludge. This ability to co-settle sludge is currently exercised during the cold weather months (approximately December to March).

2.1.1 Gravity Thickeners

The GLSD facility utilizes four, 45-foot diameter gravity thickeners. Though these thickeners are original to the original 1971 facility, odor control covers were added to these tanks during the 2002 upgrade.

Industry guidelines for recommended maximum loading of gravity thickeners suggest a range of 20 to 30 lbs/sf/day. As shown in Table 2-1, the design year values used during the 2002 upgrade design equated to a maximum loading of approximately 18 lbs/sf/day with 3 units in service.

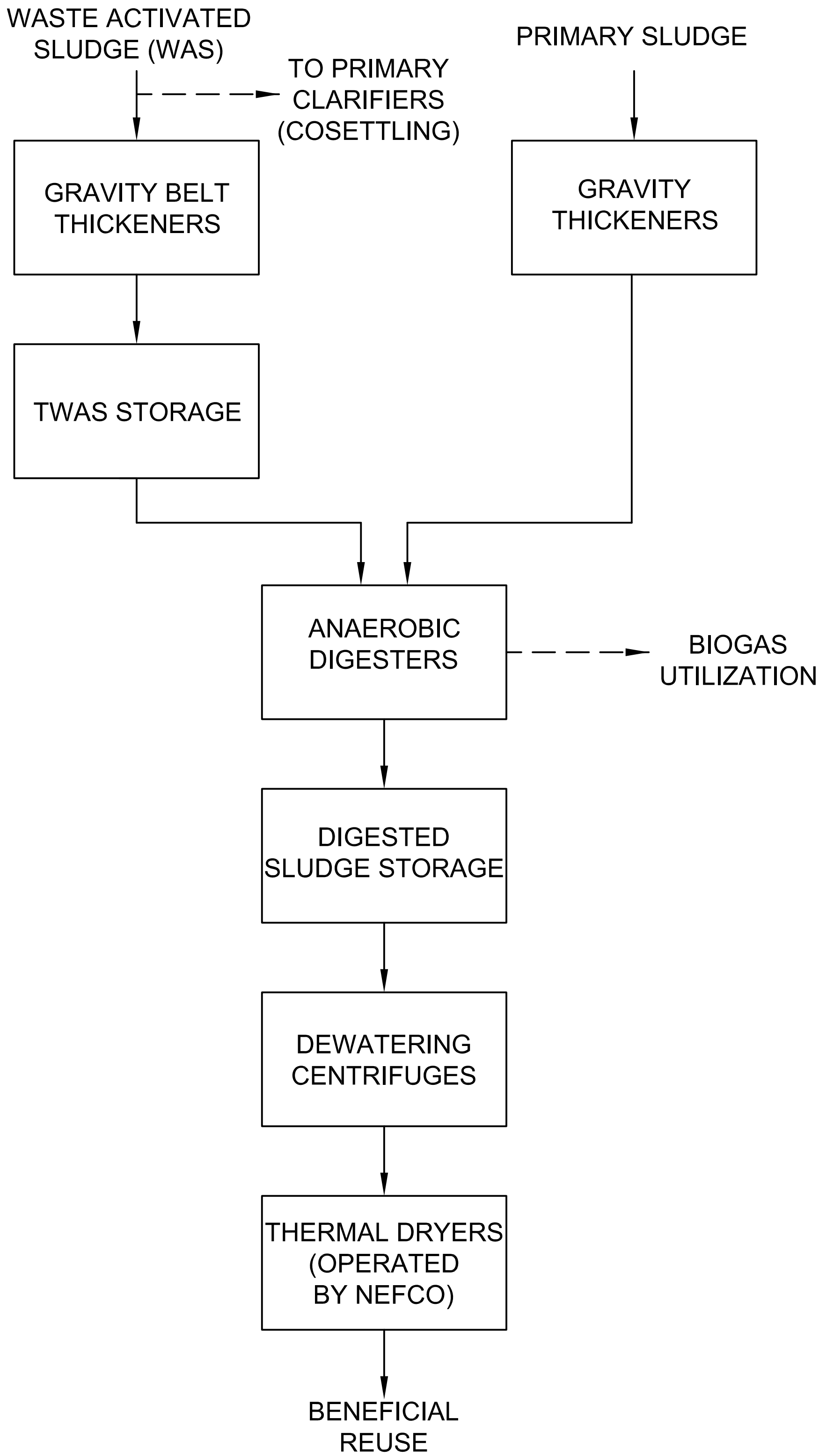

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Figure No. 2-1
Greater Lawrence Sanitary District
Existing Biosolids Treatment Train Schematic
November 2012

Based on plant records collected during co-settling operations, recent flow to the gravity thickeners averaged approximately 1.5 mgd at a solids concentration of 2,900 mg/l. Utilizing 3 of the 4 gravity thickeners for this loading would translate to a loading rate of approximately 7.6 lbs/sf/day. Though a comparison of existing and future maximum day loadings to this system was not possible due to the limited data set, the current average loading is well within the recommended design criteria of 20 Ibs/sf/day while allowing one unit to be out of service. As such, the capacity of this system is unlikely to be a limiting factor with respect to acceptance of additional outside waste into the GLSD biosolids treatment system.

Condition	Loading			
	gal/day at 0.3% solids	lbs/day	lbs/sf/day with 3 units in service	lbs/sf/day with 4 units in service
2016 Design Average	—	61,600	12.9	9.7
2016 Design Maximum	—	86,200	18.1	13.6
Current Average (Standard & Co-settling Conditions)	1,507,000	36,400	7.6	5.7

Table 2-1
Design and Current Gravity Thickener Loading Rates

2.1.2 Gravity Belt Thickeners

As part of the 2002 upgrade, two 3-meter gravity belt thickeners were installed for the purpose of thickening the secondary waste activated sludge. Both GBTs are currently located within an enclosed room inside the dewatering room, adjacent to the centrifuges.

Industry recommended GBT hydraulic loading rates for WAS thickening applications range between 200 – 300 gpm/meter of belt width with recommended solids loading rates of up to 1,000 lbs/hr/meter. When operating properly using adequate polymer dosing, solids capture of over 95% is achievable for WAS thickening applications. Using these values, a single GBT at the GLSD facility would theoretically be capable of thickening 3,000 lbs./hr of WAS at 900 GPM. It should also be noted that the ability to co-settle at the GLSD facility is considered back-up for the GBT thickening process and therefore, standby units are not considered a significant concern.

Based on 2002 design data, it appears that the maximum deign year loading using both units was intended to be approximately 438 gpm per unit. Upon review of recent operating data, it was determined that the current average and maximum loading to a single GBT has been approximately 420 and 550 gpm. Assuming the use of both existing units as duty units (co-settling as a standby), all values appear to be well within recommended operating ranges for this type of equipment.

Condition	Sludge Production (gpd)	Loading per unit with both units online (gpm)
2016 Design Year Average	862,800	313
2016 Design Year Maximum	1,207,900	438
Current Average Day	1,158,000	420
Current Max Day (95th percentile)	1,521,000	550

Note: Above values assume average operating time of 23 hr/day.

Table 2-2
Design and Current Gravity Belt Thickener (GBT) Loading Rates

2.2 Sludge Digestion

2.2.1 Effective Tank Volume

The most significant portion of the 2002 solids train upgrade was the installation of three anaerobic digestion tanks. The tanks were installed with dimensions of 85-feet diameter and 38.5-feet sidewall depth which equates to a total storage volume (excluding the bottom cone) of 4.9 million gallons (MG) for all three tanks.

Industry guidelines recommend that digester sizing include a 10% allowance for grit accumulation (in addition to the digester cone volume, which is not considered part of the digester working volume). Further, the GLSD tanks were designed with 5 feet of freeboard due to requirements associated with the cover system which is also not considered usable volume. With consideration of these two factors, the total theoretical effective working volume equates to 3.84 MG (1.28 MG/tank).

It should be noted that GLSD plant is served by a combined collection system and, therefore, experiences a significant grit loading. Though the District installed a new aerated grit removal system in 2007, the digestion tanks have not been removed from service and dewatered since 2002 and the level of accumulated grit within the system is currently unknown. Despite this, for the purpose of this study, it is assumed that the mixing system currently installed in the tanks is working properly and the accumulated grit does not exceed the volume of the tank cones plus 10% of the remaining volume as noted above.

It is also important to note that open land area currently exists within the anaerobic digestion facility to support a fourth anaerobic digester tank. As the construction of this fourth tank would allow for significant acceptance of outside waste, this potential will be further discussed in subsequent memoranda.

2.2.2 Design Parameters and Operating Results

Anaerobic digesters are primarily sized based upon solids retention time (SRT) and hydraulic retention time (HRT). Because the GLSD digestion system (like most high-rate digestion systems) does not include provisions for supernatant decant, SRT is equivalent to HRT for this application and, therefore, these terms can be used interchangeably.

Industry guidelines and CDM Smith's design practice is to size the digester system for a minimum SRT of approximately 15 days for maximum 14-day loading conditions and 20 days for average day conditions. These values served as a basis for the 2002 anaerobic digestion tank design as summarized in Table 2-3. At the time of design, the maximum 14-day loading was based on a 1.3 peaking factor from average conditions.

A number of other guidelines related to volatile suspended solids (VSS) loading, feed solids concentration and estimated VSS destruction are noted in technical literature for anaerobic digestion design, including the following:

- Feed flow should be in the general range of 4% to 7% dry solids;
- Digester loading should be 0.12 to 0.16 lbs VSS/cf/day; and
- Typical VSS reduction within digestion system should average between 45% and 55%.

As shown in Table 2-3, the design and current operating conditions appear to fall within the above guidance values. Further commentary related to excess capacity of this system that may be available for co-digestion will be included in Technical Memorandum No. 3.

	Design Average	Current Operations Average	Current Operations Max 14-Day
Total Effective Tank Volume (gal)	3,840,000	3,840,000	3,840,000
Total Effective Tank Volume (cf)	513,000	513,000	513,000
Feed Volume (gal/day)	192,000	164,000	197,000
Detention Time (days)	20.0	23.4	19.5
Feed Percent Solids (%)	5.6	4.3	4.3
Feed Dry Weight (lb/day)	89,700	58,100	69,800
Feed VSS (%)	75	81.2	81.2
Feed VSS Dry Weight (lb/day)	67,300	47,200	56,700
Feed VSS Loading (lbs VSS/cf/day)	0.13	0.09	0.11
VSS Reduction (%)	45	54.6	54.6
VSS Reduced (lb/day)	(30,300)	(25,800)	(31,000)
Digestate Dry Weight to Dewatering (lb/day)	59,400	32,400	38,900
Digestate Dry Weight to Dewatering (Tons/day)	29.7	16.2	19.4
Digestate Percent Solids (%)	-	2.4	2.4

Table 2-3
Design and Current Anaerobic Digester Loading Rates

2.2.3 Ancillary Digestion Equipment

The following section provides a brief summary of the ancillary equipment associated with the anaerobic digestion tanks. This ancillary equipment includes:

- Digester covers;
- Mixing system; and
- Heating system.

A discussion on impacts (if any) to this equipment from co-digestion options will be included in subsequent design memoranda.

Digester Covers

The GLSD digesters utilize floating covers for the collection and storage of biogas produced from the digestion tanks. This type of cover has been widely used throughout the wastewater industry for years to provide for liquid storage fluctuation as well as some limited biogas storage volume. Conventional floating covers float directly on the sludge surface, which provides for fluctuations of the liquid sludge level with minimal change in biogas pressure. Each digestion tank currently utilizes conventional gas holding covers. The covers are constructed of steel with a 12-foot travel depth. The three existing covers are currently capable of providing a total of about 146,000 CF of digester gas storage.

Mixing System

The GLSD digester system consists of mechanical draft tubes. Each digester is equipped with a center mixer and three external mixers. The draft tubes each consist of a propeller, drive shaft, and 10 hp drive (40 hp total per digester) which serve to circulate flow from the top to the bottom (or in reverse) of the digester through a tube. For the purpose of this study, the mixers are considered to be sufficient to adequately mix the tank contents. However, it should be noted that the external draft tubes have had historical issues related to pin hole leak formation which is currently being addressed by the District's operation and maintenance program.

Heating System

Maintaining a stable temperature within the digester is important, as the microbes responsible for the digestion process are extremely sensitive to temperature fluctuations. In a typical digestion system, heat is provided at (1) the point of entry in order to preheat incoming flow and (2) within a recirculation loop intended to maintain heat lost to the ambient environment. For the GLSD facility, two 4.6 MMBU/hr sludge pre-heater heat exchangers (one duty & one standby) are available to raise digester feed sludge to 95 degrees F under average conditions. For make-up of remaining heat requirements, one 1.7 MMBTU/hr sludge heat exchanger with individual sludge recirculation pump has been provided for each digester. Total heating capacity available to the system currently equates to 9.7 MMBTU/hr (excluding standby pre-heater).

2.2.4 Digester Foaming

Digester foaming has been an issue at GLSD. In recent years, the foaming has occurred primarily throughout the summer and into the early winter months. The digester cover slide guides block the foam and prevent it from flowing to the single digester tank overflow drain line. Each digester has eight slide guides around the circumference of the digester tank, spaced approximately 33 feet apart.

As a result of this condition, foam flows over the top of the digester walls, down the sides, and onto the ground. To prevent the foam from flowing into the adjacent wetlands, GLSD has installed concrete barriers around each digester to contain the foam. GLSD maintenance personal continue to spend a significant amount of time removing the foam from the containment area and cleaning the walls of the digester tanks. The district has made several operational changes to address this issue. However, as foaming is likely to occur on occasion, GLSD is interested in implementing a permanent foam containment system.

To this end, GLSD completed the Digester Foam Containment Study (February 2009, CDM). This study concluded that the installation of a containment gutter system around the exterior perimeter of each digester is the recommended foam containment alternative. As shown in Figure 2-2, the proposed gutter would consist of a shorter piece of stainless steel metal bolted onto the interior of the digester wall and a higher piece of stainless steel metal bolted onto the exterior of the digester wall. A stabilizing piece of metal would be used to connect the interior and exterior gutter. A spray water system would then be installed around the perimeter of the digester to flush the gutter and prevent foam from freezing or sticking to the inside of the gutter and would be mounted onto the stabilizer pieces. The spray water would convey the foam in the gutter to an outlet to the existing overflow pipe.

The recommended gutter has yet to be installed due to the complexity of installing this system onto an active digester. Additional discussion related to this issue will be included in TM No. 5.

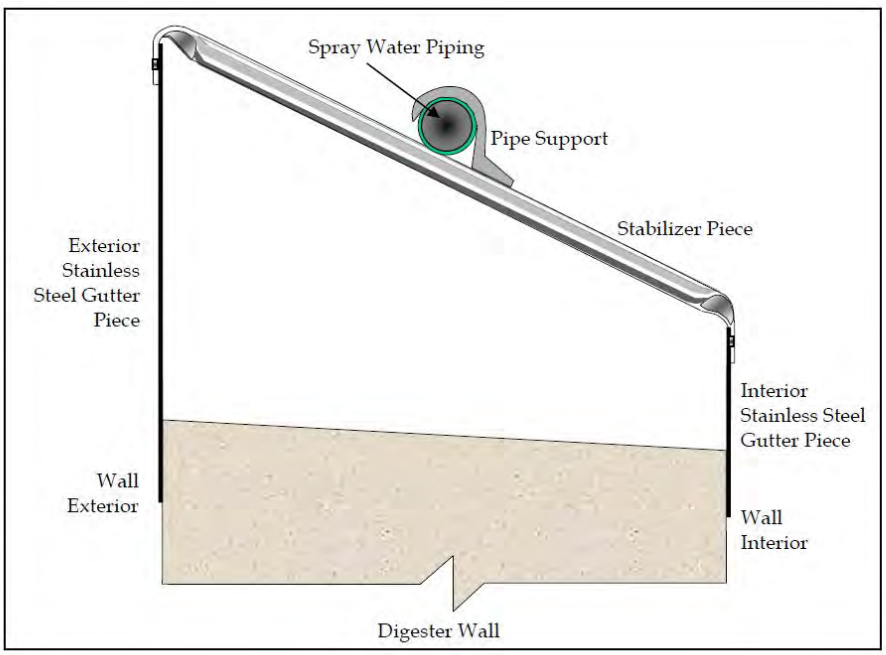


Figure 2-2
Gutter Containment System Section Schematic

2.3 Sludge Dewatering

Anaerobically digested sludge at the GLSD facility is routed to one of three 75,000 gallon digested sludge storage tanks prior to dewatering. Though the original facility utilized vacuum filters for sludge dewatering, the 2002 upgrade also included installation of two new high solids dewatering centrifuges along with associated conveyor systems to transport the cake to the downstream thermal drying facility. The existing system utilizes 2 (1 duty 1 standby) horizontal solid bowl style centrifuges. Additional design related parameters are shown within Table 2-4 below.

As noted in the table and within the plant Operations and Maintenance manual, the installed units have a theoretical working capacity of 100 – 300 gpm to achieve 95% capture of solids. However, according to the District Operations staff, the units are typically operated at a feed rate of 180 gpm and exhibit an average centrate solids concentration of 4,000mg/L. Using current average digested biosolids flows of approximately 164,000 gpd at 2.4% solids, this equates to a solids capture of approximately 83%. This loss of solids from the centrifuges was also confirmed by comparing digester effluent solids (~16.4 DT/day) to average influent weigh scale data at the thermal drying facility (~13.4 DT/day) which further confirms the historical recirculation of approximately 3 DT/day of solids within the centrifuge centrate.

Parameter	Design	Current Operations Average
Feed Concentration (%)	2.0 – 4.0	2.4
Feed Flow Range (gpm)	100-300	180
Feed Loading (lbs/hr)	3,000	2,160
Dewatered Cake (%)	28	25.8
Capture (%)	95	83

Table 2-4

Design and Current Gravity Belt Thickener (GBT) Loading Rates

During the course of this study, the District experimented with running a centrifuge at 140 gpm and a reduction (though not proportional) in polymer dose. Despite a limited data set running at these conditions, initial indications show average centrate TSS to be in the range of about 170 mg/l. If this centrate quality were to be maintained, this would correlate to a centrifuge dewatering solids capture rate of 99% and only 0.12 DT/day of solids recirculated.

2.4 Thermal Drying

The drying and beneficial reuse of biosolids was included in the 2002 upgrade under a Design-Build-Operate (DBO) contract procurement method. The result of that procurement was the design and installation of a 38 dry ton per day thermal drying and pelletizing facility currently operated by the New England Fertilizer Company (NEFCO). The pelletized end product from the GLSD facility is currently marketed as a soil amendment and also used as fuel for cement kiln fuel in the mid-Atlantic region.

The terms of the DBO contract require that the District provide "conforming" sludge cake within an allowable range of 24 to 32 percent solids in order to avoid potential financial consequences. By contract, the NEFCO facility is also provided with biogas, natural gas and electricity from the GLSD (with biogas required to be the primary fuel for use in the thermal drying process). Recent NEFCO billing records indicate an average daily processing of 52.5 wet tons per day (13.4 DT/day at ~26% solids).

2.5 Odor Control

Evaluations presented in the Sludge Management Facilities Plan/Environmental Impact Report (CDM, March 1998) recommended that all sludge thickening, dewatering, storage, and cake conveying systems associated with the 2002 upgrade be covered and ventilated to odor control. The best available control technology (BACT) analysis concluded that a biofiltration unit was the most cost effective odor control method. In biofiltration, air is passed upward through a media that supports a population of microorganisms. The pollutants in the air stream are adsorbed onto the media, where microorganisms feed on them in an aerobic environment. While the biological reactions are complex, it is safe to say that simpler and less odorous compounds are formed in the process.

In this application, the design of the biofilter was based on a total air flow of approximately 11,200 cubic feet per minute from all the odorous sources combined. Each odorous source and the corresponding air flows which were considered in the design are presented in Table 2-5.

Process Odor Source	Air Flow (scfm)
Gravity Thickener Head Space	3,200
Gravity Belt Thickener Room	3,000
Digested Sludge Storage Tanks	1,600
TWAS Storage Tank	1,600
Dewatered Cake Conveyors	1,200
Scum Concentrator	600
Total	11,200

Table 2-5

Biofilter Design Air Flow Rates

The odors air flow from these facilities was designed to be treated by four equally sized biofilter cells with a total active media area of 5,500 square feet. The system was sized to maintain the proper detention time during media change-out/ routine maintenance of one of the four cells. Each bed consists of (from the bottom up): sand, a HDPE liner, sand, gravel bed containing air distribution headers, and biofilter media. The sand is provided to protect the liner from puncture. A drainage system is also included within the biofilter to remove excess rain water, condensing humidity, and excess surface irrigation.

2.6 Biogas Utilization

Gas generated by the anaerobic digestion of organic solids is often referred to as biogas. This gas contains primarily methane and carbon dioxide and is an excellent source of energy. The energy can be harnessed in a variety of ways, including boilers for digester and building heating, thermal drying and combined heat and power application involving reciprocating engines, microturbines and fuel cells.

The Distric currently utilizes biogas produced from its anaerobic digestion tanks for the following purposes:

- Glycol boilers (3) to heat to the digestion process;
- Steam boilers (2) to heat plant-wide building space; and
- Thermal dryers within the NEFCO facility.

As further described below, in addition to the utilization equipment noted above, the biogas utilization system currently includes: (1) metering systems; (2) biogas safety and waste gas burner equipment; (3) foam, moisture and sediment removal equipment; and (4) chemical addition for biogas treatment.

2.6.1 Production and Metering

The amount of biogas produced during the anaerobic digestion process depends upon the amount volatile solids entering into and destroyed within the digester. Higher amounts of volatile solid destruction will, in turn, result in higher biogas production. For systems that digest municipal biosolids, feed stock to these systems typically consists of combined (primary and secondary) thickened sludge which contains approximately 75% VSS, 50% of which is generally able to be destroyed. As noted within Table 2-3, GLSD operations records currently show average influent VSS of 81.2% and VSS destruction of 54.6%, which is on the upper end of anticipated digestion efficiency.

For the purpose of quantifying biogas production and utilization, gas meters are typically installed within the piping from the digesters and/or in the piping leading to the points of use. The GLSD biogas system currently contains meters in lines to the boilers (one meter for all five units), the NEFCO dryers, and the flare. The digester gas flow meters consist of venturis as the primary element and differential pressure sensors as the secondary element. The meters to the dryers and boilers utilize two sensors for each venturi – a low range sensor and a high range sensor.

Unfortunately, during recent maintenance work on the differential pressure transmitters, the District became aware of issues related to meter performance. One major observation was that the boiler gas flow totalizer is not operating properly and has been under-metering the gas to that system for an unknown period of time. As a result, the total biogas production in the recent operations records is likely an understatement of actual production and a misrepresentation of the breakdown between biogas utilization areas.

As a result of the current metering issues, theoretical biogas production was also evaluated. Based on CDM Smith experience and industry guidelines, biogas produced from the VSS destruction typically ranges from 12–18 cubic feet per pound of volatiles destroyed with average production of approximately 15 cf/lb. Using this value, along with GLSD VSS destruction data, a theoretical average production of 387,000 cf was determined for the current operations.

It should also be noted that, in 2008, the District performed an energy study which evaluated the breakdown in biogas usage. For the purpose of this analysis, these values have been assumed to be an accurate representation of current operations and are carried in Table 2-6.

Biogas Utilization	Design	Current Avearge (Based on Meter Data)[1]	Current Avearge (Based on Theoritical Production and 2007 Energy Study)
VSS Converted (lb/day)	(30,200)	(25,800)	(25,800)
Biogas Production (cf)	453,000	325,000	387,000
Biogas Production (cf/lb)	15	11.9	15
Utilization			
Thermal Drying	-	64%	53.5%
Boilers (Sludge & Building Heating)	-	24%	28.5%
Flare	-	12%	18.0%

[1] Meter data likely to be under accounting for usage due to equipment malfunction.

Table 2-6
Biogas Production and Utilization

2.6.2 Biogas Safety Equipment

Since biogas is explosive at low concentrations, it is crucial that the biogas handling system be fitted with appropriate gas-safety equipment, to protect against the risk of ignition and explosion.

The safety systems which are included within the GLSD biogas system include the following:

- Biogas pressure relief valves within the floating digester covers (which ensure that excessive pressures do not develop if a cover were to become stuck);
- Flame arrestors (which works to quench the flame by dissipating any heat from a potential explosion in the piping; and
- Flame traps (combination of a flame arrestor and a thermal shutoff valve which will melt and seal off the remainder of the upstream piping from the biogas source).

Although the intention is to maximize utilization of the biogas in the boilers and thermal dryers, a waste gas burner system is also required to safely combust excess digester gas produced at the facility in the event that biogas production exceeds consumption and storage capacity. A waste gas burner safely flares excess biogas to the atmosphere and eliminates the potential for hazardous accumulation of biogas within the conveyance and storage system. The GLSD waste gas burner utilizes an enclosed burner stack with no visible flame.

2.6.3 Foam, Moisture and Sediment Removal

The purpose of a foam separator is to remove any foam from the digester biogas after it leaves the digester. The foam is dispersed and collected in the separator in order to protect downstream equipment from corrosion and/or clogging.

Following the foam separator, biogas is generally sent through a condensate and sediment trap. After leaving the digester, the biogas, at approximately 95 ºF, comes into contact with cooler piping and condensate forms within the pipeline. The condensate saturates the biogas and, as such, the biogas conveyance system must be designed to remove condensate. The condensate formed within the gas conveyance system is highly corrosive and can deteriorate gas handling equipment including check valves, relief valves, gas meters, and regulators and affect their performance. Condensate can also combine with hydrogen sulfide present in the biogas to form a sulfuric acid that will corrode piping if the moisture is not removed.

The GLSD biogas system includes foam, moisture and sediment removal systems which are located in the basement of the digester building.

2.6.4 Biogas Treatment

Though there are many impurities within biogas, hydrogen sulfide (H_2S) and siloxane (various related compounds) are the two of most significant concern. Hydrogen sulfide is formed by the reduction of sulfates by anaerobic bacteria within the digester and can cause engine damage through acid corrosion. Siloxanes can be found in personal care products (cosmetics, deodorant, etc), water repelling coatings, lubricants and other products that are found in municipal wastewater to varying degrees. When combusted, siloxanes are oxidized to silicon dioxide which then forms deposits on moving parts which can lead to excessive maintenance requirements and premature equipment failure. Utilization of biogas often requires that H_2S and/or siloxane be removed or prevented.

Hydrogen Sulfide

H_2S production is typically either prevented through the addition of ferric chloride to the solids treatment system or removed from the biogas through the use of iron sponge media. During the design of the current GLSD digestion system, for cost control reasons, it was decided to utilize ferric chloride for H_2S control. The facility currently injects ferric chloride at the plant headworks (downstream of screening) and directly into the anaerobic digester tanks via 1" wall penetrations. The addition of ferric chloride also provides advantages related to odor control, settling and thickening and also can help prevent the formation of struvite (magnesium ammonium phosphate).

Based on plant operations records (July 2011 through June 2012), the feed of ferric chloride to the anaerobic digestion system averaged approximate 440 lbs/day (115 gal/day at 34% solution). Though the feed rate for these pumps is manually adjusted so as to maintain less than 100 ppm of H_2S within the digester gas, operators report that need for adjustment to this rate is a rare occurrence. Based on recent GLSD biogas sampling and operations reports, the addition of ferric chloride appears to be providing adequate prevention of H_2S corrosion. Further, recent biogas sampling showed hydrogen sulfide levels of approximately 60 ppm which is below the level which would necessitate treatment for the District's current biogas utilization equipment.

Siloxane

Siloxanes are a common problem in biogas utilization which, when combusted, have the potential to form a hard scaling on biogas equipment. Siloxane treatment system was not included in the 2002 project as the presence of siloxanes in digester biogas is difficult to predict without pre-existing facility-specific biogas sampling. This fact, combined with the significant cost of siloxane removal systems, led to the decision not to include siloxane removal in the 2002 upgrade.

Though biogas siloxane testing results are not currently available, operations staff report that siloxane accumulation has historically been an issue within the biogas boiler systems. The District maintenance procedures currently includes annual cleaning for the boilers within the digestion facility and will likely include biannual cleaning of the dual fuel boilers recently installed for building space heat. Additionally, the biogas feed to the NEFCO facility includes filters which reportedly collect siloxane buildup continuously and require cleaning on a continuous basis. As a result of this issue, the use of more sensitive biogas cogeneration equipment in the future will likely require some sort of siloxane removal system.

Technical Memorandum No. 2

From: *Benjamin R. Mosher, P.E., BCEE*

Date: *November 2, 2012*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Description of Existing Facilities and Operations Issues*

2.0 Description of Existing Facilities and Operations Issues

As discussed within Technical Memorandum (TM) No. 1, the GLSD solids treatment train currently consists of thickening, anaerobic digestion, dewatering and thermal drying processes. The sequence of these stages is shown in Figure 2-1. The purpose of this memorandum is to document the design capacity and current operations/utilization of these existing systems. The design capacity of the systems discussed herein is based upon information obtained from work completed during the 2002 solids train upgrade while the assessment of current operations is based on discussions with GLSD staff as well as 12-months of plant operations data during the period between September 2011 and August 2012.

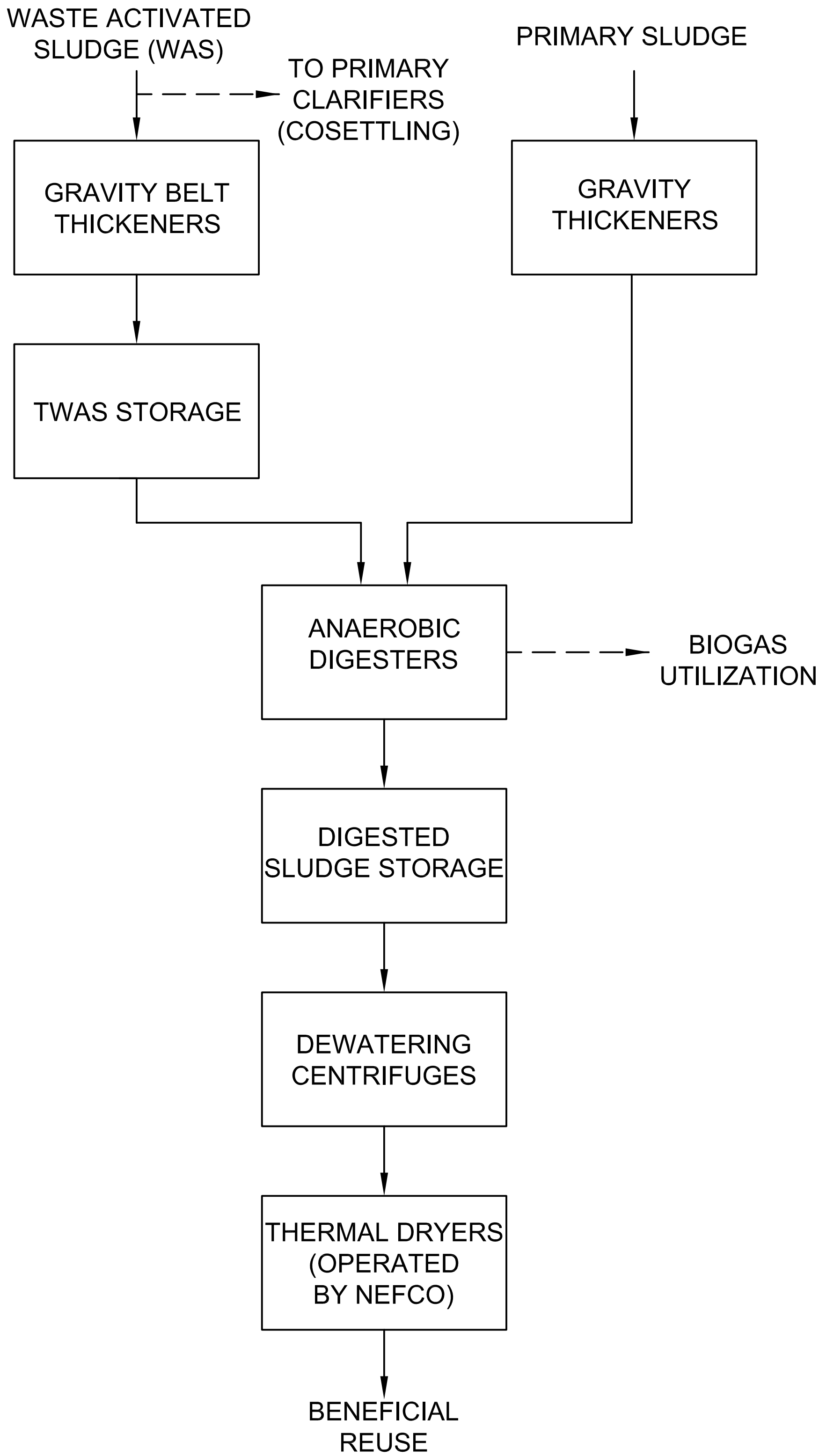
2.1 Sludge Thickening

Under normal operating conditions, the primary sludge from the primary clarifiers is pumped to one of four gravity thickeners while the waste activated sludge (WAS) from the secondary treatment train is conveyed to one of two gravity belt thickeners. In addition, the District has the ability to convey WAS to the primary clarifiers where it is co-settled with the primary sludge. This ability to co-settle sludge is currently exercised during the cold weather months (approximately December to March).

2.1.1 Gravity Thickeners

The GLSD facility utilizes four, 45-foot diameter gravity thickeners. Though these thickeners are original to the original 1971 facility, odor control covers were added to these tanks during the 2002 upgrade.

Industry guidelines for recommended maximum loading of gravity thickeners suggest a range of 20 to 30 lbs/sf/day. As shown in Table 2-1, the design year values used during the 2002 upgrade design equated to a maximum loading of approximately 18 lbs/sf/day with 3 units in service.



CDM Smith

Figure No. 2-1
Greater Lawrence Sanitary District
Existing Biosolids Treatment Train Schematic
November 2012

Based on plant records collected during co-settling operations, recent flow to the gravity thickeners averaged approximately 1.5 mgd at a solids concentration of 2,900 mg/l. Utilizing 3 of the 4 gravity thickeners for this loading would translate to a loading rate of approximately 7.6 lbs/sf/day. Though a comparison of existing and future maximum day loadings to this system was not possible due to the limited data set, the current average loading is well within the recommended design criteria of 20 Ibs/sf/day while allowing one unit to be out of service. As such, the capacity of this system is unlikely to be a limiting factor with respect to acceptance of additional outside waste into the GLSD biosolids treatment system.

Condition	Loading			
	gal/day at 0.3% solids	lbs/day	lbs/sf/day with 3 units in service	lbs/sf/day with 4 units in service
2016 Design Average	—	61,600	12.9	9.7
2016 Design Maximum	—	86,200	18.1	13.6
Current Average (Standard & Co-settling Conditions)	1,507,000	36,400	7.6	5.7

Table 2-1
Design and Current Gravity Thickener Loading Rates

2.1.2 Gravity Belt Thickeners

As part of the 2002 upgrade, two 3-meter gravity belt thickeners were installed for the purpose of thickening the secondary waste activated sludge. Both GBTs are currently located within an enclosed room inside the dewatering room, adjacent to the centrifuges.

Industry recommended GBT hydraulic loading rates for WAS thickening applications range between 200 – 300 gpm/meter of belt width with recommended solids loading rates of up to 1,000 lbs/hr/meter. When operating properly using adequate polymer dosing, solids capture of over 95% is achievable for WAS thickening applications. Using these values, a single GBT at the GLSD facility would theoretically be capable of thickening 3,000 lbs./hr of WAS at 900 GPM. It should also be noted that the ability to co-settle at the GLSD facility is considered back-up for the GBT thickening process and therefore, standby units are not considered a significant concern.

Based on 2002 design data, it appears that the maximum deign year loading using both units was intended to be approximately 438 gpm per unit. Upon review of recent operating data, it was determined that the current average and maximum loading to a single GBT has been approximately 420 and 550 gpm. Assuming the use of both existing units as duty units (co-settling as a standby), all values appear to be well within recommended operating ranges for this type of equipment.

Condition	Sludge Production (gpd)	Loading per unit with both units online (gpm)
2016 Design Year Average	862,800	313
2016 Design Year Maximum	1,207,900	438
Current Average Day	1,158,000	420
Current Max Day (95th percentile)	1,521,000	550

Note: Above values assume average operating time of 23 hr/day.

Table 2-2
Design and Current Gravity Belt Thickener (GBT) Loading Rates

2.2 Sludge Digestion

2.2.1 Effective Tank Volume

The most significant portion of the 2002 solids train upgrade was the installation of three anaerobic digestion tanks. The tanks were installed with dimensions of 85-feet diameter and 38.5-feet sidewall depth which equates to a total storage volume (excluding the bottom cone) of 4.9 million gallons (MG) for all three tanks.

Industry guidelines recommend that digester sizing include a 10% allowance for grit accumulation (in addition to the digester cone volume, which is not considered part of the digester working volume). Further, the GLSD tanks were designed with 5 feet of freeboard due to requirements associated with the cover system which is also not considered usable volume. With consideration of these two factors, the total theoretical effective working volume equates to 3.84 MG (1.28 MG/tank).

It should be noted that GLSD plant is served by a combined collection system and, therefore, experiences a significant grit loading. Though the District installed a new aerated grit removal system in 2007, the digestion tanks have not been removed from service and dewatered since 2002 and the level of accumulated grit within the system is currently unknown. Despite this, for the purpose of this study, it is assumed that the mixing system currently installed in the tanks is working properly and the accumulated grit does not exceed the volume of the tank cones plus 10% of the remaining volume as noted above.

It is also important to note that open land area currently exists within the anaerobic digestion facility to support a fourth anaerobic digester tank. As the construction of this fourth tank would allow for significant acceptance of outside waste, this potential will be further discussed in subsequent memoranda.

2.2.2 Design Parameters and Operating Results

Anaerobic digesters are primarily sized based upon solids retention time (SRT) and hydraulic retention time (HRT). Because the GLSD digestion system (like most high-rate digestion systems) does not include provisions for supernatant decant, SRT is equivalent to HRT for this application and, therefore, these terms can be used interchangeably.

Industry guidelines and CDM Smith's design practice is to size the digester system for a minimum SRT of approximately 15 days for maximum 14-day loading conditions and 20 days for average day conditions. These values served as a basis for the 2002 anaerobic digestion tank design as summarized in Table 2-3. At the time of design, the maximum 14-day loading was based on a 1.3 peaking factor from average conditions.

A number of other guidelines related to volatile suspended solids (VSS) loading, feed solids concentration and estimated VSS destruction are noted in technical literature for anaerobic digestion design, including the following:

- Feed flow should be in the general range of 4% to 7% dry solids;
- Digester loading should be 0.12 to 0.16 lbs VSS/cf/day; and
- Typical VSS reduction within digestion system should average between 45% and 55%.

As shown in Table 2-3, the design and current operating conditions appear to fall within the above guidance values. Further commentary related to excess capacity of this system that may be available for co-digestion will be included in Technical Memorandum No. 3.

	Design Average	Current Operations Average	Current Operations Max 14-Day
Total Effective Tank Volume (gal)	3,840,000	3,840,000	3,840,000
Total Effective Tank Volume (cf)	513,000	513,000	513,000
Feed Volume (gal/day)	192,000	164,000	197,000
Detention Time (days)	20.0	23.4	19.5
Feed Percent Solids (%)	5.6	4.3	4.3
Feed Dry Weight (lb/day)	89,700	58,100	69,800
Feed VSS (%)	75	81.2	81.2
Feed VSS Dry Weight (lb/day)	67,300	47,200	56,700
Feed VSS Loading (lbs VSS/cf/day)	0.13	0.09	0.11
VSS Reduction (%)	45	54.6	54.6
VSS Reduced (lb/day)	(30,300)	(25,800)	(31,000)
Digestate Dry Weight to Dewatering (lb/day)	59,400	32,400	38,900
Digestate Dry Weight to Dewatering (Tons/day)	29.7	16.2	19.4
Digestate Percent Solids (%)	-	2.4	2.4

Table 2-3
Design and Current Anaerobic Digester Loading Rates

2.2.3 Ancillary Digestion Equipment

The following section provides a brief summary of the ancillary equipment associated with the anaerobic digestion tanks. This ancillary equipment includes:

- Digester covers;
- Mixing system; and
- Heating system.

A discussion on impacts (if any) to this equipment from co-digestion options will be included in subsequent design memoranda.

Digester Covers

The GLSD digesters utilize floating covers for the collection and storage of biogas produced from the digestion tanks. This type of cover has been widely used throughout the wastewater industry for years to provide for liquid storage fluctuation as well as some limited biogas storage volume. Conventional floating covers float directly on the sludge surface, which provides for fluctuations of the liquid sludge level with minimal change in biogas pressure. Each digestion tank currently utilizes conventional gas holding covers. The covers are constructed of steel with a 12-foot travel depth. The three existing covers are currently capable of providing a total of about 146,000 CF of digester gas storage.

Mixing System

The GLSD digester system consists of mechanical draft tubes. Each digester is equipped with a center mixer and three external mixers. The draft tubes each consist of a propeller, drive shaft, and 10 hp drive (40 hp total per digester) which serve to circulate flow from the top to the bottom (or in reverse) of the digester through a tube. For the purpose of this study, the mixers are considered to be sufficient to adequately mix the tank contents. However, it should be noted that the external draft tubes have had historical issues related to pin hole leak formation which is currently being addressed by the District's operation and maintenance program.

Heating System

Maintaining a stable temperature within the digester is important, as the microbes responsible for the digestion process are extremely sensitive to temperature fluctuations. In a typical digestion system, heat is provided at (1) the point of entry in order to preheat incoming flow and (2) within a recirculation loop intended to maintain heat lost to the ambient environment. For the GLSD facility, two 4.6 MMBU/hr sludge pre-heater heat exchangers (one duty & one standby) are available to raise digester feed sludge to 95 degrees F under average conditions. For make-up of remaining heat requirements, one 1.7 MMBTU/hr sludge heat exchanger with individual sludge recirculation pump has been provided for each digester. Total heating capacity available to the system currently equates to 9.7 MMBTU/hr (excluding standby pre-heater).

2.2.4 Digester Foaming

Digester foaming has been an issue at GLSD. In recent years, the foaming has occurred primarily throughout the summer and into the early winter months. The digester cover slide guides block the foam and prevent it from flowing to the single digester tank overflow drain line. Each digester has eight slide guides around the circumference of the digester tank, spaced approximately 33 feet apart.

As a result of this condition, foam flows over the top of the digester walls, down the sides, and onto the ground. To prevent the foam from flowing into the adjacent wetlands, GLSD has installed concrete barriers around each digester to contain the foam. GLSD maintenance personal continue to spend a significant amount of time removing the foam from the containment area and cleaning the walls of the digester tanks. The district has made several operational changes to address this issue. However, as foaming is likely to occur on occasion, GLSD is interested in implementing a permanent foam containment system.

To this end, GLSD completed the Digester Foam Containment Study (February 2009, CDM). This study concluded that the installation of a containment gutter system around the exterior perimeter of each digester is the recommended foam containment alternative. As shown in Figure 2-2, the proposed gutter would consist of a shorter piece of stainless steel metal bolted onto the interior of the digester wall and a higher piece of stainless steel metal bolted onto the exterior of the digester wall. A stabilizing piece of metal would be used to connect the interior and exterior gutter. A spray water system would then be installed around the perimeter of the digester to flush the gutter and prevent foam from freezing or sticking to the inside of the gutter and would be mounted onto the stabilizer pieces. The spray water would convey the foam in the gutter to an outlet to the existing overflow pipe.

The recommended gutter has yet to be installed due to the complexity of installing this system onto an active digester. Additional discussion related to this issue will be included in TM No. 5.

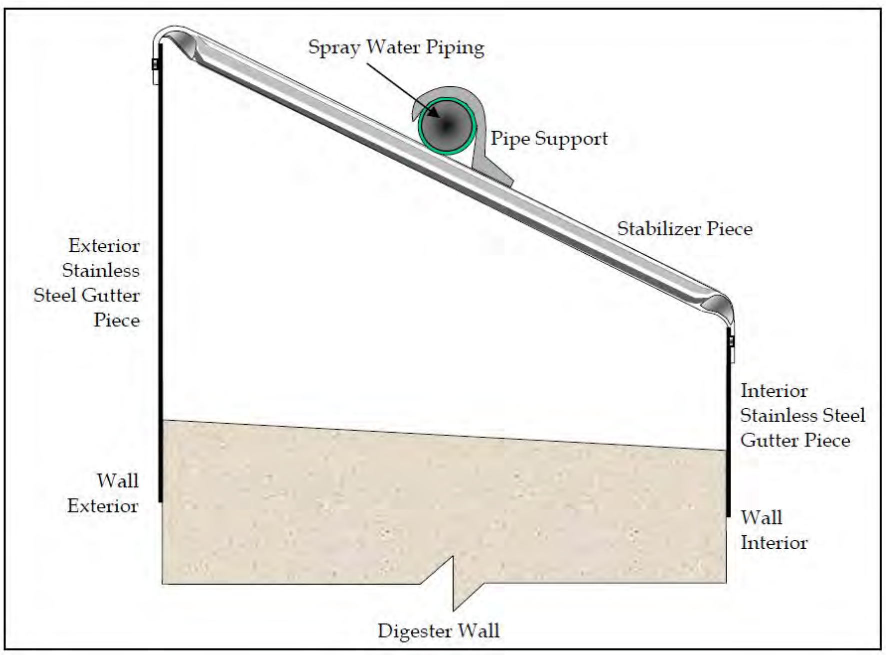


Figure 2-2
Gutter Containment System Section Schematic

2.3 Sludge Dewatering

Anaerobically digested sludge at the GLSD facility is routed to one of three 75,000 gallon digested sludge storage tanks prior to dewatering. Though the original facility utilized vacuum filters for sludge dewatering, the 2002 upgrade also included installation of two new high solids dewatering centrifuges along with associated conveyor systems to transport the cake to the downstream thermal drying facility. The existing system utilizes 2 (1 duty 1 standby) horizontal solid bowl style centrifuges. Additional design related parameters are shown within Table 2-4 below.

As noted in the table and within the plant Operations and Maintenance manual, the installed units have a theoretical working capacity of 100 – 300 gpm to achieve 95% capture of solids. However, according to the District Operations staff, the units are typically operated at a feed rate of 180 gpm and exhibit an average centrate solids concentration of 4,000mg/L. Using current average digested biosolids flows of approximately 164,000 gpd at 2.4% solids, this equates to a solids capture of approximately 83%. This loss of solids from the centrifuges was also confirmed by comparing digester effluent solids (~16.4 DT/day) to average influent weigh scale data at the thermal drying facility (~13.4 DT/day) which further confirms the historical recirculation of approximately 3 DT/day of solids within the centrifuge centrate.

Parameter	Design	Current Operations Average
Feed Concentration (%)	2.0 – 4.0	2.4
Feed Flow Range (gpm)	100-300	180
Feed Loading (lbs/hr)	3,000	2,160
Dewatered Cake (%)	28	25.8
Capture (%)	95	83

Table 2-4
Design and Current Gravity Belt Thickener (GBT) Loading Rates

During the course of this study, the District experimented with running a centrifuge at 140 gpm and a reduction (though not proportional) in polymer dose. Despite a limited data set running at these conditions, initial indications show average centrate TSS to be in the range of about 170 mg/l. If this centrate quality were to be maintained, this would correlate to a centrifuge dewatering solids capture rate of 99% and only 0.12 DT/day of solids recirculated.

2.4 Thermal Drying

The drying and beneficial reuse of biosolids was included in the 2002 upgrade under a Design-Build-Operate (DBO) contract procurement method. The result of that procurement was the design and installation of a 38 dry ton per day thermal drying and pelletizing facility currently operated by the New England Fertilizer Company (NEFCO). The pelletized end product from the GLSD facility is currently marketed as a soil amendment and also used as fuel for cement kiln fuel in the mid-Atlantic region.

The terms of the DBO contract require that the District provide "conforming" sludge cake within an allowable range of 24 to 32 percent solids in order to avoid potential financial consequences. By contract, the NEFCO facility is also provided with biogas, natural gas and electricity from the GLSD (with biogas required to be the primary fuel for use in the thermal drying process). Recent NEFCO billing records indicate an average daily processing of 52.5 wet tons per day (13.4 DT/day at ~26% solids).

2.5 Odor Control

Evaluations presented in the Sludge Management Facilities Plan/Environmental Impact Report (CDM, March 1998) recommended that all sludge thickening, dewatering, storage, and cake conveying systems associated with the 2002 upgrade be covered and ventilated to odor control. The best available control technology (BACT) analysis concluded that a biofiltration unit was the most cost effective odor control method. In biofiltration, air is passed upward through a media that supports a population of microorganisms. The pollutants in the air stream are adsorbed onto the media, where microorganisms feed on them in an aerobic environment. While the biological reactions are complex, it is safe to say that simpler and less odorous compounds are formed in the process.

In this application, the design of the biofilter was based on a total air flow of approximately 11,200 cubic feet per minute from all the odorous sources combined. Each odorous source and the corresponding air flows which were considered in the design are presented in Table 2-5.

Process Odor Source	Air Flow (scfm)
Gravity Thickener Head Space	3,200
Gravity Belt Thickener Room	3,000
Digested Sludge Storage Tanks	1,600
TWAS Storage Tank	1,600
Dewatered Cake Conveyors	1,200
Scum Concentrator	600
Total	11,200

Table 2-5

Biofilter Design Air Flow Rates

The odors air flow from these facilities was designed to be treated by four equally sized biofilter cells with a total active media area of 5,500 square feet. The system was sized to maintain the proper detention time during media change-out/ routine maintenance of one of the four cells. Each bed consists of (from the bottom up): sand, a HDPE liner, sand, gravel bed containing air distribution headers, and biofilter media. The sand is provided to protect the liner from puncture. A drainage system is also included within the biofilter to remove excess rain water, condensing humidity, and excess surface irrigation.

2.6 Biogas Utilization

Gas generated by the anaerobic digestion of organic solids is often referred to as biogas. This gas contains primarily methane and carbon dioxide and is an excellent source of energy. The energy can be harnessed in a variety of ways, including boilers for digester and building heating, thermal drying and combined heat and power application involving reciprocating engines, microturbines and fuel cells.

The Distric currently utilizes biogas produced from its anaerobic digestion tanks for the following purposes:

- Glycol boilers (3) to heat to the digestion process;
- Steam boilers (2) to heat plant-wide building space; and
- Thermal dryers within the NEFCO facility.

As further described below, in addition to the utilization equipment noted above, the biogas utilization system currently includes: (1) metering systems; (2) biogas safety and waste gas burner equipment; (3) foam, moisture and sediment removal equipment; and (4) chemical addition for biogas treatment.

2.6.1 Production and Metering

The amount of biogas produced during the anaerobic digestion process depends upon the amount volatile solids entering into and destroyed within the digester. Higher amounts of volatile solid destruction will, in turn, result in higher biogas production. For systems that digest municipal biosolids, feed stock to these systems typically consists of combined (primary and secondary) thickened sludge which contains approximately 75% VSS, 50% of which is generally able to be destroyed. As noted within Table 2-3, GLSD operations records currently show average influent VSS of 81.2% and VSS destruction of 54.6%, which is on the upper end of anticipated digestion efficiency.

For the purpose of quantifying biogas production and utilization, gas meters are typically installed within the piping from the digesters and/or in the piping leading to the points of use. The GLSD biogas system currently contains meters in lines to the boilers (one meter for all five units), the NEFCO dryers, and the flare. The digester gas flow meters consist of venturis as the primary element and differential pressure sensors as the secondary element. The meters to the dryers and boilers utilize two sensors for each venturi – a low range sensor and a high range sensor.

Unfortunately, during recent maintenance work on the differential pressure transmitters, the District became aware of issues related to meter performance. One major observation was that the boiler gas flow totalizer is not operating properly and has been under-metering the gas to that system for an unknown period of time. As a result, the total biogas production in the recent operations records is likely an understatement of actual production and a misrepresentation of the breakdown between biogas utilization areas.

As a result of the current metering issues, theoretical biogas production was also evaluated. Based on CDM Smith experience and industry guidelines, biogas produced from the VSS destruction typically ranges from 12–18 cubic feet per pound of volatiles destroyed with average production of approximately 15 cf/lb. Using this value, along with GLSD VSS destruction data, a theoretical average production of 387,000 cf was determined for the current operations.

It should also be noted that, in 2008, the District performed an energy study which evaluated the breakdown in biogas usage. For the purpose of this analysis, these values have been assumed to be an accurate representation of current operations and are carried in Table 2-6.

Biogas Utilization	Design	Current Avearge (Based on Meter Data)[1]	Current Avearge (Based on Theoritical Production and 2007 Energy Study)
VSS Converted (lb/day)	(30,200)	(25,800)	(25,800)
Biogas Production (cf)	453,000	325,000	387,000
Biogas Production (cf/lb)	15	11.9	15
Utilization			
Thermal Drying	-	64%	53.5%
Boilers (Sludge & Building Heating)	-	24%	28.5%
Flare	-	12%	18.0%

[1] Meter data likely to be under accounting for usage due to equipment malfunction.

Table 2-6
Biogas Production and Utilization

2.6.2 Biogas Safety Equipment

Since biogas is explosive at low concentrations, it is crucial that the biogas handling system be fitted with appropriate gas-safety equipment, to protect against the risk of ignition and explosion.

The safety systems which are included within the GLSD biogas system include the following:

- Biogas pressure relief valves within the floating digester covers (which ensure that excessive pressures do not develop if a cover were to become stuck);
- Flame arrestors (which works to quench the flame by dissipating any heat from a potential explosion in the piping; and
- Flame traps (combination of a flame arrestor and a thermal shutoff valve which will melt and seal off the remainder of the upstream piping from the biogas source).

Although the intention is to maximize utilization of the biogas in the boilers and thermal dryers, a waste gas burner system is also required to safely combust excess digester gas produced at the facility in the event that biogas production exceeds consumption and storage capacity. A waste gas burner safely flares excess biogas to the atmosphere and eliminates the potential for hazardous accumulation of biogas within the conveyance and storage system. The GLSD waste gas burner utilizes an enclosed burner stack with no visible flame.

2.6.3 Foam, Moisture and Sediment Removal

The purpose of a foam separator is to remove any foam from the digester biogas after it leaves the digester. The foam is dispersed and collected in the separator in order to protect downstream equipment from corrosion and/or clogging.

Following the foam separator, biogas is generally sent through a condensate and sediment trap. After leaving the digester, the biogas, at approximately 95 ºF, comes into contact with cooler piping and condensate forms within the pipeline. The condensate saturates the biogas and, as such, the biogas conveyance system must be designed to remove condensate. The condensate formed within the gas conveyance system is highly corrosive and can deteriorate gas handling equipment including check valves, relief valves, gas meters, and regulators and affect their performance. Condensate can also combine with hydrogen sulfide present in the biogas to form a sulfuric acid that will corrode piping if the moisture is not removed.

The GLSD biogas system includes foam, moisture and sediment removal systems which are located in the basement of the digester building.

2.6.4 Biogas Treatment

Though there are many impurities within biogas, hydrogen sulfide (H_2S) and siloxane (various related compounds) are the two of most significant concern. Hydrogen sulfide is formed by the reduction of sulfates by anaerobic bacteria within the digester and can cause engine damage through acid corrosion. Siloxanes can be found in personal care products (cosmetics, deodorant, etc), water repelling coatings, lubricants and other products that are found in municipal wastewater to varying degrees. When combusted, siloxanes are oxidized to silicon dioxide which then forms deposits on moving parts which can lead to excessive maintenance requirements and premature equipment failure. Utilization of biogas often requires that H_2S and/or siloxane be removed or prevented.

Hydrogen Sulfide

H_2S production is typically either prevented through the addition of ferric chloride to the solids treatment system or removed from the biogas through the use of iron sponge media. During the design of the current GLSD digestion system, for cost control reasons, it was decided to utilize ferric chloride for H_2S control. The facility currently injects ferric chloride at the plant headworks (downstream of screening) and directly into the anaerobic digester tanks via 1" wall penetrations. The addition of ferric chloride also provides advantages related to odor control, settling and thickening and also can help prevent the formation of struvite (magnesium ammonium phosphate).

Based on plant operations records (July 2011 through June 2012), the feed of ferric chloride to the anaerobic digestion system averaged approximate 440 lbs/day (115 gal/day at 34% solution). Though the feed rate for these pumps is manually adjusted so as to maintain less than 100 ppm of H_2S within the digester gas, operators report that need for adjustment to this rate is a rare occurrence. Based on recent GLSD biogas sampling and operations reports, the addition of ferric chloride appears to be providing adequate prevention of H_2S corrosion. Further, recent biogas sampling showed hydrogen sulfide levels of approximately 60 ppm which is below the level which would necessitate treatment for the District's current biogas utilization equipment.

Siloxane

Siloxanes are a common problem in biogas utilization which, when combusted, have the potential to form a hard scaling on biogas equipment. Siloxane treatment system was not included in the 2002 project as the presence of siloxanes in digester biogas is difficult to predict without pre-existing facility-specific biogas sampling. This fact, combined with the significant cost of siloxane removal systems, led to the decision not to include siloxane removal in the 2002 upgrade.

Though biogas siloxane testing results are not currently available, operations staff report that siloxane accumulation has historically been an issue within the biogas boiler systems. The District maintenance procedures currently includes annual cleaning for the boilers within the digestion facility and will likely include biannual cleaning of the dual fuel boilers recently installed for building space heat. Additionally, the biogas feed to the NEFCO facility includes filters which reportedly collect siloxane buildup continuously and require cleaning on a continuous basis. As a result of this issue, the use of more sensitive biogas cogeneration equipment in the future will likely require some sort of siloxane removal system.

Technical Memorandum No. 3

From: *Benjamin R. Mosher, P.E., BCEE*

Date: *November 16, 2012 (Revised June 26, 2013)*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Sludge and Biogas Production Estimates*

3.0 Sludge and Biogas Production Estimates

3.1 Summary of Current Operational Data

As discussed in detail within Technical Memorandum No. 2, the GLSD anaerobic digestion facility currently accepts an average of 164,000 gal/day of primary and waste activated sludge. Recent operating data also indicates that the maximum 14-day loading rate to the digesters is approximately 197,000 gal/day. With a total available effective tank volume of 3.84 million gallons, this equates to HRTs of 23 days and 20 days for average and max 14 day conditions, respectively.

Operating data and laboratory analysis also suggests that the average loading to the digesters currently equates to an average of approximately 47,000 lbs/day of volatile solids – approximately 55-percent of which is destroyed/reduced within the digestion system. Though accurate biogas production metering values are not currently available, based on proven biogas production rates related to digestion of municipal biosolids, it is estimated that the current volatile solids reduction at the GLSD facility is resulting in an average production of approximately 390,000 cf/day.

3.2 Year 2025 Expected Production

Wastewater production projections are typically determined from population projections and trends in historical facility flow data. For this study, wastewater (and municipal biosolids) production was projected to the year 2025.

As noted within the GLSD Final Sludge Management Facilities Plan (CDM, 1998), the population increase within the District service area between 2010 and 2020 was projected to be 12,220. For the purpose of comparison, according to data from the US census bureau, the population growth in the area during the period from 1990 to 2010 was 26,075 (or roughly 13,000 every ten years). For the purpose of determining an anticipated flow projection this study, it has been assumed that the population increase between present day and 2025 (~13 years) will be equivalent to the prior projections and census data (~13,000 every 10 years) which would yield a planning level population increase of approximately 16,900 people.

Due to the generally high percentage of sewered area within each of the member communities, it has been assumed that this population growth would occur exclusively within the current service area. As noted within Table 3-1, using an industry standard solids loading of 0.2 lbs/day/capita, the projected population increase would translate into an additional load to the anaerobic digestion system of 3,400 lbs/day. At 4.3% solids, this would equate to 9,500 gal/day of thickened sludge.

Parameter	Value
Projected Population Increase Between 2012 and 2025	16,900
Anticipated Solids from Growth (lbs/capita/day)	0.2
Digestion Feed Percent Solids (%)	4.3
Additional Average Loading to Digestion (lbs/day)	3,400
Additional Average Loading to Digestion (gal/day)	9,500
Total Future Average Loading to Digesters (lbs/day)	62,500
Total Future Average Loading to Digesters (gal/day)	174,000

Table 3-1
2025 Projected Population and Average Solids Loading

3.3 Estimate of Available Capacity Available for Outside Waste

As noted in Section 3.2 above, assuming the service area population expands at the projected rate, the total future projected flow to the GLSD anaerobic digestion system would be approximately 174,000 gal/day. This average loading would equate to a HRT within the tanks of 23 days. Using historical plant peaking factors associated with maximum 14 day loading of 1.2, the future max 14 day loading would equate to 208,000 gal/day and an HRT of 18 days. As the projected average and max 14 day HRTs are below the design values of 20 days and 15 days, respectively, there appears to be available capacity within the digestion system for additional loading even after accounting for future growth within the service area.

Available Capacity With Growth
As shown in Table 3-2, it appears that an additional average daily loading of approximately 18,500 gal/day could be accepted into the existing tankage while meeting the 20 day design HRT and without sacrificing digestion capacity intended for future system growth. Assuming the feed solids of the outside waste were accepted at 13% (see TM 4 for further discussion), this would equate to an additional 20,000 lb/day. It should also be noted that, though the max 14 day loading will likely not dictate planning for acceptance of outside waste, the system could accept an additional loading of up to approximately 41,000 gal/day (or 45,000 lbs/day at 13% solids) under this limited maximum condition.

The above projected available capacity is based on the assumptions that:

- The projected growth will occur; and
- The capacity needed for future growth cannot be utilized under current conditions.

Available Capacity Without System Growth
Realizing that the growth projections are highly variable and that acceptance of outside waste can be adjusted as needed, for the purpose of this study, an additional estimate of available capacity was developed. This second projection assumes that either no growth were to occur during the planning period and/or the present day available capacity would be utilized and adjusted as-needed based on actual service area growth. Under this assumption, the capacity available to outside wasters would equate to approximately 28,000 gal/day under average conditions and 53,000 gal/day under maximum 14 day conditions.

Available Capacity Without System Growth and With 4th Digester
As noted within TM No. 2, the initial planning of the GLSD anaerobic digestion facility included provisions and space for future installation of a fourth anaerobic digestion tank at the facility. The tank would be located to the northwest of the existing digester building and would be supported by additional infrastructure (recirculation pumps, heat exchangers, etc) within the digester building. Assuming the tank were constructed with the same general dimensions as the existing tanks, it is assumed that an additional 1.28 million gallons of effective digestion capacity (discounting the cone and assumed grit volume) could be gained within the system.

Using the same basis of design as the current digestion volume, the capacity of this tank would be determined using a minimum SRT of approximately 20 days for average day conditions and 15 days for maximum 14-day loading conditions. With 1.28 MG of available volume, these available hydraulic capacity numbers would equate to 64,000 and 85,000 gallons per day, respectively. When adding this to the available capacity within the existing digester tanks (without system growth), the total available capacity equates to approximately 92,000 and 138,000 gallons per day, respectively.

The available capacity under all three of the above loading scenarios is summarized in Table 3-2.

		Average Day	Max 14 Day
Current Loading	Influent Loadings (gpd)	164,000	197,000
	Influent Loadings (lb/day)[1]	58,000	70,000
	Hydraulic Retention Time (days)	23	19
Future Loading w/Growth	Influent Loadings (gpd)	174,000	208,000
	Influent Loadings (lb/day)[1]	62,000	74,000
	Hydraulic Retention Time (days)	22	18
Full Design (3 Digesters)	Influent Loadings (gpd)	192,000	250,000
	Influent Loadings (lb/day)[2]	90,000	117,000
	Hydraulic Retention Time (days)	20	15
Full Design (4 Digesters)	Influent Loadings (gpd)	256,000	333,000
	Influent Loadings (lb/day)[2]	120,000	155,000
	Hydraulic Retention Time (days)	20	15
Available Capacity (w/Growth)	Influent Loadings (gpd)	18,000	41,000
	Influent Loadings (lb/day)[3]	20,000	45,000
Available Capacity (No Growth)	Influent Loadings (gpd)	28,000	53,000
	Influent Loadings (lb/day)[3]	30,000	57,000
Available Capacity (w/No Growth w/4th Digester)	Influent Loadings (gpd)	92,000	138,000
	Influent Loadings (lb/day)[3]	100,000	150,000

[1] Assumes digester feed dry solids concentration of 4.3% based on operating data.
[2] Assumes digester feed dry solids concentration of 5.6%.
[3] Assumes outside waste accepts at dry solids concentration of 13%.
[4] Above estimates denote theoretical capacity. Refer to TM No. 5 for additional information pertaining to practical limitations of digestion systems with respect to receiving logistics and solids loading.

Table 3-2
Current, Future and Excess Digestion Capacity

3.4 Future Potential Biogas Production

Based on recent studies[1], it has been shown that the ratio of volatile solids to total solids and the biogas production per pound of volatile solids reduced for source separated organic (SSO) waste is relatively similar to that of municipal biosolids. However, it was also shown that the reduction of the volatile solids in the SSO stream within an anaerobic digester is significantly greater than is typically seen with municipal sludge (82% VS reduction for SSO vs. 55% VS reduction of municipal sludge). This, combined with the fact that SSO is generally fed to digesters at higher solids concentrations, enables the biogas yield from a gallon of SSO to significantly exceed that of from a gallon of municipal sludge. When this difference in gas production is considered on a unit basis, the yield from SSOs is approximately four times that of municipal sludge (10 cf biogas/gal SSO vs. 2.5 cf biogas/gal sludge).

As previously discussed, the evaluation of excess digestion capacity for the District evaluated three scenarios to represent the potential bounds for SSO acceptance volumes. These scenarios include:

- Reserving capacity for flows from year 2025 projected service area growth while utilizing the remainder for acceptance of SSO ("With Growth");
- Utilize all existing reserve capacity for acceptance of SSOs ("Without Growth"); and
- Utilize all existing reserve capacity for SSOs along with construction of a new 4th digester tank ("Without Growth and With 4th Digester").

It was determined that the average available SSO acceptance capacities under each of the above scenarios were approximately 18,500, 28,000 and 92,000 gal/day, respectively. Using these values, sludge digestion performance parameters from GLSD operations data and proven industry values for digestion of SSO, the total anticipated biogas yield under each of these scenarios was calculated. As shown in Tables 3-3 through 3-6, the total theoretical biogas production in year 2025 while digesting municipal sludge from system growth combined with SSO would yield a potential 55% increase from existing operations. However, if the total present day available capacity were to be used for SSO, the biogas production could be theoretically increased by approximately 80% when compared to present yields. As shown in Table 3-6, Construction of a fourth digester for SSO digestion capacity would yield a biogas increase of over 250% as compared to existing production.

It should also be noted that, though the historical ideal digester VSS loading range has been considered to be between 0.12 to 0.16 lb VSS/cf/day, recent studies have shown that codigestion of SSO with biosolids is stable at loadings up to 0.2 lb VSS/cf/day. With the addition of high VSS SSOs at GLSD, the loading under future worst case conditions would be approximately 0.19 lb VSS/cf/day and, therefore, is likely not an issue for digestion process stability.

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[1] Anaerobic Digestion and Energy Recovery from Food Waste, J. Amador, D. Nelsen, C. McPherson, P. Evans and D. Parry (CDM), H. Stensel (University of Washington), and T. Hykes, (U.S. Air Force Academy), WERF, 2012.

		Annual Average	Max 14-Day
Current	Flow (gal/day)	164,000	197,000
	Solids (lbs/day)	58,000	70,000
	VS Reduced (lbs/day)	26,000	31,000
	Solids Remaining (lbs/day)	32,000	39,000
	Digester VS Loading (lbs/cf/day)	0.09	0.11
	Biogas Produced (cf/day)	**390,000**	**460,000**

Table 3-3
Current Biogas Production

		Annual Average	Max 14-Day
Future w/Growth	Service Area (Municipal) Loading[1]		
	Flow (gal/day)	174,000	208,000
	Solids (lbs/day)	62,000	74,000
	VS Reduced (lbs/day)	27,000	33,000
	Solids Remaining (lbs/day)	34,000	41,000
	Biogas Produced (cf/day)	409,000	491,000
	Outside Waste (SSO) Loading[2]		
	Flow (gal/day)	18,000	41,000
	Solids (lbs/day)	20,000	45,000
	VS Reduced (lbs/day)	14,000	31,000
	Solids Remaining (lbs/day)	6,000	14,000
	Biogas Produced (cf/day)	190,000	423,000
	Total		
	Flow (gal/day)	192,000	250,000
	Digestate Solids (lbs/day)	40,000	55,000
	Digester VS Loading (lbs/cf/day)	0.13	0.19
	Biogas Produced (cf/day)	**600,000**	**910,000**

[1] Assumes TS of 4.3%, VS/TS of 81.2%, VS reduction of 54.6% and biogas production of 15 cf/lb VSR.
[2] Assumes TS of 13%, VS/TS of 85%, VS reduction of 82% and biogas production of 13.6 cf/lb VSR.

Table 3-4
Theoretical Potential Biogas Production
With System Growth and SSO Acceptance

Future w/out Growth		Annual Average	Max 14-Day
	Service Area (Municipal) Loading[1]		
	Flow (gal/day)	164,000	197,000
	Solids (lbs/day)	58,000	70,000
	VS Reduced (lbs/day)	26,000	31,000
	Solids Remaining (lbs/day)	32,000	39,000
	Biogas Produced (cf/day)	387,000	464,000
	Outside Waste (SSO) Loading[2]		
	Flow (gal/day)	28,000	53,000
	Solids (lbs/day)	30,000	57,000
	VS Reduced (lbs/day)	21,000	40,000
	Solids Remaining (lbs/day)	9,000	17,000
	Biogas Produced (cf/day)	288,000	541,000
	Total		
	Flow (gal/day)	192,000	250,000
	Digestate Solids (lbs/day)	42,000	56,000
	Digester VS Loading (lbs/cf/day)	0.14	0.21
	Biogas Produced (cf/day)	**670,000**	**1,000,000**

Table 3-5
Theoretical Potential Biogas Production
Without System Growth and With SSO Acceptance

Future w/out Growth and w/4th Digester		Annual Average	Max 14-Day
	Service Area (Municipal) Loading[1]		
	Flow (gal/day)	164,000	197,000
	Solids (lbs/day)	58,000	70,000
	VS Reduced (lbs/day)	26,000	31,000
	Solids Remaining (lbs/day)	32,000	39,000
	Biogas Produced (cf/day)	387,000	464,000
	Outside Waste (SSO) Loading[2]		
	Flow (gal/day)	92,000	138,000
	Solids (lbs/day)	100,000	150,000
	VS Reduced (lbs/day)	70,000	104,000
	Solids Remaining (lbs/day)	30,000	45,000
	Biogas Produced (cf/day)	946,000	1,400,000
	Total		
	Flow (gal/day)	256,000	335,000
	Digestate Solids (lbs/day)	63,000	84,000
	Digester VS Loading (lbs/cf/day)	0.19	0.27
	Biogas Produced (cf/day)	**1,300,000**	**1,900,000**

[1] Assumes TS of 4.3%, VS/TS of 81.2%, VS reduction of 54.6% and biogas production of 15 cf/lb VSR.
[2] Assumes TS of 13%, VS/TS of 85%, VS reduction of 82% and biogas production of 13.6 cf/lb VSR.

Table 3-6
Theoretical Potential Biogas Production
Without System Growth, With SSO Acceptance and With 4th Digester

3.5 Current and Future Energy Balance

3.5.1 Current Energy Use

The existing energy systems at the GLSD facility utilize a combination of biogas, natural gas, purchased electricity and solar energy. For the purpose of this study, the energy balance evaluation was limited to the systems which currently utilize biogas or a combination of biogas and natural gas. As shown on Figure 3-1, these systems currently consist of:

- Boilers for digester heating (a.k.a. Glycol Boilers which are located in the Boiler & Fan Building);
- New steam boilers for facility space heating demand (which are located in a room within the maintenance garage);
- Old natural gas steam boilers for facility space heating demand (located within the process/maintenance building);
- Biosolids drying facility (operated by NEFCO); and
- Waste gas burner (flare).

The glycol boilers provide heating for the digester heat exchanges, space heat for the fan and boiler buildings and the influent heat exchangers. It should be noted that waste heat, in the form of condensate, from the thermal drying operation can also be used to supply heat to sludge influent heat exchanger No.1 (IHE No.1), though the system is currently offline due to pump impeller issues. When in use, this system is able to recover heat from the drying process back into the digestion system which further reduces the load on the glycol boilers. All boilers, with the exception of the old steam boilers, are provided with duel fuel gas trains (natural and digester gas) to ensure that the heating demand can be met if the digesters are not producing an adequate volume of gas to meet the demands of the system. The switching between digester and natural gas is currently a manual operation performed as necessary in order to manage the inventory of digester gas.

As previously discussed, though the facility does utilize biogas meters, recent operations data is thought to underestimate production and usage. For this reason, the previously determined theoretical biogas production estimates were utilized in the energy balance evaluation. There are also meters and sub meters within the natural gas system. Available data from there meters between September 2011 to August 2012 was analyzed and average usage for each system determined to the maximum extent practical. For the purpose of determining a general overall energy balance between biogas and natural gas use, all data was converted to MMBtu/hr and included on Figure 3-1.

It should also be noted that heating value of digester biogas typically ranges from 500 to 650 BTU/cubic foot, with 600 BTU/cf being used in this estimate. For comparison, natural gas typically contains an average heating value of approximately 1,000 BTU/cf.

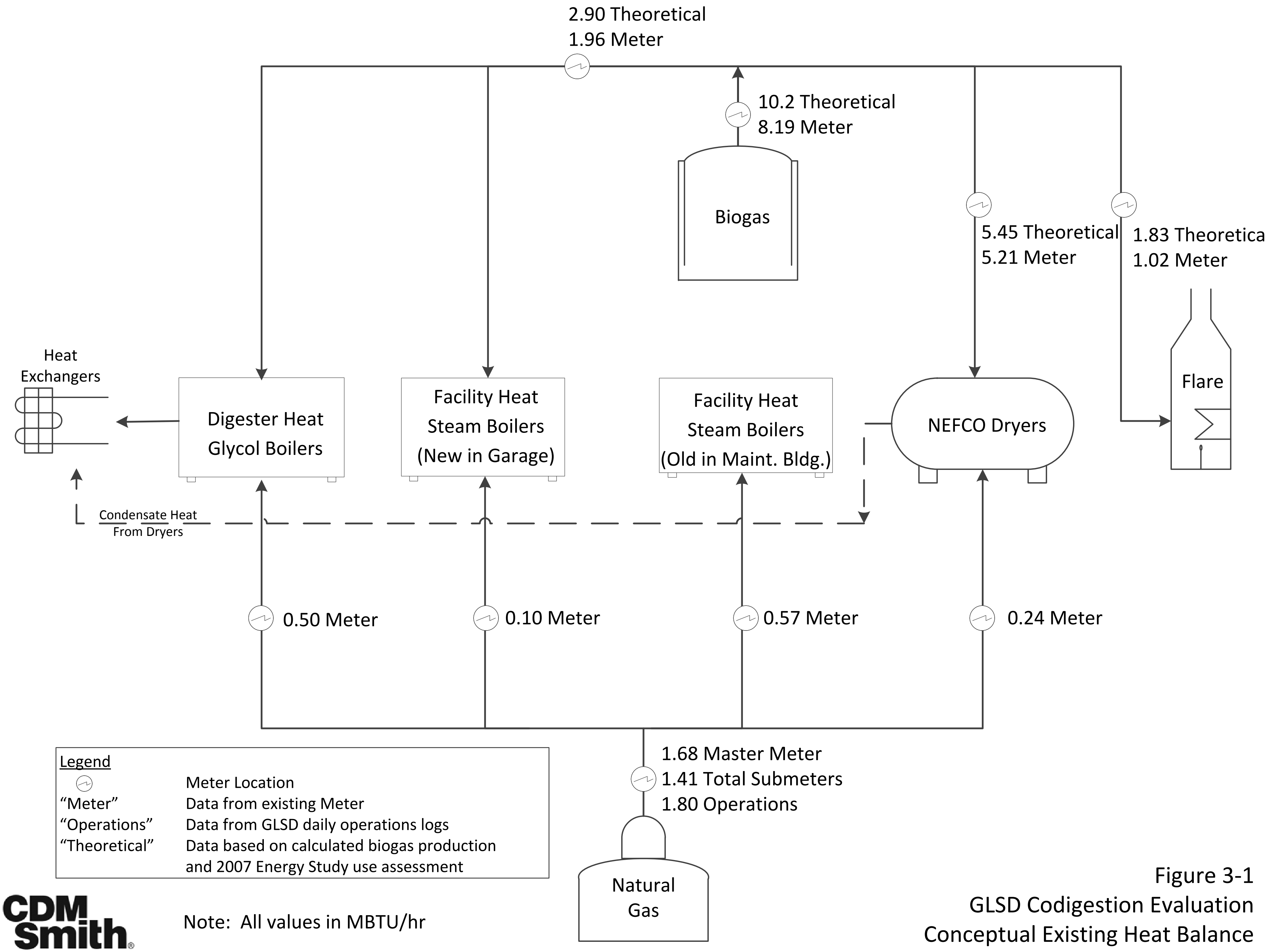


Figure 3-1
GLSD Codigestion Evaluation
Conceptual Existing Heat Balance

3.5.2 Future Projected Energy Balance

An increase in digester loading carries with it the previously discussed biogas production boost and associated energy recovery opportunities. However, the processing of additional solids yields an increase in energy consumption in the following areas:

- Heat required for preheating of outside/additional waste; and
- Energy required for downstream processing of additional digestate solids.

Though the downstream processing of solids would also involve electrical energy and chemical consumption (i.e. centrifuge, conveyor, polymer, etc), the current energy balance has been limited to thermal energy and biogas utilization. Cost associated with all energy and chemical demands will be addressed within TM No. 7.

As shown in Table 3-7, the current average heat demand from the anaerobic digestion process equates to approximately 4.5 MMBtu/hr. With the added thermal demands associated with increased feed heating within the existing tankage, this demand could increase to approximately 4.8 MMBtu/hr depending on the incoming outside waste temperature. Additionally, with the added digestion capacity and heating load created by a fourth digester tank, the thermal demand of the system could increase to approximately 6.4 MMBtu/hr.

More significantly, however, is the increased demand for gas within the thermal drying system. Based on existing data, it appears that the energy required to process each dry ton (DT) of solids is approximately 8.0 MMBtu/hr. Utilization of the existing reserve digestion capacity, could increase the daily solids processing by 4.6 DT/day, thereby increasing the demand for thermal energy by 1.3 MMBtu/hr. Further, the addition of a fourth digester to accept SSO could increase the daily solids processing by 15 DT/day, thereby increasing the demand for thermal energy by 5 MMBtu/hr. Despite the use of additional biogas for preheating and the thermal drying process, as shown in Table 3-4, the net potential yield from this additional waste is estimated to be between approximately 150,000 and 670,000 cf/day.

It is important to note in this balance that it has been assumed that current operations remain similar to those which occurred during the data collection period. Of most significance is the District's ability to maximize their current use of biogas. Based on the 12-month operations data set, there appear to be a number of days where there is significant biogas flaring concurrent with natural gas use. For example, during the top 30 days of flaring, the natural gas use appears to have averaged approximately 40,000 cf/day. Further, the 2007 energy study had noted that approximately 18% of the total biogas production had been flared on an average basis. Though much of this may have to do with the limitations within the current biogas holding covers (which currently has the ability to contain ~8.6 hrs of average production), combined with the systems at the facility that utilize only natural gas as a fuel source, it may be possible to improve the biogas utilization in the boiler and reduce the associated use of natural gas in the future.

	Current Average	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Total Available Heat From Biogas				
Average Biogas Production (cf/day)	390,000	600,000	670,000	1,300,000
Biogas Unit Heat Value (Btu/cf)	600	600	600	600
Total Available Heat (MMBtu/hr)	**9.7**	**15.0**	**16.9**	**33.3**
Anaerobic Digestion Process Heat Requirements				
Municipal Biosolids Feed Heating				
Incoming Temperature (assumed) (deg F)	60	60	60	60
Final Temperature (deg F)	95	95	95	95
Flow Rate (gpm)	114	121	114	114
Heat Required (MMBtu/hr)	1.99	2.11	1.99	1.99
Outside Waste (SSO) Heating				
Incoming Temperature (assumed) (deg F)	-	60	60	60
Final Temperature (deg F)	-	95	95	95
Flow Rate (gpm)	-	13	19	64
Heat Required (MMBtu/hr)	-	0.22	0.34	1.12
Tank Heat Loss to Ambient Air (MMBtu/hr)	1.25	1.25	1.25	1.67
Total AD Process Heat Demand (MMBtu/hr)	**3.24**	**3.58**	**3.58**	**4.78**
Thermal Drying Heat Requirements				
Average Digestate Dried Solids (DT/day)	16.18	20.15	20.78	31.29
Biogas Use (cf/day)	207,000	-	-	-
Biogas Energy (MMBtu/hr)	5.17	-	-	-
Natural Gas Use (cf/day)	5,700	-	-	-
Natural Gas Energy (MMBtu/hr)	0.24	-	-	-
Average Dryer System Energy Use (MMBtu/DT)	8.02	8.02	8.02	8.02
Total Energy to Thermal Drying (MMBtu/hr)	**5.41**	**6.74**	**6.95**	**10.46**
Net Energy Difference				
Additional Energy From Biogas (MMBtu/hr)	-	5.31	7.19	23.6
Heat Required for Additional Flow (MMBtu/hr)	-	(0.34)	(0.34)	(1.53)
Heat Required for Additional Drying (MMBtu/hr)	-	(1.33)	(1.54)	(5.05)
Net Energy Difference (MMBtu/hr)	-	**3.64**	**5.32**	**17.1**
Net Available Biogas Equivalent (cf/day)	-	**146,000**	**213,000**	**682,000**

Table 3-7

Current and Future Energy Balance

Draft Technical Memorandum No. 4

From: *Benjamin R. Mosher, P.E., BCEE*
Eric Spargimino, P.E., LEED®AP

Date: *February 11, 2013 (Revised June 26, 2013)*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Outside Wastes Evaluation*

4.0 Outside Wastes Evaluation

As noted in Technical Memorandum No. 1, over the past two years, the Massachusetts Department of Environmental Protection (MassDEP) has announced plans to impose a ban on source-separated organics (SSO), with the goal of diverting an additional 350,000 tons per year of SSO by 2020. The new regulations provide the following definitions pertaining to SSO and related materials:

- Food Material means source separated material produced from human or animal food production, preparation and consumption activities which consists of, but is not limited to, fruits, vegetables, grains, and fish and animal products and byproducts.
- Compostable Material means an organic material, excluding sanitary waste water treatment residuals, that has the potential to be composted and which is source separated from waste.
- Organic Material means vegetative material, food material, agricultural material, biodegradable products, biodegradable paper, and yard waste.
- Source Separated means separated from solid waste at the point of generation and kept separate from solid waste.

MassDEP expects to have the proposed ban on disposal of SSO go into effect in the summer of 2014. Initially the ban will only impact generators of more than one wet ton per week of organic wastes. The current focus on diverting SSO is also driven by the interest of MassDEP and the Governor's Office in expanding renewable energy production, including through biogas.

MassDEP is concurrently promulgating regulations intended to streamline the siting of facilities that can process the additional diverted SSO, including anaerobic digestion and composting facilities, and taking other steps to encourage such development. One of the regulation changes allows for wastewater treatment plants, such as GLSD, to accept SSO for processing in their anaerobic digesters.

4.1 Types of Outside Wasters

The focus of this study is co-digestion of pre-consumer SSO. The MassDEP intends to ban such wastes from landfills and municipal solid waste (MSW) incinerators. These wastes typically include food wastes from supermarkets, institutions, food producers, and other large generators. However, there are other organic wastes such as fats, oils and greases (FOG), or airport deicing fluid that could also be considered.

The highest purity FOG wastes (e.g. fryolater grease) are typically collected from restaurants and other food establishments and recycled through rendering companies. These high quality wastes are a tradable commodity since they can be used directly in the manufacturing of biodiesel fuels. But other FOG wastes, with greater levels of contamination, have good properties for co-digestion, with high energy content and nearly 100 percent conversion to biogas. However, in comparison to other types of wastes, FOG is currently not managed by large-scale waste consolidators (haulers), but rather by many small companies (e.g. septage haulers). It would be a challenge for GLSD to interface with a large number of FOG waste haulers. However, if FOG wastes are a component of an organic food waste they will improve the biodegradability of the mixture.

MassDEP estimates that there are approximately 950,000 wet tons of such organics in the waste stream, and that currently only about 100,000 wet tons of pre-consumer food wastes are diverted, mostly by supermarkets, institutions, and other large generators. MassDEP had recently published a 2011 survey which was compiled by USEPA Region 1. The survey identified nine sectors where SSOs are generated with the food and beverage manufacturing and processing producing nearly 60 percent of the total waste as shown in Table 4-1. Table 4-2 shows that most of the wastes are generated by a relatively small number of generators; approximately 80 percent of the annual tonnage is generated by only 30 percent of the total number of generators.

The SSO that is currently diverted is managed in any of the following ways:

- Edible food is provided to food banks – this is the highest priority use, if appropriate;
- Animal feed (e.g. at pig farms);
- Commodity processors, such as Baker Commodities (recycles high value grease and oil);
- Anaerobic digestion – a very limited amount is processed in anaerobic digesters at food production facilities or stand-alone commercial operations, such as the Jordan Dairy Farm digester (details below); and
- Composting – at municipal composting sites or the several commercial and/or on-farm composting operations (Figure 4-1) in Massachusetts or in neighboring states.

Generator Sector	*Estimates Tons/Year*	*Percent*
Food and Beverage - Manufacturers and Processes	550,000	58
Restaurants	165,000	17
Supermarkets and Grocery Stores	105,000	11
All Other Sectors	130,000	14
Total	950,000	100

Table 4-1: Survey of Source Separated Organics Generators

Tons Per Year Per Organics Generator	*Number of Generators*	*Percent by weight*
Greater than 400	860	59
200 - 400	295	8
100 - 200	930	14
Less than 100	4,775	19
Total	6,860	100

Table 4-2: Generator Size Distribution

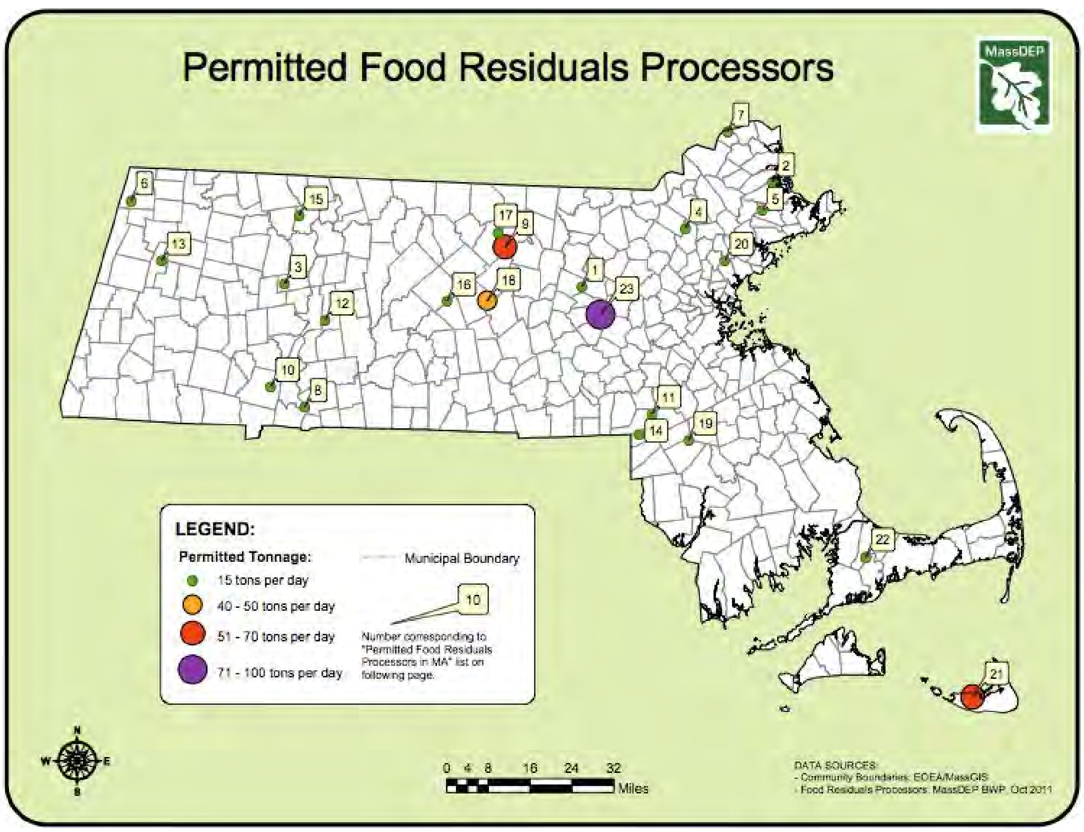


Figure 4-1: Permitted Food Residuals Processors throughout MA (courtesy of MassDEP)

4.2 Industry Experience with Co-Digestion

While co-digestion of outside wastes at municipal wastewater treatment plant anaerobic digesters is not a common practice in the U. S., it has proven successful at several facilities. These experiences are summarized below.

4.2.1 National Experience with Co-Digestion

Nationwide, approximately 8 percent of all municipal wastewater treatment plants operate anaerobic digesters. Of the approximately 1200 wastewater treatment plants with operating anaerobic digestion only 15 percent take in outside waste and feed it directly into anaerobic digesters.

Three well known examples of co-digestion in the U. S. are the 55 mgd East Bay Municipal Utilities District (EBMUD) in California, the 14 mgd Gloversville-Johnstown Joint Wastewater Treatment Facility (GJJWTF) in New York, and the 40 mgd City of Des Moines Water Reclamation Facility in Iowa. All three programs began within the last ten years, demonstrating the relative novelty of co-digestion programs in this country.

East Bay Municipal Utilities District (EBMUD)

EBMUD is the first utility in the United States to undertake the co-digestion of post-consumer food waste, which it began doing in 2008 as an expansion of its 2002 trucked waste program. The EBMUD plant is ideally located adjacent to a major interstate highway in Oakland, CA with easy access from the entire San Francisco Bay area. In EBMUD's program, a private waste hauler pre-screens food waste collected curbside from San Francisco residents and businesses. EBMUD has created a patented pretreatment process that slurries and pulps the food waste, removing debris and impurities, such as plastics, cutlery, and metal objects. EBMUD has created both engineering mechanisms and contractual mechanisms to ensure that the pulped food waste that is fed to the digesters is readily digestible and relatively free of contaminants. The treated food waste is digested along with other imported organic wastes, such as FOG, at an average ratio to wastewater sludge of about 10 percent by volume. EBMUD charges its customers as follows:

	$/gal
Liquid organic wastes	0.03
Septage	0.07
Unconcentrated FOG	0.11
Concentrated FOG	0.15

The EBMUD co-digestion program is widely considered to be a successful experience and is often used as a case study on this subject. Most notably, the additional biogas obtained, in part, from the co-digestion process combined with the recent installation of a new 4.6-megawatt biogas turbine has reportedly enabled the facility to become more than 100% energy self-sufficient.

Gloversville-Johnstown Joint Wastewater Treatment Facility (GJJWTF)

The GJJWTF imports industrial organic waste from local food processing facilities. The plant is located a few miles from the New York State Thruway. Some of these industrial wastes are generated in an industrial park adjacent to the plant which allows pipeline transport of wastes. This waste consists of cheese and yogurt whey; in 2010, the GJJWTF accepted nearly 25 MG per year of this high strength whey waste. The plant staff feed the digesters approximately 40,000 gallons of sludge for every 80,000 gallons of outside waste. The GJJWTF constructed new waste receiving tanks that allow for on-site storage of whey waste, such that the digesters can be evenly fed, avoiding process upsets. Both EBMUD and GJJWTF had excess digester capacity, but had to construct outside waste receiving infrastructure and new power generation units to accommodate the increase in digester gas that resulted from the importation of organic wastes.

Based on 2011 operations, the GJJWTF codigestion program has yielded 66% VSS reduction rates and 18 cf/lb VS biogas production rates as a result of the whey codigestion. In addition, the additional revenues realized from the acceptance of the whey combined with the additional biogas production have yielded net revenues or approximately $600,000 after accounting for added costs (additional chemicals, solids disposal, etc). As a result, co-digestion at this facility is considered to be successful.

City of Des Moines Water Reclamation Facility

In Des Moines, hauled-in organic waste accounts for 45 percent of the digester's volatile solids loading. Wastes received at the WWTP include FOG, biodiesel and ethanol manufacturing byproducts, and food and animal processing wastes. Des Moines constructed a new waste receiving facility and storage tank to accommodate the large volume of organic wastes coming into the plant. Des Moines also had to upgrade digesters and gas storage. Des Moines uses some of the biogas to fuel an internal combustion engine CHP system that provides digester heating and some of the plant electrical demand. Excess biogas is sold to a nearby manufacturing facility at a discount in comparison to natural gas costs.

Similar to the previous examples, the Des Moines co-digestion program has been quite successful and has enabled a substantial increase in biogas production, sale and ultimately reinvestment in the facility infrastructure. In recent years, the facility has generated over 460-mcf/year of biogas by co-digesting 26-million gallons of high-strength organic waste. This has resulted in generation of over 8-million kWh of electricity, providing for building and process heat in addition to the sale of about 40 percent (211-mcf) of the biogas to a neighboring industrial facility.

4.2.2 Regional Experience with Co-Digestion

In New England, of the 34 plants with digesters there are only four that take in outside wastes – mostly FOG and septage – and feed them directly into their digesters. The largest of this group is Norwich, CT which is a 5.2 mgd WWTF. Of these, only Essex Junction, VT also takes in commercial and industrial organics. There are two other facilities in construction that plan to take in outside wastes for co-digestion: Fairhaven, MA and Lewiston-Auburn, ME (Table 4-3).

Many New England wastewater treatment facilities also receive septage wastes. Typical costs range from approximately $0.05 to $0.10 per gallon. The Massachusetts Water Resource Authority (MWRA) accepts septage wastes at approximately ten locations throughout its service area. Individual septage haulers are permitted by MWRA which charges the individual towns a fee based on the volume of wastes recorded at the receiving locations. The individual towns charge the haulers at rates similar to those shown previously.

Anaerobic digestion is also being promoted and developed at sites other than at wastewater treatment facilities. There are about 200 farm-based digesters in operation in the U. S. Some food processors and industrial facilities (e.g. Stonyfield Yogurt, Tropicana) operate digesters. Biogas is also produced and utilized at larger landfills, with encouragement from U. S. EPA and state agencies.

MassDEP and the Governor's office are promoting the development of anaerobic digestion capacity around the state. They have supported and applauded the creation of the "five farm" project that involves construction of new anaerobic digesters and CHP at five farms around the commonwealth.

The Jordan Dairy Farm in Rutland, MA – northwest of Worcester – is the first of the five farm-based anaerobic digesters that will process a mixture of farm manures and SSO. The Jordan Farm's digester has been in operation since summer 2011 and treats a mixture of dairy manure and SSOs. The single digester has a capacity of approximately 25,000 gallons per day. The biogas produced is fed to an internal combustion engine, which is designed to produce 2280 MW hours of electricity a year (260 kW average power production). Heat from the engine jacket is run through a heat exchanger to maintain digester temperature. Electricity generated by the facility provides 100 percent of the electricity needs of the farm; excess power is sold to the grid. The digestate residual is pumped to a digestate holding tank, where it is stored until the farmer applies it to soils to support the growth of corn silage and hay crops.

MassDEP's promotion of anaerobic digestion capacity is likely to continue, but working through regulatory and public acceptance hurdles and creating actual new facilities will be time-consuming.

Municipality	*WWTP*	*Average Flow (MGD)*	*Feed Outside Waste Into Digester(s)?*	*Use of Biogas*
CONNECTICUT				
Danbury	Danbury WPCF	10.7	No	
Fairfield	Fairfield WPCF	8.2	No	
Manchester	Manchester Hockanum River WPCF	6.7	No	
Milford	Milford (Beaver Brook) WPCF	2.0	No	
Milford	Milford (Housatonic) WPCF	8.0	No	
North Haven	North Haven WPCF	3.4	No	
Norwich	Norwich Public Utilities WWTF	5.2	FOG	Microturbine
Windsor	Poquonock WPCF	2.5	No	
Plantsville	Southington WPCF	3.6	No	
Wallingford	Wallingford WPCF	5.0	No	
MAINE				
Lewiston	Lewiston-Auburn WPCA (under construction)	15.0		IC engine
MASSACHUSETTS				
Clinton	Clinton (MWRA) WWTP	2.6	No	
Winthrop	Deer Island (MWRA) WWTP	363	No	Turbine
Fairhaven	Fairhaven WPCF	2.7	Yes	IC engine
No. Andover	Greater Lawrence Sanitary District	30.0	No	Heat-drying
Pittsfield	Pittsfield WWTP	12.0	No	Turbine
Rockland	Rockland WWTP	2.5	No	
NEW HAMPSHIRE				
Franklin	Winnepesaukee River Basin Program	5.5	Septage, FOG	
Hanover	Hanover WWTP	1.5	No	
Nashua	Nashua WWTP	12.5	No	IC engine
RHODE ISLAND				
Providence	Narragansett Bay Commission	21.0	No	IC engine
VERMONT				
Barre	Barre WWTF	2.6	No	
Brattleboro	Brattleboro WWTF	1.5	No	Microturbine
Burlington	Burlington North Ave. WWTF	1.3	No	
Burlington	Burlington Riverside WWTP	0.7	No	
Essex Junction	Essex Junction WWTF	2.0	FOG, food, industrial	Microturbine
Montpelier	Montpelier WWTF	1.9	FOG	
Newport	Newport City WWTF	0.8	No	
Rutland	Rutland (City) WWTF	6.0	No	
So. Burlington	South Burlington WWTF	1.8	No	Microturbine
Springfield	Springfield WWTF	1.1	No	
St. Albans	St. Albans WWTF	2.1	No	
St. Johnsbury	St. Johnsbury WWTF	1.0	No	
Windsor	Windsor (Main) WWTF	0.4	N0	
	TOTAL (MGD)	**545**		

Almost all listed WWTPs use biogas for digester heating and building heat.

Table 4-3

New England WWTF with Anaerobic Digesters

4.3 Ongoing Waste Characterization and Co-Digestion Studies

As part of a concurrent contracted project for the MWRA involving CDM Smith, Fay, Spofford & Thorndike (FST) and Dr. Chul Park at the University of Massachusetts/Amherst (MWRA project 7274A), an evaluation of the co-digestibility of food waste and wastewater solids is being investigated. The following steps are currently being taken:

- Conduct a bench-scale digestibility study of SSO from various sources;
- Assess the biochemical methane potential (BMP) for these SSO;
- Review the side-stream impacts from co-digestion of these SSO (toxicity, nutrient load);
- Quantify volatile solids reduction; and
- Compare various mix ratios of food waste to sludge.

The bench scale digestibility research will be conducted with the help of graduate students at Dr. Park's lab. Results are expected in mid-2013. The information from this research will assist in estimating biogas production (BMP) and residual solids (volatile solids reduction) experienced while co-digesting SSOs with municipal sludge. Though these analyses are being conducted specifically pertaining to a potential co-digestion program at the MWRA's Deer Island Treatment Plant (DITP), the results are likely to be valuable and generally representative of the potential performance of co-digestion at GLSD.

CDM Smith has also been conducting co-digestion research for several years. As part of these efforts, a laboratory treatability study was completed to evaluate the feasibility of an anaerobic digestion to process food wastes from Department of Defense (DOD) installations. This work was conducted on food wastes generated at the U.S. Air Force Academy in Colorado with the goal of quantifying food waste digestibility and energy yield, identifying potential nutrient limitations, and determining appropriate specific energy loading rates (SELR) for these wastes. Though these evaluations were completed in the absence of waste activated sludge (i.e., separate food waste digestion rather than co-digestion), the results have provided estimates of expected VS reduction and biogas production from SSO digestion that have been used in this analysis for GLSD.

4.4 Private Sector Role in Co-Digestion at GLSD

Currently private-sector solid waste transporters and disposal companies (referred to herein as "haulers") direct approximately 100,000 tons per year of food wastes to organics processing facilities in Massachusetts. There are approximately two dozen such facilities currently operating. The typical processing facility is a small-scale composting facility. MassDEP estimates that approximately 400 businesses and institutions are currently diverting organic wastes. The typical waste generator is a supermarket, large restaurant, college or university, or food producer.

When the organics waste ban for pre-consumer food waste is instituted in 2014, MassDEP expects that approximately 3,000 businesses and institutions will be impacted – or nearly ten times the present number. Approximately 350,000 tons per year or approximately 1,000 tons per day of organic wastes will need to be recycled. To service these customers, haulers are making plans to establish new or modified transfer stations throughout the commonwealth to serve as collection and processing points for organics.

4.4.1 Preprocessing Facilities

Though very few facilities presently exist nationwide, a food waste processing facility is expected to include equipment to process in-coming wastes in order to produce an engineered food waste product that can be easily digested. Processing is expected to include machinery to screen and pulp the wastes, remove contaminants (e.g., glass, plastics, metals, and cardboard), and produce a uniform pumpable material that is readily digestible.

One of the limited examples of preprocessing systems that has been utilized to-date is the "CORe" (Centralized Organics Recycling equipment) system developed by Waste Management. This system is a source separated food waste processing and blending system designed to remove the non-degradable contaminants from source separated food waste streams. The major components of this system include an organic material feed hopper, hopper auger feed, bio-separator (cylindrical screen) and bio-slurry tanks. It is intended to utilize a small footprint and provide a totally enclosed solution for SSO preprocessing at a WM transfer station(s), landfill, or on a partner's property. Using this system, the received material is blended into a consistent feedstock (called Engineered Food Waste (EFW) Product). Pilot testing of the CORe system was completed at Victor Valley Water Reclamation Authority in CA with reportedly positive results.

Despite the potential to develop an on-site preprocessing facility at GLSD, construction, operation and maintenance of such a facility would also bring with it several distinct disadvantages, including:

- Responsibility for continuously seeking customers with the likelihood that most waste producers are unlikely to engage in long-term contracts to guarantee the waste stream;
- Management of a high quantity of smaller volume deliveries including ensuring delivered waste is free of gross contaminants and the waste does not contain any compounds that could negatively impact the digestion process;

- Cost of disposal and/or recycling of potentially high percentage of inorganic residuals that are separated from the incoming waste stream;
- Potential local sensitivity to development of an additional waste receiving facility at the facility; and
- Additional labor costs associated with operation and maintenance of significant waste receiving facility.

As a result of the above reasons, for purposes of this analysis, we have assumed that GLSD would enter into arrangements with private sector hauler(s) to accept and process food waste off-site rather than attempt to own and operate a separate onsite preprocessing system. The private sector would own and operate any pre-processing facility and be responsible for transportation of the product to the GLSD facility by truck. The product would be delivered at a range of solids content which, for this report we have assumed to be 13 percent based on limited experience at similar facilities.

4.4.2 Private Hauler Contractual Considerations

GLSD staff has noted that there may be legal and procurement issues that would need to be addressed prior to entering into contracts with private companies that manage and haul wastes. These will obviously have to be addressed in order for the District to manage SSO. To ensure smooth operations of a co-digestion program, it is necessary to have simple, clear legal and regulatory structures, as well as an operating system for SSO suppliers that are simple and cost-competitive. For purposes of this study we have assumed that any legal issues would be resolved by GLSD. EBMUD has established SSO quality criteria and a simple legal and shared-liability structure. Operationally, it has established a convenient system that allows qualifying material to be discharged at the WWTP at any time and at a rate that is lower than other options, especially for organics that EBMUD prefers, such as FOG.

Technical Memorandum No. 5

From: *Benjamin R. Mosher, P.E., BCEE*

Date: *March 7, 2013 (Revised June 26, 2013)*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Digestion Improvements, Co-Digestion and Biogas Utilization Options*

5.0 Digestion, Co-Digestion and Biogas Utilization Improvements

In order to successfully receive SSO at the GLSD facility, several improvements must be made to ensure proper reliability and process control. For this analysis, we have examined a wide range of potential acceptance quantities to fully understand the benefits and costs. As discuss previously and in more detail below, the three scenarios would bring with them a varying degree of impact to the existing digestion process and its operations.

In general, the impact of the SSO acceptance alternatives on the GLSD digestion process would include the following:

Available Capacity With Growth

Under this alternative, the current excess digestion capacity would be utilized for SSO acceptance (18,500 gal/day) with the exception of a small portion of the capacity (9,500 gal/day) that would be reserved for future growth within the municipal collection system. Under these conditions, the overall digestion process would not change substantially as this additional volume represents less than 10% of the future/full design loading to the digestion system. With the exception of foam control, it is likely that only limited infrastructure improvements would be required to accept and process this waste. However, as shown in Table 3-4 and discussed further below, this alternative is likely to yield an increase in biogas production on the order of 50% above current levels. As a result, substantial investment in biogas utilization systems would be required to harness this resource.

Available Capacity Without System Growth

The second alternative has assumed that all existing available capacity would be utilized for SSO processing. Under this assumption, the capacity available to outside wasters would equate to approximately 28,000 gal/day which represents slightly less than 15% of the total processing capacity. Similar to the previous alternative, the significant improvements required to process this waste while realizing the benefit of the expected 70% increase in biogas production would include foam control and biogas utilization systems.

Available Capacity Without System Growth and With 4th Digester
This alternative evaluates the maximum theoretical amount that might be accepted at the GLSD facility utilizing the current digestion complex layout. This further assumes that the 4^{th} anaerobic digester tank along with the required ancillary equipment were to be constructed in the area reserved for future anaerobic digestion facility expansion as shown within Figure 5-1. Under this scenario, the total system capacity would be increased to approximately 256,000 gal/day while the existing municipal load (at its current level) would only utilize 64% of this capacity. The remaining capacity would be capable of processing approximately 92,000 gal/day at the current 20 day average SRT. It should also be noted that this quantity of SSO (140,000 tons per year) equates to approximately 40% of the total SSO wastes projected by MassDEP to be diverted from landfills and incinerations state-wide in 2020.

Since the SSO is expected to have much higher solids content (~13%) as compared to the current municipal sludge feed (~4.25%), the blend of sludge and SSO would approach 8 percent solids. The ability of the digesters to be operated successfully at this higher concentration of solids would likely need to be proved through piloting. Further, due to the high volatile solids content of the SSO, the resulting loading to the digesters under these conditions could approach 0.20 lbs/cf/day which is above the historically accepted range of 0.12 to 0.16 lb/cf/day. However, it has been proven in recent studies and operating facilities that VS loading under some co-digestion conditions can approach almost double the previously understood values. It should be noted, however, that the presence of high concentrations of FOG in the feed could reduce this acceptable VS loading limit so as to reduce the potential for upset or exacerbated foaming. Due to the complexity of these loading conditions and variable nature of organic waste, piloting of this feed scenario is recommended as noted later this this study.

In addition to the above process considerations, significant facility upgrades would be required to handle the 230% increase in biogas production and downstream dewatering and drying modifications may be required to handle the 100% increase in post digestion solids that would result.

The subsequent sections of this memorandum discuss additional detail as to the improvements required for these co-digestion alternatives. Costs associated with the required improvements will be presented and further evaluated in TM No. 7.

5.1 Digestion Pretreatment and Receiving

Pretreatment
As noted in TM No. 4, it is assumed for the purpose of this evaluation that hauler(s) would pre-treat and transport SSO to the GLSD facility. The source separated organics are expected to have an average concentration of 13 percent. This is a critical design value and impacts biogas production estimates and facility economics. The SSO will be blended with the combined primary and secondary sludge. Therefore, no thickening of SSO will be required. Off-site processing of the SSO is assumed to involve screening to 8 mm or less and removal of all non-biodegradable material

(plastics, cutlery, and metal objects) to avoid any further processing of these wastes at the GLSD facility. However, these are critical assumptions which need to be demonstrated in further testing.

Contractual mechanisms to ensure that the pulped food waste (also commonly referred to as Engineered Food Waste or EFW) that is fed to the digesters is readily digestible and relatively free of contaminants would be essential. As noted above, obligations and control regarding acceptance of FOG should also be considered in detail.

Transportation

Transportation of SSO to the GLSD facility will likely occur via truck. Its proximity to Interstate 495 as well as lack of residential areas through which trucks would need to travel minimizes potential concerns regarding disturbance caused by the increased traffic. Additionally, it should be noted that even under the "no outside growth" SSO acceptance scenario shown in Table 3-5, average truck traffic would be limited to approximately five trucks per day based on the available capacity in the GLSD digestion system and assuming 6,000 gallon truck capacity. However, in the event a fourth digester were to be constructed for outside waste acceptance, this traffic could potentially increase to approximately 15 trucks per day under average conditions.

SSO Receiving Stations

The 2002 digestion upgrade also involved the installation of a septage receiving station connected to the outside sludge storage tanks. Though the single receiving station is likely acceptable for any of the three digester options (~5 trucks per day), there is likely to be a practical limitation as to the number of trucks that can be effectively offloaded at the facility with a single station. These deliveries would occur during regular working hours and, due to the assumed high solids percentage (13%) of the material, offload time from a single truck would be greater than that from a typical liquid waste. Assuming a one hour per truck offload time and the ~15 truck trips per day required for options involving a fourth digester, it is assumed that a second receiving station would be required along with the construction of a fourth digester.

It is also noted that the staffing required to labor manage this receiving operation must also be considered. Based on conversation with GLSD management, it is assumed that though 5 trucks per day could be logged and monitored with existing resources, it is estimated that a new dedicated staff member would be needed to perform these duties for 15 trucks per day. This labor cost will be incorporated into the Technical Memorandum No. 7 cost analysis.

SSO Receiving Tanks

The GLSD facility currently has four sludge storage tanks, each with a capacity of 75,000 gallons. These tanks are located immediately to the east of the main process building and adjacent to the boiler and fan building. Under current operations, two of the four tanks are utilized to store digested sludge prior to centrifuge dewatering. During the construction of the digestion system, one tank was divided in half for use in storing thickened waste activated sludge (TWAS) discharged from the GBTs. The remainder of that tank as well as the fourth remaining tank were repurposed to accept outside sludge with a total available storage capacity of approximately 110,000 gallons. This volume, if used to accept SSO, would provide for approximately 4 to 6 days of storage capacity depending on the amount of existing available digestion capacity to be utilized for co-digestion.

If outside SSO waste were to be accepted at a rate sufficient to utilize existing available capacity as well as that contained within a fourth digester, the available outside waste holding tank capacity would only be capable of holding slightly greater than one day of SSO flow. Under these conditions, additional outside waste holding capacity would be required (an additional 75,000 gallons based on 2 days of storage) to address variations in SSO supply and potential system operational issues.

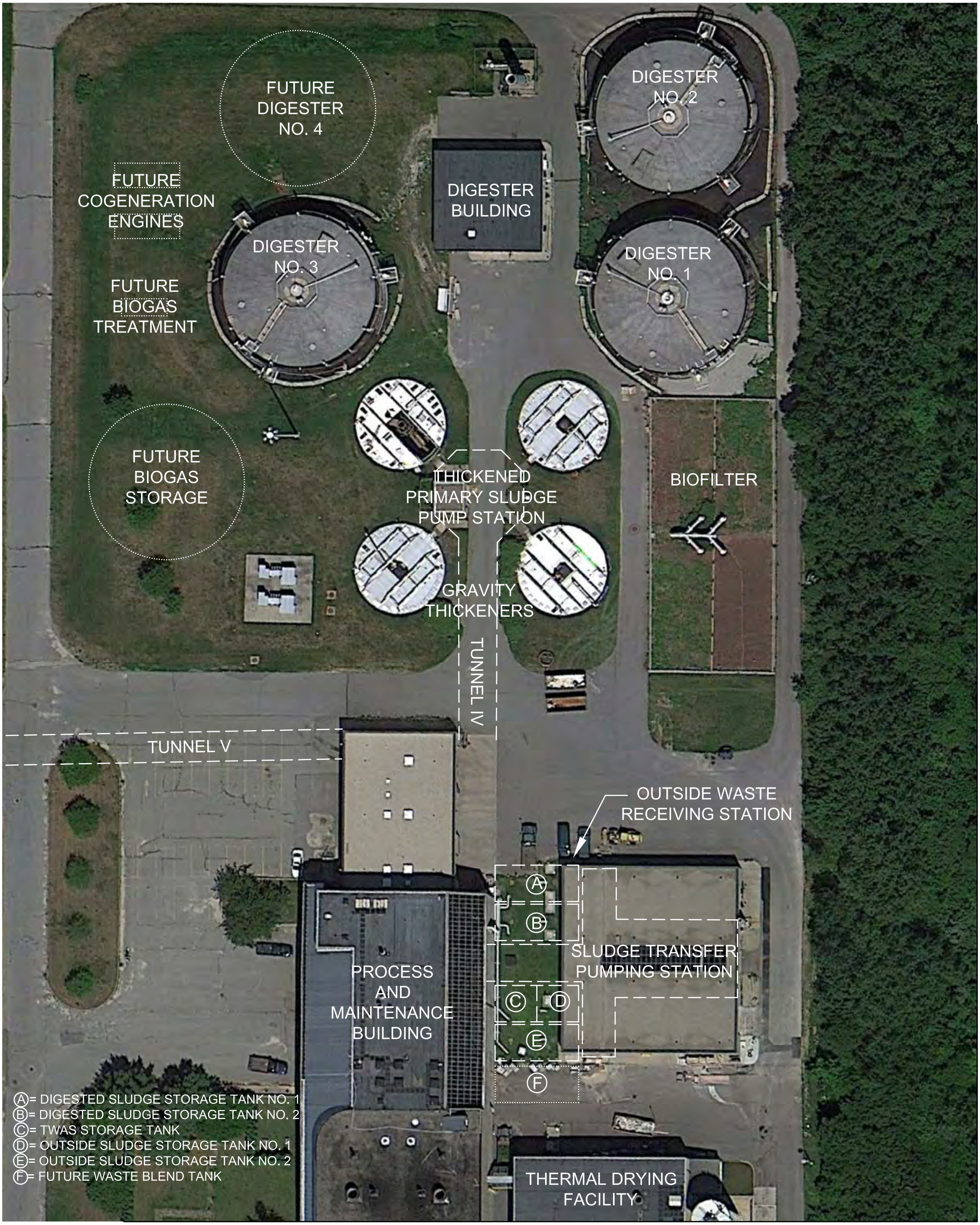
Regardless of available storage capacity, the logistics of pumping the high solids concentration SSO solution (estimated to be 13% solids) from the area of the receiving tanks to the digestion complex would pose a potential problem. Based on recent information from GLSD operations staff, conveyance of solutions in excess of 6% solids creates excessive pump discharge pressures which the existing feed pumps are incapable of providing. Since the addition of 13% waste to this system would exacerbate the issue, the most feasible solution to this challenge is to provide a blend tank in which the existing thickened sludge (~4.3%) and the incoming SSO (~13%) can be blended to a solution of ranging from 5-8%, depending on the SSO acceptance option pursued. For this reason, the additional 75,000 gallon receiving tank noted above was assumed to be required under all options, along with high pressure feed pumps (1 duty 1 standby) to convey the solution from the blend tank to the influent heat exchangers. Under this scenario, the existing feed pumps would be utilized to feed thickened waste sludge and the as-received SSO from the existing holding tanks to the new blend tank. The quality of the SSO has the potential to vary considerably, and blending to create consistent feed is essential. This new blending tank system will also allow operations staff to have control of the consistency and feed rate to the digestion system.

The location of the existing and proposed receiving tanks is shown in Figure 5-1.

5.2 Digester Modifications

As detailed in TM No. 2, Section 2.2, the existing digestion tanks were designed to accept a total average feed volume of 192,000 gal/day at a feed solids percentage of 5.6%. As a result, despite the receiving system upgrades that would likely be required, no significant modifications to the actual anaerobic digestion tanks would be required as a result of the addition of SSO for co-digestion into the existing tankage. As noted in other sections of this evaluation, exceptions to this could include:

- Potential upgrades to the external draft tubes to correct recent pin hole leak formation (issue currently being investigated by GLSD operations staff);
- Dewatering and grit removal from the digestions tanks to confirm/renew available effective capacity; and
- Mitigation of the seasonal foam production issue (discussed further below).



CDM Smith

Figure No. 5-1
Existing and Future Potential GLSD Digestion Facility Layout

In the event GLSD were to pursue the most aggressive co-digestion scenario, construction of the fourth anaerobic digestion tank would be required. In addition to the tank structure, ancillary equipment including center and external draft tube mixers, recirculation pumps, heat exchanger, biogas collection piping, safety systems and a new cover system would be required to be installed. As shown on the design plans for the existing digestion facility, space within the digester building basement has already been reserved to support the required heat exchanger and pumps and, therefore, no additional building space would be required for this purpose.

5.3 Foam Containment

As discussed in TM No. 2, foam discharge from the anaerobic digestion tanks has been an issue at GLSD for some time. Though the exact cause of the episodes is unknown, when the foam is produced it collects in the annular space between the tank walls and the digester cover and ultimately flows over the top of the digester walls, down the sides, and onto the ground. GLSD maintenance personal continue to spend a significant amount of time removing the foam and cleaning the walls of the digester tank. Since there is no evidence that implementation of a co-digestion program would mitigate this operational issue, addressing this long-standing issue prior to implementing a co-digestion program would be prudent.

The 2009 Digester Foam Containment Study (CDM) had evaluated multiple options to address this situation and ultimately recommended the installation of a gutter system around the perimeter of the digesters. As shown in Figure 5-2, the gutter would consist of a shorter piece of stainless steel metal bolted onto the interior of the digester wall and a higher piece of stainless steel metal bolted onto the exterior of the digester wall. In addition, a spray water system would be installed around the perimeter of the digester to convey the foam in the gutter to the outlet connected to the existing overflow pipe. The recommended gutter has yet to be installed due to cost and complexity of installing this system onto an active digester.

The complexity associated with this type of construction results from the fact that any anaerobic digester which contains material has the potential to produce flammable and potentially explosive biogas. For this reason, the area within and directly surrounding digestion tanks is considered to be "classified" and allowable activities within this area is regulated by the National Fire Protection Association (NFPA) 820 publication as well as the Occupational Safety and Health Administration (OSHA).

As part of this co-digestion evaluation, CDM Smith consulted with experienced staff from its integrated construction division (CDM

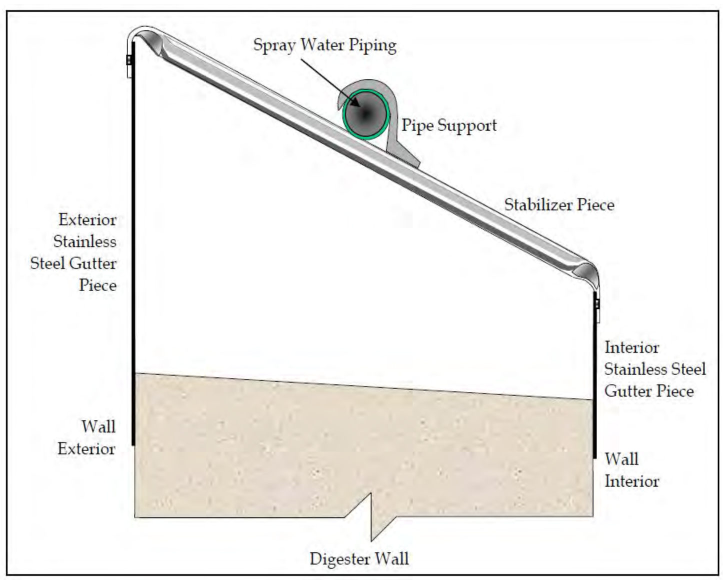


Figure 5-2
Gutter Containment System Section Schematic

Constructors Inc.) to evaluate the potential to install this system without taking the digesters offline. Unfortunately, despite their decades of experience with constructing wastewater treatment facility upgrades, no successful experience was identified in this type of hazardous operation. The consensus of the discussions concluded that removing one digester at a time from service and performing work on a dewatered digester was the safest and recommended approach.

The recommended plan to implement this measure would involve the following:

- Evacuate digester gas from digester tank;
- Take digester offline and dewater sludge in digester;
- Test and continually monitor lower explosive limit (LEL) to ensure worker safety; and
- Proceed with traditional construction.

Additional benefits of this approach include the fact that cleaning of and grit removal from the digesters could be completed simultaneously. As the amount of grit accumulation within the tank is currently unknown, it is possible that removal of these materials will increase the actual working volume of the tanks and improve digestion performance beyond that shown in recent operating data.

It should also be noted that, concurrent with installation of the above gutter system, it is recommended that site paving and drainage improvements around the digester tanks be completed. The current temporary containment system, though functional for its current purpose, limits access to the tanks and promotes overgrowth of vegetation. Costs for all foam control related improvements will be considered in TM No. 7.

5.4 Biogas Utilization Options

As is currently practiced at GLSD, digester biogas is commonly used at wastewater treatment plants to heat the digester and facility buildings by using the biogas in hot water boilers. However, in recent years, the prevalence of biogas fueled cogeneration systems have increased in popularity due to the ability of them to produce electricity and heat simultaneously, thereby increasing the overall efficiency of the system. These are commonly referred to as Combined Heat and Power (CHP) systems.

5.4.1 Biogas Quantities Available for Cogeneration

As detailed in TM No. 3, the increase in usable biogas energy under the co-digestion options evaluated could range between approximately 3.6 to 17 MMBtu/hr (140,000 to 680,000 cubic feet of biogas per day) after accounting for the additional heating requirements of the additional waste as well as downstream biosolids drying. In order to realize an environmental and financial benefit from this remaining energy, the biogas could be fed to a CHP cogeneration system. The systems typically used for this purpose (internal combustion engines and microturbines) have an average electrical generation efficiency generally between 30- and 40-percent. However, the waste heat produced by this equipment is typically recovered and reused for process or facility heating requirements yielding an overall system efficiency which will commonly exceeds 80%.

In the case of the GLSD facility, the waste heat from the CHP equipment would likely be recovered and applied to influent preheating and to maintain mesophilic digestion tank temperatures. Since the breakdown of the current biogas usage for these process heating purposes is unknown at this time due to biogas metering limitations, the theoretical energy use was calculated and included in Table 3-7. For the purpose of sizing of cogeneration equipment, it has been assumed that the waste heat from the new CHP systems would replace the use of biogas in the process boilers and, therefore, the associated amount of biogas energy was assumed to be available for CHP. As shown in Table 5-1, this additional energy would increase the available energy by between 3.6 and 4.8 MMBtu/hr. It should also be noted that these values assume that current operation of the building heat boilers would remain unchanged.

As was previously noted, the operations of the current system has reportedly yielded biogas utilization rate of 82% (18% of production flared). Though any loss of energy through a flare is undesirable, this is not uncommon of system with limitations in biogas storage volumes, monitoring abilities and metering systems. This loss is inevitable due to the variation in biogas production throughout the year (seasonal) as well as daily variations in digester feed and biogas production. Though improvements to the biogas metering and monitoring systems have been recommended above, the inability to fully utilize the additional co-digestion biogas is likely to continue without installation of significant offline biogas storage. For the purpose of this assessment, it has been assumed that 80% of the additional biogas would be capable of being utilized without the addition of storage systems. In the event offline storage were installed, it has been assumed that the utilization rate of this additional biogas could be increased to 95%. The resulting biogas volumes under each of these conditions have been shown in Table 5-1.

	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Net Additional Energy From Co-Digestion	3.64	5.32	17.1
Process Heat Demand (Biogas Energy Switched to Cogen)	3.58	3.58	4.78
Energy Loss Without Biogas Storage (20%)	(1.44)	(1.78)	(4.37)
Energy Loss With Biogas Storage (5%)	(0.36)	(0.44)	(1.09)
Available Energy for CHP w/out Biogas Storage	**5.78**	**7.12**	**17.5**
Available Energy for CHP w/Biogas Storage	**6.86**	**8.45**	**20.7**

* All values in MMBtu/hr

Table 5-1
Energy Available for CHP

5.4.2 Cogeneration Technology Alternatives

As noted, in cogeneration (cogen) systems which produces heat and power, the electricity generated is typically used onsite to offset power purchased from the grid while waste heat is used for digester and facility heating. Currently, the most common technologies used for cogen are microturbines and reciprocating engines. In addition, other innovative technologies may become competitive in the future by reducing the need for biogas cleaning prior to use, therefore reducing overall complexity and equipment cost. For general background and potential future consideration, both established and innovative CHP technologies are briefly described below.

Internal Combustion Engines

Internal combustion (IC) engines are the most widely used CHP technology. They are often the most economical CHP technology for WWTPs and have combined electrical and heat recovery efficiencies higher than any other currently available CHP technology. Heat can be recovered from the engine jacket water and from the exhaust gas. The available size range for IC engines matches biogas production rates of most WWTPs (from 70 kw to over 5 MW). The technology is reliable and available from a number of reputable manufacturers. IC engines are less sensitive to biogas contaminants than most other CHP technologies, reducing the gas cleaning performance requirements; however, cleaning is recommended to remove moisture, hydrogen sulfide, and siloxanes as discussed later in this memorandum.

One disadvantage of IC engines is their relatively high emissions, as compared to other CHP technologies, such as microturbines and fuel cells. IC engine emissions can cause permitting difficulties in areas with strict air quality limits and may require additional emissions control, such as selective catalytic reduction to meet emission requirements. However, most IC engines installed since 2005 are lean-burn engines, with higher fuel efficiency and lower emissions than rich-burn engines which were more commonly used before the 1970s.

Combustion Gas Turbines

Combustion gas turbines are often a good fit for the largest WWTPs. Like IC engines, combustion gas turbines are a reliable, well-proven technology available from several manufacturers. Large WWTPs in the US use biogas-fueled combustion gas turbines for CHP. Heat can be recovered from the exhaust gas. Combustion gas turbines are relatively simple, containing few moving parts and consequently requiring little maintenance. While infrequent, the maintenance of combustion gas turbines requires specialized service.

Microturbines

As the name suggests, a microturbine is a much smaller version of a combustion gas turbine. Microturbine capacities range from 30 kW to 250 kW and are often a good fit for smaller WWTPs with anaerobic digestion. Microturbines are relatively new, introduced about 15 years ago. Despite their somewhat recent development, microturbines have become the second most widely used technology at WWTPs for harvesting electricity and heat from biogas energy due to their small capacity and clean emissions. However, microturbine electrical efficiency is considerably lower than that of IC engines. Microturbines require relatively clean fuel, increasing the performance requirements and cost of biogas treatment, but their exhaust emissions are among the lowest of all CHP technologies. Microturbines are currently available from two manufacturers.

Fuel Cells

Fuel cells are unique in that they do not combust biogas to produce power and heat. Instead, fuel cells convert chemical energy to electricity using electrochemical reactions. Their benefits include high electric efficiency and extremely clean exhaust emissions. However, fuel cells are one of the most expensive CHP technologies in terms of both capital and operation and maintenance (O&M) costs. In addition, they are extremely sensitive to impurities in the biogas, requiring the highest level of biogas cleaning of all CHP technologies. For these reasons, fuel cell installations are typically limited to locations with strict air quality regulations and fuel cell-specific grants or incentives.

Stirling Engines

While Stirling engine technology is well established, their application to biogas is innovative. There has been increased interest in this CHP technology in recent years due to its reduced biogas cleaning requirements. A Stirling engine is an external combustion process. Biogas is combusted outside of the prime mover. The heat generated by the combustion process expands a working gas (generally helium), which moves a piston inside a cylinder. Because combustion occurs externally to the cylinder and moving parts, very little biogas cleaning is required.

Pipeline Injection

Pipeline quality biogas has extremely low concentrations of contaminants and must be compressed to match the natural gas transmission line pressure. Biogas contaminants that must be removed include foam, sediment, water, siloxanes, hydrogen sulfide, and carbon dioxide. Following cleaning, biogas must be compressed for pipeline injection. Biogas cleaning to pipeline quality has high capital and O&M costs. In most situations, generation of pipeline quality biogas is not cost-competitive with CHP. This biogas use is a better fit for large WWTPs (to take advantage of economies of scale) that near a natural gas pipeline. If finanacial incentives are available, pipeline injection can become attractive. There are currently only a few facilities cleaning biogas to pipeline quality in the US.

CNG or LNG Vehicle Fuel

Biogas can be upgraded to displace CNG or liquid natural gas (LNG) in vehicles capable of using these fuels. In Europe, upgrading biogas to fuel vehicular fleets is a well-established practice. In the US, there are only a few installations. Purity requirements for vehicular fuel are lower than those for pipeline injection. The biggest barriers to CNG or LNG conversion are the lack of a widespread infrastructure for gas filling stations and the cost of vehicle conversion for CNG or LNG use. Small scale packaged CNG conversion systems and filling station equipment are available from a single manufacturer and includes sulfur removal in a vessel with proprietary media, siloxanes removal in an activated carbon vessel and membrane carbon dioxide removal. There are currently three biogas CNG installations in the US, two at landfills and one at the Janesville, WI WWTP.

5.4.3 Cogeneration Technology Selection and Sizing

As previously noted, reciprocating internal combustion engines are the most widespread, economical and efficient of all CHP technologies currently used for biogas cogeneration. Though the selection of CHP technology should be revisited during later stages of co-digestion implementation at GLSD, internal combustion engines were selected for use in the following system sizing as well as the economic evaluation included in TM No. 7.

Figure 5-3
GE Jenbacher 850 kW IC Engine

For the purpose of engine sizing, it was assumed that engine selection would be based on ensuring that the average biogas production rate under each alternative would be capable of being utilized by two engines. Though some cost savings may be able to be realized through the use of a single engine, there are distinct operations benefits to utilizing two engines. Biogas feed rate to the engine less than the total rated capacity would be utilized by either running the engines at a reduced rate or running less than the total number of installed units. It was further assumed that a parasitic load of 15% of the total electrical output is needed to provide energy for compression, gas boosting and gas treatment. For example, a 400 kW unit will produce 340 kW assuming 15% of the power produced is consumed by the parasitic load of the equipment used to operate the cogeneration system.

Table 5-2 summarizes the amount of power and heat produced if the biogas is utilized in a reciprocating engine. As shown, the total estimated electrical output is estimated to range from 600 kW to approximately 870 kW under the options which utilize the existing anaerobic digester tanks for co-digestion. However, in the event a fourth digester tank were to be installed, the total electrical output from co-digestion is estimated to range from 2,000 kW to 2,400 kW without and with additional biogas storage, respectively.

It should also be noted that the above sizing has assumed that all process heat would be satisfied by the waste heat recovered from the of the CHP equipment. However, as noted in Table 5-2, three of the six options result in a limited amount of remaining average heat demand ranging between 1.0 and 0.4 MMBtu/hr. Due to the significant expected fluctuations in this heat demand between the seasons and the expected variations in biogas production, for the purpose of this average conditions analysis, it has been assumed that this remaining demand would be satisfied through the purchase of natural gas for the process heat boilers. Conversely, the options which utilize larger CHP equipment yield recovered heat that exceeds the average process heat demand by between 0.2 and 5.6 MMBtu/hr. For the purpose of this analysis, it has been assumed that this energy could be utilized to offset building heat demands and a credit based on the equivalent cost of natural gas offset will be account for. These financial evaluations will be further detailed in TM No. 7.

	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Without Biogas Storage			
Available Energy for CHP (MMBtu/hr) (See Table 5-1)	5.78	7.12	17.5
CHP Unit Size (kW)	400	600	1,550
Number of Units	2	2	2
Total CHP Input Capacity (MMBtu/hr)	6.55	9.94	23
Percent Utilized at Average Production	88%	72%	77%
Net Electrical Output (Less 15% Parasitic Load) (kW)	600	731	2,029
Recoverable Heat (MMBtu/hr)	2.59	3.15	8.73
Process Heat Energy Demand Remaining (MMBtu/hr)	1.00	0.43	(3.95)
With Biogas Storage			
Available Energy for CHP (MMBtu/hr) (See Table 5-1)	6.86	8.45	20.74
CHP Unit Size (kW)	500	600	1,550
Number of Units	2	2	2
Total CHP Input Capacity (MMBtu/hr)	8.24	9.94	23
Percent Utilized at Average Production	83%	85%	91%
Net Electrical Output (Less 15% Parasitic Load) (kW)	707	868	2,409
Recoverable Heat (MMBtu/hr)	3.05	3.74	10.37
Process Heat Energy Demand Remaining (MMBtu/hr)	0.53	(0.16)	(5.59)

Table 5-2
Reciprocating Engine Selection

5.4.4 Biogas Treatment Systems

Prior to being utilized in a cogeneration system, some level of biogas treatment is typically required to remove contaminants. The level of treatment depends on the concentrations of contaminants in the biogas and end use of the gas. Contaminants often found in municipal wastewater digester gas include hydrogen sulfide (H2S) and siloxanes. Additionally, biogas pressure boosting is also common due to the relatively low gas pressures which anaerobic digesters are typically operated at and to overcome additional gas pressures losses induced by biogas treatment systems.

Hydrogen Sulfide Biogas Treatment

Hydrogen sulfide (H2S) in biogas is formed by the reduction of sulfates by anaerobic bacteria within the digester. Sulfates occur naturally in wastewater from the decomposition of urine and protein in the influent sludge. Utilization of biogas in boilers or cogeneration equipment often requires that H2S be removed to reduce corrosion of the equipment. The most common methods to remove H2S from digester biogas include chemical treatment such as the addition of ferric chloride to the digesters (as is currently practiced by GLSD) or flow-through systems that utilize iron-oxide impregnated wood chip media, known as an iron sponge system, to remove it from the biogas.

As previously discussed, recent GLSD biogas sampling showed hydrogen sulfide levels of approximately 60 ppm. Though other CHP other biogas utilization technologies are more sensitive to hydrogen sulfide concentrations, the recommended maximum feed concentrations to reciprocating internal combustion engines is typically <250 ppm. As the current levels are maintained below this level through the use of ferric chloride, it has been assumed that this operation will remain unchanged and that no separate hydrogen sulfide treatment will be required upstream of biogas fired internal combustion engines at the GLSD facility.

Siloxane Removal

Siloxanes are a family of man-made organic compounds that contain silicon, oxygen and methyl groups. Siloxanes are often used in the manufacture of personal hygiene, health care and industrial products and eventually end up in wastewater. Siloxanes volatilize into the biogas during the digestion process and when this biogas is combusted, siloxanes are converted to silicon dioxide (SiO_2), which is then deposited in the combustion or exhaust stages of the equipment. In reciprocating engines, evidence of siloxanes is found in the form of white powder deposited on combustion surfaces. In boilers, siloxanes are often deposited in the fire tubes utilizing biogas. The most commonly used method to reduce siloxane levels is carbon adsorption of the siloxane compounds.

Deposition of siloxane within the existing boilers and dryers is a known issue for GLSD which could also cause significant issues within any of the CHP options being considered. According to data from one leading manufacturer of reciprocating cogeneration engines, the preferred gas cleanliness levels include H_2S < 250 PPM and Siloxanes <5 PPB. Though siloxane testing results are not currently available for the GLSD biogas, it was assumed based on operations observations that siloxane treatment of the biogas prior to use in a proposed CHP system would be required. It has further been assumed that siloxane treatment of the entire biogas stream including gas used for building heat and thermal drying would be prudent to reduce the operation and maintenance issues currently experienced as a result of biogas quality.

The siloxane removal system required for GLSD would consist of two vessels in series along with a final particulate filter. Though a separate H_2S removal system is not required, the media inside the siloxane vessels would consist of a dual media where the initial stage would be designed to further reduce the levels of H_2S. This polishing is required to prevent premature saturation and breakthrough of the siloxane treatment stage. The remainder of the media in the vessels would then be a carbon based system exclusively designed for siloxane removal. Table 5-3 shows the approximate system sizing for each of the co-digestion alternatives being considered. It should

Figure 5-4
Representative Siloxane Treatment Vessels

also be noted that, due to the freeze potential within various portions of this treatment equipment, unless new building space were provided (which would be electrically classified due to the presence of the biogas), the system would likely be provided within a factory prefabricated heated enclosure. It should also be noted that, as with most carbon based contaminant removal systems, change-out of the carbon media will be required on an intermittent basis to prevent breakthrough of H2S or siloxane. Based on discussions with vendors of this equipment, it is estimated that one vessel per 6 months (or one complete change out of the 2 vessel system) will be required each year. Costs for this maintenance will be incorporated into the TM NO. 7 cost evaluation.

	Total Production (cf/d)	Treatment Flow Rate (cfm)	Approximate Skid Dimensions (entire flow)
Future w/growth	600,000	420	8’W x 18’L x 14’H
Future w/out growth	670,000	470	8’W x 18’L x 14’H
Future w/out growth and w/4th AD	1,300,000	900	10’W x 25’L x 14’H

Table 5-3
Siloxane Treatment Skid Sizing

Biogas Pressure Boosting

Figure 5-5
Representative Biogas Booster System

The pressure of the biogas from the existing anaerobic digesters is approximately 11" water column (0.4 psi). As previously noted, this head space pressure is not sufficient to convey the biogas through biogas treatment or for internal combustion engines which generally require an inlet pressure of between 2–5 psi of inlet gas pressure. As a result, the upgraded biogas utilization systems would require a biogas booster system upstream of the siloxane treatment stage. In this system, the digester gas would first enter through a blower inlet moisture/particulate filter to remove any free moisture and particulates prior to being compressed with a blower. The blower would compress the gas to about 5 psig prior to entering a heat exchanger which would reduce the dew point of the gas to 40°F and reheat the gas to 80°F. All condensed moisture would be removed inside the heat exchanger and drained through a no-gas-loss drain. The heat exchanger would be supplied with cold glycol from a remote mounted glycol chiller. The booster system would likely be supplied integral to the siloxane removal equipment skid summarized in Table 5-3.

5.4.5 Biogas Storage Systems

As previously noted, because digesters do not produce biogas at a constant rate, biogas storage is often recommended. As is currently used by GLSD, one common gas storage system is a floating gasholder digester cover which floats on the biogas produced in the tank. The cover moves up and down to create variable volume and allow a constant biogas pressure within the headspace of the cover. The current gas holding cover system currently contains approximately 8 hrs of average production. As previously discussed, though this is in line with current design standards for biogas storage, the existing limitations in biogas metering and monitoring are likely contributing to the current waste gas rate of approximately 18%.

With respect to available storage, the existing hours of storage would be significantly reduced as a result of the significant increase in biogas production expected when implementing co-digestion. As such, additional storage would be required to absorb the variations between production and use and enhance the reliability of the cogeneration system. The most likely and viable alternative for increasing the storage capacity at GLSD would be the installation of a new double membrane gas holder.

Gas Membrane General Information

Gas membrane covers were first used in the U.S. in the early 1990s. They provide a large volume of digester gas storage using a double membrane design. The outer membrane maintains a consistent dome shape while the inner membrane moves up or down depending upon gas storage requirements. Ambient air fans and valves add or release air from the space between the inner and outer membranes to maintain the consistent outer membrane shape and constant biogas pressure. Some of the key drivers for this technology have been the need for large gas storage volumes and/or large fill and draw capacity in the tank.

There are several suppliers of membrane covers in the U.S. including WesTech, Ovivo, Siemens and JDV. WesTech, Siemens and JDV have several installations in the U.S. and most of the JDV and WesTech membrane systems are standalone on a concrete pad as opposed to on top of a tank.

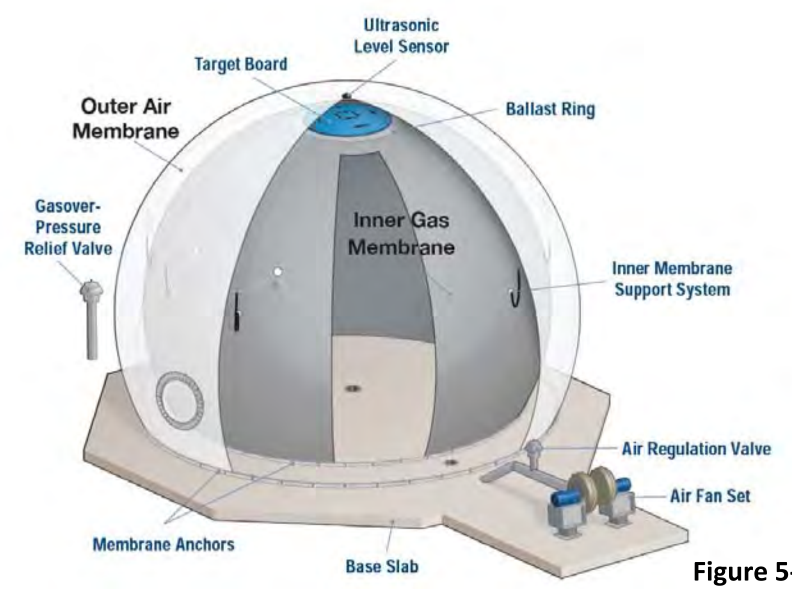


Figure 5-6
Typical Gas Membrane Storage System
Figure Courtesy of WesTech

Membrane covers have proven to be reliable systems with the older installations having a life expectancy of 10 years. However, suppliers indicate that the technology has improved in recent years and newer membranes should have a service life of approximately 15 years. The exterior membrane is typically made out of polyester fiber fabric that is coated with PVC that is microbial and abrasion resistant. The internal membrane is also typically manufactured from PVC coated polyester fiber fabric, which is microbial, abrasion and biogas resistant.

From a daily operations perspective, the membrane covers typically require minimal operator attention. A PLC is used for controlling the system and it can be linked with the SCADA system. Typical maintenance is required for the fans and instrumentation requires periodic inspections and calibration. The exterior membrane requires periodic inspection for deterioration and tears. If access to the tank interior is required, the covers need to be removed.

GLSD Additional Biogas Storage Sizing

In an attempt to maintain the existing total of 8 hrs of average storage capacity, gas membrane holders have been sized for the various co-digestion scenarios being evaluated. As shown in Table 5-4, the additional storage required to be supplied by this new storage system would range from approximately 60,000 to 290,000 cf. The potential location of this storage system has been shown in Figure 5-1 while costs associated with this improvement are evaluated in TM No. 7.

	Production (cf/d)	Production (cf/hr)	Storage (avg hrs)	Total Storage (cf)	Additional Storage Required (cf)	Approximate Dimensions[1]
Current	390,000	16,000	8.9	143,000	-	-
Future w/growth	600,000	25,000	8	200,000	57,000	51'Dia X 40'H
Future w/out growth	670,000	28,000	8	224,000	81,000	55'Dia X 44'H
Future w/out growth and w/4th AD	1,300,000	54,000	8	432,000	289,000	81'Dia X 66' H

[1] For reference, the existing GLSD digestion tanks are 85-ft diameter.
Refer to Figure 5-1 for potential siting and relative size of biogas storage.

Table 5-4
Estimated Additional Biogas Storage Requirements

5.5 Downstream Considerations

In addition to the direct impact to the digestion and biogas utilization systems, building a co-digestion program and accepting SSO at the GLSD facility would have additional impact on various aspects of the downstream liquid wastewater treatment and solids processing trains. Some of these impacts may include:

- More digested sludge will require more dewatering and drying and the value of the pellet product could be impacted depending on the quantity and quality of outside wastes being accepted; and
- The amount of the side stream (centrate) from dewatering will increase and its characteristics may change in BOD, TSS, and ammonia concentration.

5.5.1 Dewatering and Drying Implications

When co-digesting large amounts of source separated organics, there may be an impact on the dewatering performance (cake percent solids, polymer use, capture). However, there appears to be very little data on downstream impacts of co-digestion at other facilities. EBMUD experiences a decrease of 2 percentage points in dewatered cake solids content with a "significant amount" of food waste fed to their digesters. However, these results may not be typical.

There is also limited data to support the impact co-digestion would have on thermal drying operations. What is known as a result of this evaluation is that the quantity of dry solids would increase under any of the options being considered with increases ranging from approximately 5 DT/day (using existing tanks for co-digestion) to 15 DT/day (with the addition of a fourth tank). Since the GLSD drying system is handled by outside contract operations with NEFCO, the financial impact of this change is measurable and will be evaluated further in TM No. 7. It should also be noted that impact of SSO on drying operations and pellet quality is thought to be minimal as the majority of the SSO is volatile solids that are converted to biogas in the digestion process. However, these impacts of co-digestion have not been widely studied and would require further analysis as part of a co-digestion program at GLSD.

5.5.2 Side Stream Considerations

As noted above, the amount of the centrate from GLSD dewatering operations would increase with co-digestion and its characteristics may change in BOD, TSS, and ammonia concentration. The greatest impact on liquid train treatment costs would be seen in the aeration requirements associated with the additional BOD as well as that required for nitrification of the Ammonia in the side stream.

Table 5-5 summarizes recent centrate quality data and calculates the impact that additional centrate flow would have on the aeration requirements of the secondary treatment system. As shown in the table, impact on this system could equate to an increase in aeration requirements of between approximately 2% and 7% over current aeration demands. The cost implications of this increase will be evaluated in TM No. 7.

Scenario	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Current Secondary Influent BOD (lb/day)	28,000	28,000	28,000
Current Average NH3 Removed (lb/day)	1,600	1,600	1,600
Total Current Process Oxygen Requirement (lbs/day)*	35,000	35,000	35,000
Digestate SSO Solids (lbs/day)	6,100	9,200	30,000
Digestate Solids Concentration	2.5%	2.6%	2.9%
Cake Solids Concentration	24.8%	24.8%	24.8%
Additional Centrate (gpd)	15,000	23,000	77,000
Centrate BOD (mg/l)	50	50	50
Centrate Process Oxygen Requirement (lbs/day)	6	10	32
Centrate NH3 (mg/l)	930	930	930
Centrate Oxygen Requirement for Nitrification (lbs/day)*	490	760	2,500
Total Process Oxygen Requirement from Centrate (lbs/day)	500	770	2,600
Percent additional Process Oxygen Requirement	1.4%	2.2%	7.4%

** Assumes 4.25 lbO2/lb NH3 Nitrified*

Table 5-5
Potential Impact of SSO on Secondary Aeration

5.6 Summary of Impacts to Existing System

As detailed in the prior sections of this memorandum, there are a variety of digestion and biogas utilization related improvements that are recommended in association with implementation of a co-digestion program. Table 5-6 includes a summary of the anticipated improvements along with the associated operational impacts.

	Future w/Growth	Future w/out Growth	Future w/out Growth and w/4th Digester
Capital Improvements*	▪ Digester cleaning and foam control ▪ External draft tube leak issue resolution ▪ Biogas metering and monitoring repairs ▪ New outside waste blending tank and mixing system and new high pressure digester feed pumps ▪ New biogas siloxane treatment ▪ New cogeneration engines (2X400/500kw) ▪ Optional biogas storage system (60,000cf)	▪ Digester cleaning and foam control ▪ External draft tube leak issue resolution ▪ Biogas metering and monitoring repairs ▪ New outside waste blending tank and mixing system and new high pressure digester feed pumps ▪ New biogas siloxane treatment ▪ New cogeneration engines (2X600 kw) ▪ Optional biogas storage system (80,000cf)	▪ Digester cleaning and foam control ▪ External draft tube leak issue resolution ▪ Biogas metering and monitoring repairs ▪ Additional receiving station, new outside waste blending tank and mixing system and new high pressure digester feed pumps ▪ New anaerobic digester tank (1.4 MG) and ancillary digestion equipment (heat exchangers, pumps, mixers, etc.) ▪ Upgraded flare and safety equipment and biogas collection piping size upgrades ▪ New biogas siloxane treatment and new cogeneration engines (2X1550kw) ▪ Optional biogas storage system (300,000cf)
Operations Impacts	▪ Increase in load to dewatering and drying (3 DT/Day) ▪ Increased secondary aeration (1.4%) ▪ O&M of new biogas utilization systems	▪ Increase in load to dewatering and drying (5 DT/Day) ▪ Increased secondary aeration (2.2%) ▪ O&M of new biogas utilization systems	▪ Increase in load to dewatering and drying (15 DT/Day) ▪ Increased secondary aeration (7.4%) ▪ O&M of new biogas utilization systems ▪ Additional staffing for receiving operations

* *Preprocessing and screening of SSO/EFW is assumed to be addressed by others prior to delivery at GLSD.*

Table 5-6
Summary of Co-Digestion Alternatives Impacts

Technical Memorandum No. 6

From: *Benjamin R. Mosher, P.E., BCEE*

Date: *March 7, 2013 (Updated June 26, 2013)*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Regulatory and Permitting Trends and Issues*

6.0 Regulatory and Permitting Trends and Issues

As part of the current feasibility study, an initial assessment was completed related to the regulatory trends and drivers for co-digestion at GLSD along with the potential permitting associated with upgrades to or expansion of the existing facility.

6.1 Regulatory Trends

6.1.1 National Regulatory Trends

At the national level, the 20-year-old 40 CFR Part 503 regulations remain a consistent structure by which biosolids are managed. Two National Academy of Sciences reviews and regular biennial reviews have not resulted in changes to Part 503. However, there is ongoing discussion of potential future changes to the rule, including elimination of some options for pathogen reduction, updating some of the referenced analytical methods, and establishing an Exceptional Quality (EQ) biosolids numerical standard for molybdenum (Mo). The latter is the only change that would have any effect on GLSD's current biosolids management program – and the effect would be positive. However, even as there is speculation of a future rule change, the fact is that EPA continues to reduce staffing and budget for the biosolids program. As a result, it is unlikely that any federal biosolids rule change will go into effect in the foreseeable future.

One notable issue in the federal regulatory landscape is the U. S. EPA air office's recent increased involvement in regulating sewage sludge incinerators (SSIs). The new SSI regulations, finalized in February 2011 clarified that sewage sludge that is combusted is considered a solid waste. This results in a requirement that it be regulated under Section 129 of the Clean Air Act (CAA), rather than under the less stringent Section 112. While we understand that GLSD is not intending to pursue incineration, what this means is that incineration as an option for wastewater solids management is becoming a more costly option. More specifically, if any regional SSI shuts down in response to the new standards (as has happened with the incinerator at Fitchurg, MA), there will be an increase in supply of biosolids materials to be managed in the New England market, in which the GLSD/NEFCO product competes.

6.1.2 State Regulatory Trends

Background

In Massachusetts, the 310 CMR 32 sludge regulations have been in effect since September 11, 1992 – prior to the current federal standards. While MassDEP has repeatedly stated its intent to update these regulations, no update has occurred. Although there is increasing pressure from the regulated industry to pursue an update, it is uncertain whether MassDEP will take action on this anytime in the near future. What is clear in federal and state regulations is that if any wastewater solids are part of a product's feedstocks, then the product is regulated under the sludge rules (federal Part 503 and MassDEP 310 CMR 32). Since co-digested SSO is not going to be kept separate from municipal biosolids, the SSO treated at GLSD will enter the market as more biosolids pellets, which in the current public acceptance climate, have a lower market value than non-sludge organic residuals products.

Specific Recent Regulatory Revisions

As has been previously noted, MassDEP is now focusing a great deal of attention on other organic residuals: especially SSO. The agency has announced its intention to ban certain large scale (e.g. commercial and institutional) SSO from landfills in 2014. In preparation for this ban on landfill disposal, two significant regulatory changes were developed in 2011, one to the solid waste regulations (310 CMR 16.00 and 19.00) and one to the wastewater regulations (314 CMR 12.00). These changes were finally adopted in late November, 2012, and now the solid waste rules allow for streamlined siting of facilities that process SSO (e.g. compost or anaerobic digestion facilities). The wastewater rules have been changed to allow for wastewater treatment facilities with anaerobic digesters to accept and process SSO. The change to the wastewater treatment facility regulations is a simple rule change that was widely supported while the solids waste changes (siting of new facilities) received opposition from those representing local boards of health.

A few specific changes in the recent promulgation include the following:

- 310 CMR 16.02 defines "source separated" as "separated from solid waste at the point of generation and kept separate from solid waste."
- 310 CMR 16.02 (and 310 CMR 19.000) revised the definition of solid waste to exempt "organic material when handled at a Publicly Owned Treatment Works as defined in 314 CMR 12.00 and as approved by the Department pursuant to 314 CMR 12.00."
- 314 CMR 12.00 will require written approval from MassDEP to accept SSO materials at AD units.
- A site assignment under the solid waste regulations and laws (310 CMR 16.00 and MGL ch.111 § 150A, respectively) is only required for an area of land where solid waste uses can occur. Therefore, since the SSO materials handled at POTW's is not considered a solid waste by definition, it would not require a solid waste site assignment.

- The current wastewater treatment regulations are unclear as to whether a site assignment process similar to that typically required for new wastewater treatment facilities is required for SSO processing at an existing POTW. However, based on recent discussions with MassDEP, it was determined that the acceptance of SSO at an existing facility would not necessitate any revisions to an existing POTW site assignment and would not require any new wastewater facility site assignment.
- 314 CMR 12.00 notes that "Fish and animal material from slaughterhouses, butchering and processing facilities, pet food production facilities and supermarkets may not be accepted into anaerobic digesters operated at a wastewater treatment facility without specific written approval of such materials by the Department."

Clearly, GLSD is affected by the change to the wastewater rules: barring other restrictions of a legal, technical, or environmental nature, the District is now able to accept outside waste in its digesters. In addition, GLSD is indirectly affected by the changes to the solid waste regulations: streamlining siting of other facilities processing SSO will increase the competition for SSO, thus driving down the tipping fees that the District may be able to charge. However, this is not likely to be a significant factor, because GLSD has a distinct advantage (second only to MWRA) of having large, existing digestion capacity already in place. There are only five other wastewater treatment facilities in the state with existing operational anaerobic digestion, and only 26 more in all of the rest of New England – and most are smaller facilities with limited capacity.

Future Potential Regulatory Climate

MassDEP's focus on organics seems to be a lasting trend, driven, in large part, by the fact that organics are the last and greatest untapped potential resource in landfilled solid waste – and it can be a source of renewable energy. As long as the political will remains, it seems likely that a landfill ban will be enacted in Massachusetts in the next few years, if not by the current 2014 deadline. This change will result in a large influx of fertilizer and soil amendment products entering the marketplace in which GLSD's fertilizer pellets compete.

Air regulations at the state level have significant potential effects on GLSD's current and future biosolids management options. Foremost are air emissions requirements for biogas combustion, with which GLSD has already been complying. Should co-digestion occur and more biogas be produced, the District may need to update its emissions permits for any new biogas utilization systems.

In addition, whereas comprehensive energy and GHG emissions policy has stalled at the national level, Massachusetts has adopted leading programs for both. With new alternative energy production from biogas, GLSD would be able to take advantage of markets for renewable portfolio standards (RPS). Planning for GLSD's future biosolids management should presume that these kinds of state policies will continue, making renewable energy and documented reductions in GHG emissions likely more valuable with time. National and private market incentives may also come to play a significant role in the future.

6.1.3 Local Regulatory Trends

Within some local communities, there remains concerted opposition to biosolids reuse on soils. GLSD should be aware that there is some dedicated opposition to biosolids use close by, including the Resource Institute for Low Entropy Systems (RILES, www.riles.org) and the Toxics Action Center (www.toxicsaction.org). The latter recently entered the debate about MassDEP's proposed regulation for streamlining the siting of facilities that process organic wastes, warning that "sludge" may become mixed with other organics (SSO), thus tainting those other organics. When considering co-digestion, GLSD should be aware of this opinion, which surfaces sometimes even in professional and regulatory circles, that biosolids are inherently dirtier and of lower grade and value than SSO and other organics, and that they should be kept segregated.

If GLSD becomes involved in co-processing SSO, significant public outreach and education will be required to heighten public awareness of the benefits of biosolids and the reasons for co-digesting them with SSO. GLSD will need to be ready to respond to concerns that will be voiced about co-digestion and the increased amount of "sludge" product on the market. We recommend an increased public outreach program focused on the benefits of GLSD biosolids pellets; this program should be instituted in coordination with the development of co-digestion.

Massachusetts local Boards of Health are also raising concerns about the proposed MassDEP regulations streamlining the siting of organics processing facilities. Their objections appear to be mostly about having their local power taken away in the siting process for smaller facilities. In general, as noted above, local control is a strong force in Massachusetts, and Boards of Health express concern about local nuisance and environmental impacts from managing organics – which can be odorous if not handled properly.

For many of those opposed to biosolids use on soils, Class A biosolids – such as that produced by the GLSD program – are as bad as any other. Being aware of these perceptions and concerns – some of which are voiced locally by a few advocacy groups – is important for GLSD's planning efforts. We especially recommend increased public outreach be conducted if co-digestion is developed at the GLSD facility, because co-digestion will lead to an increase of biosolids product, and having public recognition of that product's value will be necessary to ensure that the increased volume can be successfully marketed.

6.2 Anticipated Permitting Requirements

Though the extent various between the options, installation of new infrastructure at the GLSD treatment facility is required for each of the alternatives evaluated in this study. State and local permits are required whenever proposed work may affect certain environmentally sensitive resources, disturbs a specific amount of land and/or constructs new infrastructure subject to local building and zoning board reviews. Though a detailed permitting review would need to be conducted during later stages of project implementation, the following provides a brief description of the likely permits required for co-digestion related improvements to the GLSD facility.

6.2.1 MassDEP and Board of Health Approvals

As noted above, the changes to the CMR solid waste and wastewater treatment regulations allowed for streamlining of new facility siting and eliminated the need to acquire a solids waste site assignment for SSO processing. However, it is currently unclear as to whether a "site assignment" process where the local Board of Health must approve use of land for SSO processing will be required.

Also at noted within revisions to 314 CMR 12.00, acceptance of SSO at GLSD will require a written approval to accept SSO materials at AD units from the MassDEP. However, based on the known goals for the SSO initiative, this approval is unlikely to meet resistance at the state level.

6.2.2 Air Quality Permitting

The addition of new biogas cogeneration engines is expected to require a new air permit. Per 310 CMR 4.10(2), it would be necessary to apply for a Non-Major Comprehensive Plan Approval from the MassDEP, and to have this permit in hand before installing the cogeneration equipment. A Non-Major Comprehensive Plan Approval application can take four to six weeks to prepare, and is required to include a Best Available Control Technology analysis, and possibly also a dispersion modeling demonstration. MassDEP approval of this permit is expected to take about six months.

In addition, all digester-gas fired engines must comply with U.S. EPA emission limits in 40 CFR 60 Subpart JJJJ, Standards of Performance for Stationary Spark Ignition Internal Combustion Engines, shown in Table 6-1, for nitrogen oxides (NOx), carbon monoxide (CO), and volatile organic compounds (VOC). The reciprocating biogas fired cogeneration engines investigated under this evaluation for potential use at GLSD do appear to meet the USEPA limits identified in Table 6-1.

Engine Type	Manufacture Date	Maximum Rated Engine Power	Oxides of Nitrogen	Carbon Monoxide	VOC
Digester Gas, Except Lean Burn 500≤HP<1,350	On and after 1/1/2011	HP<500	2.0 g/HP-hr or 150 ppmvd @ 15% O_2	5.0 g/HP-hr or 610 ppmvd @ 15% O_2	1.0 g/HP-hr or 80 ppmvd @ 15% O_2
	On and after 7/1/2010	HP≥500	2.0 g/HP-hr or 150 ppmvd @ 15% O_2	5.0 g/HP-hr or 610 ppmvd @ 15% O_2	1.0 g/HP-hr or 80 ppmvd @ 15% O_2
Digester Gas, Lean Burn	On and after 7/1/2010	500≤HP<1,350	2.0 g/HP-hr or 150 ppmvd @ 15% O_2	5.0 g/HP-hr or 610 ppmvd @ 15% O_2	1.0 g/HP-hr or 80 ppmvd @ 15% O_2

Note: g/HP-hr: grams per horsepower-hour ppmvd @ 15% O_2: parts per million by volume, dry, corrected to 15% oxygen
Source: 40 CFR 60 Subpart JJJJ, Table 1

Table 6-1
U.S. EPA Emissions Standards for Stationary Digester Gas Engines

6.2.3 Wetland Resources

The new work associated with digestion facility expansion is likely to fall within the 100-foot Buffer Zone of the facility drainage swales which border the site on the north and east. Since these swales have previously been (and would likely still be) flagged as a wetland, they are therefore protected under the Massachusetts Wetlands Protection Act (WPA). As such, authorization would be required from the municipal Conservation Commission for any work in or adjacent to protected wetland resource areas.

Authorization from the Conservation Commission can be provided via two different mechanisms. Authorization for work within the 100-foot Buffer Zone to certain resource areas can be approved via a Determination of Applicability. Alternatively, the Conservation Commission may determine that an Order of Conditions (wetland permit) is required for work in the protected resources area or within the 100-foot Buffer Zone. The Conservation Commission holds a public hearing to review the proposed activities subject to jurisdiction of the Wetlands Protection Act and receives input from the public before issuing a permit decision.

6.2.4 Planning and Zoning

GLSD was established by Chapter 750 of the Massachusetts Acts of 1968. As a result of being established as a “District,” improvements to the treatment facility are deemed exempt from planning and zoning review or approval despite being within the Town of North Andover municipal limits.

6.2.5 Local Building Permits

Local building permits are typically the responsibility of the general contractor performing the construction and are obtained during the construction phase.

6.2.6 Flood Protection

Commonly accepted wastewater treatment plant design guidelines, including the Guide for the Design of Wastewater Treatment Works (TR-16), suggests that treatment plants should provide for uninterrupted operation of all units under flood conditions of a 25-year frequency and should be placed above or protected against structural and equipment drainage from the 100-year flood level. According to the most recent FEMA flood insurance mapping (latest version dated July 3, 2012), the digestion facility is currently shown outside of the 100-year floodplain of the Merrimack River. As such, special permitting and/or construction practices to resist flood damage do not appear to be required for upgrades to or expansion of the existing facility.

6.2.7 Stormwater

EPA currently regulates stormwater discharges from construction sites that disturb 1 acre or more and construction dewatering activities. In the event a fourth digester were to be installed, it is possible that the facility upgrades would disturb greater than 1 acre of land and will therefore require a Construction Activities Permit. As part of the construction contract, the Contractor typically obtains the required NPDES Permit.

A Stormwater Pollution Prevention Plan (SWPPP) would also be prepared during final design according to the MassDEP General Permit requirements for stormwater discharges. The Plan would identify a pollution prevention team, potential pollutant sources, stormwater monitoring requirements, record keeping, reporting responsibilities, and stormwater management controls. The Plan would also include a site map showing discharge locations, stating receiving water bodies, and showing locations of materials exposed to precipitation.

6.2.8 Other Potential Permits

During the early stages of the project, a review for the potential presence of "Rare and Sensitive Habitats" would be required to be completed. This process generally involves a review of the Massachusetts Natural Heritage Atlas along with correspondence with the Massachusetts Natural Heritage and Endangered Species Program (NHESP). In the event no estimated habitat of rare wildlife or priority habitat of rare species are identified within the project area or in the immediate vicinity, no additional permitting would be required.

Additionally, a review of the Massachusetts Cultural Resource Information System (MACRIS) would be required to identify any potential historical or archaeological resources at the site. Due to the fact that the facility consists of previously disturbed land, issues with this review are unlikely.

It should also be noted that investigations and determinations related to the above potential permits also occurred during the development of the existing digestion facility. As such, this information will likely prove useful during later stages of implementation of the current project.

Technical Memorandum No. 7

From: *Benjamin R. Mosher, P.E., BCEE*

Date: *April 4, 2013 (Revised June 26, 2013)*

Project: *Greater Lawrence Sanitary District Co-digestion Evaluation*

Subject: *Recommended Improvements for Further Consideration*

7.0 Recommended Improvements for Further Consideration

Determining the economic feasibility of co-digestion requires an understanding of the cost of the improvements that would be required to accept and process the SSO materials, the infrastructure necessary to harness energy value of the additional biogas produced along with the impact to ongoing operations costs. Once these costs and the benefit of the new combined heat and power systems have been quantified, the life cycle value of co-digestions at GLSD can be determined.

The purpose of this memorandum is to provide a conceptual estimate of these costs and benefits and suggest steps for further consideration.

7.1 Summary of Impacts and Improvements

Three SSO acceptance conditions were evaluated during this study to evaluate a wide range of potential cost and benefits. Table 7-1 summarizes some of the key expected process performance values under average annual conditions associated with each of these options.

In order to successfully receive and process SSO under the above scenarios, several improvements should be made to ensure proper reliability and process control. Table 7-2 provides an overview of the capital improvements recommended and operational impacts under each scenario.

	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
SSO Quantity Received (gal/day)	18,000	28,000	92,000
SSO Quantity Received (dry lb/day)	20,000	30,000	100,000
Additional Biogas Produced (cf/day)	190,000	288,000	946,000
Net Available Biogas for Cogeneration (cf/day)	146,000	213,000	682,000
Net Electrical Production w/out Biogas Storage (kW)	600	731	2,029
Net Electrical Production w/Biogas Storage (kW)	707	868	2,409
Excess Heat from Cogeneration w/out Biogas Storage (MMBtu/hr)	(1.00)	(0.43)	3.95
Excess Heat from Cogeneration w/out Biogas Storage (MMBtu/hr)	(0.53)	0.16	5.59
Increase in Process Oxygen Requirement from Side Stream (%)	1.4%	2.2%	7.4%
Increase in Solids to Downstream Dewatering and Drying (DT/day)	3	5	15

Table 7-1
Summary of Co-Digestion Process Parameters

Capital Improvement	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Digester cleaning and foam control	√	√	√
External draft tube leak issue resolution	√	√	√
Biogas metering and monitoring repairs	√	√	√
Additional outside waste receiving station			√
New outside waste blending tank and mixing system	√	√	√
New high pressure digester feed pumps	√	√	√
New anaerobic digester tank (1.4 MG)			√
New ancillary digestion equipment (HEX, pumps, mixers)			√
Upgraded biogas collection, flare and safety equipment			√
Biogas storage system	O	O	O
New biogas siloxane treatment	√	√	√
New cogeneration engines	√	√	√
Operational Impacts			
Increase in load to dewatering and drying	√	√	√
Increased secondary aeration	√	√	√
Biogas utilization system maintenance	√	√	√
Additional staffing for receiving operations			√

O = Optional

Table 7-2
Summary of Co-Digestion Capital Improvements and Operational Impacts

7.2 Conceptual Life Cycle Costs and Energy Benefits

To compare relative costs and benefits of the alternatives, estimates of probable project cost were developed for each of the improvements noted in Table 7-2. In addition, the associated operations costs impacts were quantified. The basis for the various line item estimates are described below while the cost summaries for each alternative are include in Tables 7-4 through 7-9.

7.2.1 Capital Cost Estimates

The basis for the capital cost estimated included in Tables 7-4 through 7-9 included the following:

- Digester cleaning: As the existing digesters have not been removed from service or cleaned since their original construction, a conceptual cost of $500,000 for dewatering and removal of material from the existing digesters has been included in the cost tables for each option. However, as this work would likely be completed regardless of any co-digestion program, the cost has been shown, but excluded from the breakeven tip fee analysis for each option.
- External draft tube leak issue resolution: The recent formation of pin hole leaks on the external draft tube mixers has been noted and investigated by GLSD operations staff. Based on these investigations, it has been determined that the leaks are relegated to a few discrete areas and is has been recommended that plates be welded to the exterior of the tubes in these area to mitigate the issue. However, as this work would likely be completed regardless of any co-digestion program, the cost has been shown, but not factored into the breakeven tip fee analysis for each option.
- Foam control: Periodic foaming from the digesters has been a historical issue at GLSD. However, in recent years, the frequency of these events has significantly decreased. However, with the addition of SSO to the digestion process, the potential for this foaming is likely to increase and foam control measures are recommended as detailed in TM No. 2. The project cost estimate for the foam control improvements recommended in the February 2009 foam control study was approximately $305,000. Using the historical and current Engineering News Record (ENR) construction cost index as a basis for escalation, this estimate would equate to approximately $340,000 in January 2013 dollars. In addition to this cost, an allowance has been included to cover site improvements around the digesters including drainage and paving improvements.
- Biogas metering and monitoring repairs: As noted in TM No. 2, it was noted during recent maintenance work on the biogas metering system that there appear to be issues related to meter performance. As a result, the total biogas production in the recent operations records is likely an understatement of actual production and a misrepresentation of the breakdown between biogas utilization areas. In addition, GLSD staff have noted that the digester cover monitoring systems have historically experienced reliability issues and are not currently operational. Though these metering and monitoring issues are not detrimental to existing operations, these systems would be integral to operation and maximizing CHP utilization

under any co-digestion alternative. As a result, an allowance for biogas metering improvements and installation of a new radar-based cover metering system have been included in the capital cost estimates.

- Additional outside waste receiving station: Per discussion included in TM No. 5, though the single existing receiving station is likely acceptable for any of the three digester options, the ~15 truck trips per day required for options involving a fourth digester, it is assumed that a second receiving station would be required.
- New outside waste blending tank and feed pumps: Due to the problems associated with pumping high solids concentration SSO solution from the area of the receiving tanks to the digestion complex, a blend tank, along with an associated submersible mixing system, has been recommended for installation under all of the options. The existing thickened sludge (~4.3%) and the incoming SSO (~13%) would be blended in this new tank to a solution of ranging from 5-8%, depending on the SSO acceptance option pursued. In addition, the cost for new high pressure feed pumps (1 duty 1 standby) to convey the solution from the blend tank to the influent heat exchangers has been included within each option. This new blending tank system will also allow operations staff to have control of the consistency and feed rate to the co-digestion system.
- New anaerobic digester tank and ancillary digestion equipment: The largest of the SSO acceptance options is based on the construction of a new 4^{th} anaerobic digester in the location which was reserved for this expansion during the original digestion facility design. This new cast in place concrete tank would provide an additional 1.4 MG of digestion volume. For the purpose of cost estimating, it has been assumed that this tank would be provided with a concrete submerged fixed cover (to limit foaming concerns) and with draft tube mixing similar to the existing units. Additionally, a new 1.7 MMBtu heat exchanger and new recirculation pumps would be required to maintain mesophylic temperatures in the tank.
- Upgraded biogas collection, flare and safety equipment: Due to the significant increase in biogas production under the 4^{th} digester options (230% increase), the existing biogas conveyance, safety and flare systems would likely need to be upgraded. As a result, cost allowances have been included in the respective options for new collection headers, foam separator, sediment trap, flame arrestors, condensate traps, emergency relief valves, as well as a new, fully enclosed waste gas burner system to handle the additional capacity.
- Biogas storage system: The existing biogas storage would be reduced as a result of the significant increase in biogas production expected when implementing co-digestion. As such, additional storage would be required to absorb the variations between production and use and enhance the reliability of the cogeneration system. The most likely and viable alternative for increasing the storage capacity at GLSD would be the installation of a new double membrane gas holder ranging in size from 60,000 to 300,000 cf depending on the loading option. For this reason, a second cost analysis was completed for each of the three loading

options (one with biogas storage and one without for each of the loading alternatives). The costs for the options that include storage have been included in Tables 7-5, 7-7 and 7-9.

- New biogas siloxane treatment: Though H2S levels within the biogas are maintained at relatively low levels through the use of ferric chloride, deposition of siloxane within the existing boilers and dryers is a known issue for GLSD. The presence of this condition would likely cause significant issues within a new biogas fired cogeneration system. As such, a two vessel, carbon based siloxane removal and pressure boosting system has been recommended for all options and costs have been carried accordingly.
- New cogeneration engines: As previously noted, reciprocating internal combustion engines are the most widespread, economical and efficient of all CHP technologies currently used for biogas cogeneration. Though the selection of CHP technology should be revisited during later stages of co-digestion implementation at GLSD, internal combustion engines were selected for use in the system sizing as well as the economic evaluation included in the following tables. As shown, all conceptual options utilize a total of 2 units with engine size ranging from 400 kW to 1,550 kW.

All capital costs include a 25% allowance for project contingencies and an additional 25% for engineering of the associated improvements. The costs for the above improvements were estimated and then amortized assuming a 20-year bond at an interest rate of 2.5 percent to achieve an equivalent annual cost.

7.2.2 Operation and Maintenance Costs

Tables 7-4 through 7-9 also include annual operation and maintenance (O&M) costs associated with the following categories:

- Increased secondary aeration: Recent centrate quality data estimates of existing secondary aeration costs were used to calculate the impact that additional centrate flow would have on the aeration requirements of the secondary treatment system. As shown in Table 7-2, impact on this system could equate to an increase in aeration requirements of between approximately 2% and 7% over current aeration demands. With current secondary aeration costs estimated to be approximately $1.25M annually, this addition side stream aeration cost ranges from approximately $20,000 to $100,000 per year, depending on the level of SSO acceptance.
- Biogas utilization system maintenance: The addition of new biogas treatment and cogeneration systems will inherently carry with it ongoing costs for operations and maintenance. For general maintenance activities, it has been conceptually assumed that this annual cost would equate to ~2% of the equipment capital cost. Above and beyond that would be the cost for carbon replacement within the biogas treatment system which is estimated to range from $35,000 to $68,000 per year depending on the size of the system.

- Additional staffing for receiving operations: As noted in TM No. 5, it is estimated that, along with the addition of a 4th digester, the significant number and extended offload times associated with SSO deliveries would necessitate the addition of a dedicated staff member to manage these operations. As such, an assumed labor cost of $50/hr (including fringe benefits) and a 40 hr/week was carried for a total annual additional labor cost of approximately $100,000.
- Increase in load to dewatering and drying: As noted in TM No. 5, the quantity of dry solids requiring dewatering and thermal drying would increase under any of the options being considered. Increases would range from approximately 5 DT/day (using existing tanks for co-digestion) to 15 DT/day (with the addition of a fourth tank). In an effort to quantify this impact, data pertaining to electrical and polymer use in dewatering in addition to electrical, natural gas and contractual fee arrangements for thermal drying (NEFCO operations) were collected from GLSD. It should be noted that the thermal drying natural gas use noted in TM No. 3 (Figure 3-1) of 0.24 MMBtu/hr results from multiple uses within the NEFCO facility. It was assumed that half of this use would be impacted by additional solids processing and a resulting unit usage of 0.0536 MMBtu/WT processed was calculated based on recent NEFCO billing records. As shown in Table 7-3, the resulting financial impact of processing the additional downstream solids received from co-digestion would range from $430K to $1.5M.

7.2.3 Combined Heat and Power Energy Benefits

The attached tables 7-4 through 7-9 also show the equivalent electricity produced by utilizing the additional biogas. As noted earlier, to determine the economic value of biogas electrical conversion, the net engine output was used along with the average value of electricity at GLSD which is currently $0.1225 per kWh. At this current rate, the electrical benefit realized when using the biogas within a reciprocating engine would range from approximately $640K to $2.6M per year.

Additionally, as discussed in TM No. 5, the waste heat from the cogeneration system would be utilized to heat incoming product and maintain digestion temperatures. When considering the conceptual heat demand and the available waste heat for each option, the resulting difference ranges from a remaining heat deficit of 1.0 MMBtu/hr to an excess heat amounts of 5.6 MMBtu/hr. Due to the significant expected fluctuations in this heat demand between the seasons and the expected variations in biogas production, for the purpose of this average conditions analysis, it has been assumed that any remaining demand would be satisfied through the purchase of natural gas for the process heat boilers. Using the current natural gas rate for GLSD of $10.50/MMBtu, the cost of natural gas to satisfy this demand would range from $0 to $90,000. Though reuse of excess heat in other areas of the plant may be possible, it has been assumed for this financial analysis that excess heat energy from CHP is not reused for any systems outside of the digestion process demands.

	Existing	Future w/Growth	Future w/out Growth	Future w/out Growth w/4th Digester
Solids Production Summary				
Digestate Solids to Dewatering (lbs/day)	32,400	40,300	41,600	62,600
Digestate Solids to Dewatering (DT/yr)	5,900	7,400	7,600	11,400
Dewatering Capture	83%	90%	90%	90%
Dewatered Cake Solids Content	25%	25%	25%	25%
Dewatered Cake to Thermal Drying (DT/yr)	4,900	6,600	6,800	10,300
Dewatered Cake to Thermal Drying (WT/yr)	19,600	26,500	27,300	41,100
Dewatering Costs				
Electric (@251 kWh/DT, $0.1225/kWh)	$ 182,000	$ 226,000	$ 233,000	$ 351,000
Polymer (@39 lbs/DT, $1.49/lb Polymer)	$ 343,000	$ 427,000	$ 441,000	$ 664,000
Labor (@150 gpm, 3% digestate solids, $50/hr)	$ 262,000	$ 327,000	$ 337,000	$ 507,000
Thermal Drying Costs				
NEFCO Capacity Charge ($2,293,445/20,000 WT dewatered cake)	$ 2,293,445	$ 2,293,445	$ 2,293,445	$ 2,293,445
NEFCO Additional Processing Fee (@$24.97/WT above 20,000 WT)	$ -	$ 162,000	$ 182,000	$ 527,000
Electric (@350 kWh/DT, $0.1225/kWh)	$ 210,000	$ 284,000	$ 293,000	$ 441,000
Natural Gas (0.0536 MMBtu/WT, $10.50/1MMBtu)	$ 11,000	$ 15,000	$ 15,000	$ 23,000
Total				
Annual	$ 3,302,000	$ 3,734,000	$ 3,794,000	$ 4,806,000
Increase from Existing	**$ -**	**$ 433,000**	**$ 493,000**	**$ 1,505,000**

Table 7-3

Potential Impact of SSO on Downstream Solids Treatment Costs

Capital Costs		Unit Size		Total
Digester cleaning[4]		-		$ 500,000
External draft tube leak issue resolution[4]		-		$ 20,000
Foam control and site improvements				$ 490,000
Biogas metering and monitoring repairs		-		$ 370,000
New outside waste blending tank and mixing system		75,000 gal		$ 380,000
New high pressure digester feed pumps		200 gpm		$ 710,000
New biogas siloxane treatment		600,000 cfd		$ 1,400,000
New cogeneration engines		2 X 400kW		$ 3,800,000
			Total[4]	$ 7,150,000
			Amortized Annual Cost [1]	***$ 465,000***
O&M Costs	**Current Annual**	**Load Increase**	**Percent Increase**	**Annual Increase**
Increase in load to dewatering and drying		3 DT/Day		$ 433,000
Increased secondary aeration	$ 1,250,000		1.4%	$ 18,000
Biogas cleaning media replacement				$ 35,000
General O&M (2% of additional equipment cost)				$ 39,000
			Annual O&M Cost	***$ 525,000***
Combined Heat and Power	**Quantity**	**Total Annual**	**Unit Cost**	
CHP Electrical Production	600 kW	5,256,000 kWh	$0.1225/kWh	$ (640,000)
CHP Process Heat Demand Remaining[2]	1.00 MMBtu/hr		$10.50/MMBtu	$ 92,000
			Annual CHP Cost	***$ (548,000)***
Total				
			Net Annual Cost	$ 442,000
			Annual SSO Received (gal/yr)	6,570,000
			Break Even Tip Fee ($/gal)	$ 0.067
			Break Even Tip Fee ($/WT)	$ 16.13

[1] Based on 2.5% interest rate on 20-year bond

[2] Based on equivalent cost of natural gas needed to satisfy heat demand.

[3] Negative values in above table indicate financial credit

[4] Costs for cleaning and draft tube leaks not included in total co-digestion project cost.

Table 7-4
GLSD Co-Digestion Financial Feasibility
Future With System Growth and Without Additional Biogas Storage

Capital Costs		Unit Size			Total
Digester cleaning[4]		-		$	500,000
External draft tube leak issue resolution[4]		-		$	20,000
Foam control and site improvements				$	490,000
Biogas metering and monitoring repairs		-		$	370,000
New outside waste blending tank and mixing system		75,000 gal		$	380,000
New high pressure digester feed pumps		200 gpm		$	710,000
New biogas siloxane treatment		600,000 cfd		$	1,400,000
New biogas storage system		60,000 cf		$	840,000
New cogeneration engines		2 X 500kW		$	4,500,000
			Total[4]	$	8,690,000
			Amortized Annual Cost [1]	***$***	***565,000***
O&M Costs	**Current Annual**	**Load Increase**	**Percent Increase**		**Annual Increase**
Increase in load to dewatering and drying		3 DT/Day		$	433,000
Increased secondary aeration	$ 1,250,000		1.4%	$	18,000
Biogas cleaning media replacement				$	35,000
General O&M (2% of additional equipment cost)				$	45,000
			Annual O&M Cost	***$***	***531,000***
Combined Heat and Power	**Quantity**	**Total Annual**	**Unit Cost**		
CHP Electrical Production	707 kW	6,193,000 kWh	$0.1225/kWh	$	(760,000)
CHP Process Heat Demand Remaining[2]	0.53 MMBtu/hr		$10.50/MMBtu	$	49,000
			Annual CHP Cost	***$***	***(711,000)***
Total					
			Net Annual Cost	$	385,000
			Annual SSO Received (gal/yr)		6,570,000
			Break Even Tip Fee ($/gal)	$	0.059
			Break Even Tip Fee ($/WT)	$	14.05

[1] Based on 2.5% interest rate on 20-year bond

[2] Based on equivalent cost of natural gas needed to satisfy heat demand.

[3] Negative values in above table indicate financial credit

[4] Costs for cleaning and draft tube leaks not included in total co-digestion project cost.

Table 7-5
GLSD Co-Digestion Financial Feasibility
Future with System Growth and With Additional Biogas Storage

Capital Costs		Unit Size		Total
Digester cleaning[4]		-		$ 500,000
External draft tube leak issue resolution[4]		-		$ 20,000
Foam control and site improvements				$ 490,000
Biogas metering and monitoring repairs		-		$ 370,000
New outside waste blending tank and mixing system		75,000 gal		$ 380,000
New high pressure digester feed pumps		200 gpm		$ 710,000
New biogas siloxane treatment		670,000 cfd		$ 1,500,000
New cogeneration engines		2 X 600kW		$ 4,800,000
			Total[4]	$ 8,250,000
			Amortized Annual Cost [1]	***$ 536,000***
O&M Costs	**Current Annual**	**Load Increase**	**Percent Increase**	**Annual Increase**
Increase in load to dewatering and drying		5 DT/Day		$ 493,000
Increased secondary aeration	$ 1,250,000		2.2%	$ 28,000
Biogas cleaning media replacement				$ 35,000
General O&M (2% of additional equipment cost)				$ 46,000
			Annual O&M Cost	***$ 602,000***
Combined Heat and Power	**Quantity**	**Total Annual**	**Unit Cost**	
CHP Electrical Production	731 kW	6,404,000 kWh	$0.1225/kWh	$ (780,000)
CHP Process Heat Demand Remaining[2]	0.43 MMBtu/hr		$10.50/MMBtu	$ 40,000
			Annual CHP Cost	***$ (740,000)***
Total				
			Net Annual Cost	$ 398,000
			Annual SSO Received (gal/yr)	10,220,000
			Break Even Tip Fee ($/gal)	$ 0.039
			Break Even Tip Fee ($/WT)	$ 9.33

[1] Based on 2.5% interest rate on 20-year bond

[2] Based on equivalent cost of natural gas needed to satisfy heat demand.

[3] Negative values in above table indicate financial credit

[4] Costs for cleaning and draft tube leaks not included in total co-digestion project cost.

Table 7-6
GLSD Co-Digestion Financial Feasibility
Future Without System Growth and Without Additional Biogas Storage

Capital Costs		Unit Size		Total
Digester cleaning[4]		-		$ 500,000
External draft tube leak issue resolution[4]		-		$ 20,000
Foam control and site improvements				$ 490,000
Biogas metering and monitoring repairs		-		$ 370,000
New outside waste blending tank and mixing system		75,000 gal		$ 380,000
New high pressure digester feed pumps		200 gpm		$ 710,000
New biogas siloxane treatment		670,000 cfd		$ 1,500,000
New biogas storage system		80,000 cf		$ 900,000
New cogeneration engines		2 X 600kW		$ 4,800,000
			Total[4]	$ 9,150,000
			Amortized Annual Cost [1]	***$ 595,000***
O&M Costs	**Current Annual**	**Load Increase**	**Percent Increase**	**Annual Increase**
Increase in load to dewatering and drying		5 DT/Day		$ 493,000
Increased secondary aeration	$ 1,250,000		2.2%	$ 28,000
Biogas cleaning media replacement				$ 35,000
General O&M (2% of additional equipment cost)				$ 52,000
			Annual O&M Cost	***$ 608,000***
Combined Heat and Power	**Quantity**	**Total Annual**	**Unit Cost**	
CHP Electrical Production	868 kW	7,604,000 kWh	$0.1225/kWh	$ (930,000)
CHP Process Heat Demand Remaining[2]	(0.16) MMBtu/hr		$10.50/MMBtu	$ -
			Annual CHP Cost	***$ (930,000)***
Total				
			Net Annual Cost	$ 273,000
			Annual SSO Received (gal/yr)	10,220,000
			Break Even Tip Fee ($/gal)	$ 0.027
			Break Even Tip Fee ($/WT)	$ 6.40

[1] Based on 2.5% interest rate on 20-year bond

[2] Based on equivalent cost of natural gas needed to satisfy heat demand. Credit not taken for potential reuse in building heat demands.

[3] Negative values in above table indicate financial credit

[4] Costs for cleaning and draft tube leaks not included in total co-digestion project cost.

Table 7-7
GLSD Co-Digestion Financial Feasibility
Future Without System Growth and With Additional Biogas Storage

Capital Costs		Unit Size			Total
Digester cleaning[4]		-		$	500,000
External draft tube leak issue resolution[4]		-		$	20,000
Foam control and site improvements				$	490,000
Biogas metering and monitoring repairs		-		$	370,000
New outside waste blending tank and mixing system		75,000 gal		$	380,000
New high pressure digester feed pumps		200 gpm		$	710,000
New anaerobic digester tank and ancillary equipment		1.4 MG		$	4,700,000
Biogas collection and safety equipment upgrades		-		$	1,800,000
New biogas siloxane treatment		1,300,000 cfd		$	1,900,000
New cogeneration engines		2 X 1,550kW		$	10,400,000
			Total[4]	$	20,750,000
			Amortized Annual Cost [1]	***$***	***1,349,000***
O&M Costs	**Current Annual**	**Load Increase**	**Percent Increase**		**Annual Increase**
Increase in load to dewatering and drying		15 DT/Day		$	1,500,000
Increased secondary aeration	$ 1,250,000		7.4%	$	93,000
Biogas cleaning media replacement				$	68,000
General O&M (2% of additional equipment cost)				$	116,000
Additional staffing for receiving operations		2080 hrs	$50/hr	$	104,000
			Annual O&M Cost	***$***	***1,881,000***
Combined Heat and Power	**Quantity**	**Total Annual**	**Unit Cost**		
CHP Electrical Production	2,029 kW	17,774,000 kWh	$0.1225/kWh	$	(2,180,000)
CHP Process Heat Demand Remaining[2]	(3.95) MMBtu/hr		$10.50/MMBtu	$	-
			Annual CHP Cost	***$***	***(2,180,000)***
Total					
			Net Annual Cost	$	1,050,000
			Annual SSO Received (gal/yr)		33,580,000
			Break Even Tip Fee ($/gal)	$	0.031
			Break Even Tip Fee ($/WT)	$	7.50

[1] Based on 2.5% interest rate on 20-year bond

[2] Based on equivalent cost of natural gas needed to satisfy heat demand. Credit not taken for potential reuse in building heat demands.

[3] Negative values in above table indicate financial credit

[4] Costs for cleaning and draft tube leaks not included in total co-digestion project cost.

Table 7-8
GLSD Co-Digestion Financial Feasibility
Future Without System Growth, Without Additional Biogas Storage and With 4th Digester

Capital Costs		Unit Size		Total
Digester cleaning[4]		-		$ 500,000
External draft tube leak issue resolution[4]		-		$ 20,000
Foam control and site improvements				$ 490,000
Biogas metering and monitoring repairs		-		$ 370,000
New outside waste blending tank and mixing system		75,000 gal		$ 380,000
New high pressure digester feed pumps		200 gpm		$ 710,000
New anaerobic digester tank and ancillary equipment		1.4 MG		$ 4,700,000
Biogas collection and safety equipment upgrades		-		$ 1,800,000
New biogas siloxane treatment		1,300,000 cfd		$ 1,900,000
New biogas storage system		300,000 cf		$ 1,900,000
New cogeneration engines		2 X 1,550 kW		$ 10,400,000
			Total[4]	$ 22,650,000
			Amortized Annual Cost [1]	***$ 1,472,000***
O&M Costs	**Current Annual**	**Load Increase**	**Percent Increase**	**Annual Increase**
Increase in load to dewatering and drying		15 DT/Day		$ 1,500,000
Increased secondary aeration	$ 1,250,000		7.4%	$ 93,000
Biogas cleaning media replacement				$ 68,000
General O&M (2% of additional equipment cost)				$ 130,000
Additional staffing for receiving operations		2080 hrs	$50/hr	$ 104,000
			Annual O&M Cost	***$ 1,895,000***
Combined Heat and Power	**Quantity**	**Total Annual**	**Unit Cost**	
CHP Electrical Production	2,409 kW	21,103,000 kWh	$0.1225/kWh	$ (2,590,000)
CHP Process Heat Demand Remaining[2]	(5.59) MMBtu/hr		$10.50/MMBtu	$ -
			Annual CHP Cost	***$ (2,590,000)***
Total				
			Net Annual Cost	$ 777,000
			Annual SSO Received (gal/yr)	33,580,000
			Break Even Tip Fee ($/gal)	$ 0.023
			Break Even Tip Fee ($/WT)	$ 5.55

[1] Based on 2.5% interest rate on 20-year bond

[2] Based on equivalent cost of natural gas needed to satisfy heat demand. Credit not taken for potential reuse in building heat demands.

[3] Negative values in above table indicate financial credit

[4] Costs for cleaning and draft tube leaks not included in total co-digestion project cost.

Table 7-9
GLSD Co-Digestion Financial Feasibility
Future Without System Growth, With Additional Biogas Storage and With 4th Digester

7.3 Summary of Financial Analysis

As shown in detail within Tables 7-4 through 7-9 and as summarized in Table 7-10, the total annual net cost of implementing co-digestion is estimated to range from $385K to $1.05M before accounting for tipping fee revenues. At these costs and assumed SSO quantities, the break-even tipping fee would equate to between $0.02 and $0.07 per gallon (or $6 to $16 per wet ton received). These potential fees are in line and slightly less than fees charged at other facilities and less than what is currently charged for outside waste receiving at GLSD (currently $0.05 to $0.10 per gallon depending on material and source). For comparison, other New England wastewater treatment facilities accepting wastes directly to digesters typically charge between $0.05 and $0.10 per gallon – similar to GLSD. At the EBMUD facility in Oakland, CA tipping fees are $0.03 to $0.15 per gallon depending on the type of waste.

It is also important to note that discussions with national private haulers during the course of this study indicated that tipping fees for organic waste in other parts of the country are commonly in the range of $30 to $40 per wet ton. As shown in Table 7-10, if this rate were to be charged for SSOs at GLSD, the net annual revenue would equate to an estimated surplus between $380K to $3.4M. As an additional point of comparison, Table 7-10 also includes the estimated total electrical production from the CHP system as a percentage of total current plant-wide power use.

All costs noted with this memorandum are in present day (April 2013) dollars. Though overall costs would be expected to increase in the future proportional to the rate of inflation, based on recent history, energy price escalation will likely exceed that of standard inflation indices. Therefor the net benefit of additional biogas production and net revenues from co-digestion are likely to be greater in future years. A few of the conservatisms included herein which, upon refinement, may yield additional financial benefit include:

- Reuse of excess CHP heat (if any) may be possible for non-digestion purposes (e.g. plant-wide building heat);
- Assumed biogas utilization (capture) of 82% (with current biogas storage) and 95% (with expanded biogas storage) may be able to be exceeded with improved metering and control systems;
- The assumption that biogas treatment would utilize 15% of total cogeneration electric power ("parasitic load"), is very likely to be able to be reduced though detailed system design;
- Organic waste volatile solids reduction (VSR) and biogas production have been shown in some studies to exceed the assumed values of 82% VSR and 13.6 cf biogas/lb VSR; and
- Financial benefits available from the sale of Renewable Energy Certificates (RECs) have not been taken into account.

	Annual Cost Excluding Tip Fee	Annual SSO Received (gal/day)	Break Even Tip Fee ($/gal)	Break Even Tip Fee ($/WT)	Annual Surplus @ $30/WT Tip Fee	Plant-Wide Power Offset from CHP
Future With System Growth Without Additional Biogas Storage	$442,000	18,000	$0.067	$16.13	$380,000	26%
Future with System Growth With Additional Biogas Storage	$385,000	18,000	$0.059	$14.05	$437,000	30%
Future Without System Growth Without Additional Biogas Storage	$398,000	28,000	$0.039	$9.33	$881,000	31%
Future Without System Growth With Additional Biogas Storage	$273,000	28,000	$0.027	$6.40	$1,010,000	37%
Future Without System Growth, Without Additional Biogas Storage With 4th Digester	$1,050,000	92,000	$0.031	$7.50	$3,150,000	87%
Future Without System Growth, With Additional Biogas Storage With 4th Digester	$777,000	92,000	$0.023	$5.55	$3,420,000	104%

* Negative values in above table indicate financial credit

Table 7-10
GLSD Co-Digestion Financial Feasibility Summary

As shown in Table 7-10, the largest of the waste acceptance options (construction of a 4th digester) brings with it the largest potential annual surplus along with the largest offset of plant power consumption. However, due to the significant capital cost required for the 4th digester, the “Future Without System Growth and With Additional Biogas Storage” option which maximizes the use of existing infrastructure yields a comparable breakeven tip fee. As a result of this, along with the inherent risk related to waste availability and the expected variable market for this material in the Commonwealth over the coming few years, it is likely in the District’s best interest to pursue a co-digestion options which maximizes the existing infrastructure while adding biogas storage and cogeneration facilities. This path would not preclude the future development of the 4th digester in the event the organic waste market was to prove to be a viable, long-term source of revenue.

7.4 Demonstration Testing

The co-digestion of wastewater solids and other organic wastes is not common in the U.S. However, it is an expanding practice that has been proven successful by several large wastewater utilities that have taken in compatible outside wastes and co-digested them with wastewater solids to significantly increase digester gas production. GLSD is considering co-digestion at its facility and this study provides an analysis of the potential costs and benefits.

MassDEP has proposed a ban on the disposal of source separated organics (SSO) in landfills and incinerations for commercial wastes. Regulations resulting from this ban are expected to be implemented in mid-2014. Approximately 1,000 wtpd of SSO would be diverted state-wide to recycling facilities such as anaerobic digestion or composting facilities. It has been assumed that the wastes would be collected and pre-processed at an off-site location by the private sector and transported to GLSD by truck. At the time of this study, the pre-processing facilities do not presently exists, and costs for such facilities are not examined in this report since they would be borne by the haulers.

Based on CDM Smith's experience at other co-digestion facilities, SSO available to GLSD can be expected to have high levels of biodegradable organic material that can be converted to biogas under the same temperatures and detention times utilized for current GLSD biosolids. To be conservative, the report assumes that 70 percent of the SSO co-digested at GLSD would be converted to biogas.

Undertaking a program as significant as co-digestion of source separate organic waste requires significant investment and is a notable change to facility operations. Due to the site specific nature of organic waste sources and of municipal biosolids, as a next step in implementation of a co-digestion program at GLSD, it is recommended that a pilot testing program be pursued. The pilot program should seek to evaluate the following issues:

- Laboratory testing of the expected waste for its biomethane production (BMP) potential;
- Limited onsite feed of SSO waste into one or more digesters to monitor process performance compared to current digestion and biogas production performance;
- Monitoring of feed and mixing of waste at the percentages assumed in this study to ensure the adequacy of the existing mixing systems;
- Evaluation of dewatering performance and polymer consumption following the addition of limited SSO to the digestion system;
- Monitoring for impact on thermal drying operations and resultant product quality and nutrient content; and
- Sampling and analysis of dewatering sidestream ammonia and other constituent levels to confirm impact on secondary liquid train aeration process air demand.

Following successful completion of a comprehensive pilot program to verify the above consideration, and assuming discussions with local waste haulers indicate a viable long-term source of SSO, co-digestion within the GLSD anaerobic digestion process could likely yield significant economic and environmental benefits.