

Lewiston Auburn Water Pollution  
Control Authority

**Anaerobic Digestion/Energy Recovery  
Feasibility Study**

August, 2009

*Final Report*

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# Executive Summary

## Background and Purpose of Feasibility Study

The Lewiston Auburn Water Pollution Control Authority (LAWPCA) owns and operates the Lewiston Auburn Water Pollution Control Facility (LAWPCF). The facility is permitted to discharge an average daily flow of 14.2 million gallons per day (MGD) and currently operates at an average daily flow of approximately 12.7 MGD.

Currently, biosolids are dewatered at the wastewater treatment facility and either trucked to the Authority's composting facility in Auburn, trucked to sites in the greater Lewiston-Auburn area for application to farmland or transported to distant disposal sites. Due to rising costs associated with managing biosolids, LAWPCA is considering anaerobic digestion for biosolids stabilization and volume reduction. Anaerobic digestion with energy recovery is a well established technology with hundreds of installations in the United States.

## Project Recommendations

Based on the amount of biosolids currently produced and accounting for future flow and loading increases to the wastewater treatment plant, it is recommended that two, single stage high rate anaerobic digesters be constructed. The digesters, each approximately 65 feet in diameter, will generate biogas to be used in a cogeneration system, creating electricity and heat for use at the treatment facility. The biogas cogeneration system will consist of two, 270 kW reciprocating engines. Depending on the quality of the biogas, the biogas cleaning system will most likely consist of hydrogen sulfide, water and siloxane removal.

To produce sludge that is best amenable to anaerobic digestion, it is recommended that the existing dissolved air floatation (DAF) units that currently thicken waste activated sludge (WAS) be replaced with gravity belt thickeners (GBTs) or rotary drum thickeners (RDTs).

The equipment selection and layouts in this feasibility study are based on proven anaerobic digestion and energy recovery technologies. The costs presented in this feasibility study are consistent with standard digestion practices. During the preliminary design phase of the project, it may be possible to reduce project costs and/or optimize facility efficiency by further evaluating several facility components.

## Project Benefits

Anaerobic digestion of biosolids offers several advantages that justify the associated capital and operating costs. The advantages of utilizing anaerobic digestion to stabilize biosolids at LAWPCA include:

- Reduction of total solids by approximately 40%. This reduction in solids will reduce biosolids related annual operating costs by approximately \$640,000 per year.

- Eliminating the need to add lime to biosolids prior to land application.
- Eliminating transportation and tipping fees associated with trucking biosolids to distant disposal sites, accounting for approximately 12% of biosolids produced annually.
- Generating electricity and heat on-site, utilizing two, 270 kW reciprocating engine generator sets, operating on digester biogas.
- Additional labor for new digester system offset by reduced labor hours for operation of thickening and dewatering equipment.
- Reducing plant-wide purchased power by approximately two-thirds, or approximately \$282,000 annually at current energy prices.
- Replaces outmoded waste activated sludge thickeners with new, more efficient thickening equipment.
- Reduction of biosolids odors, thereby making the LAWPCA's existing Class B land application program more acceptable to nearby property owners.
- Increase overall capacity of the plant, which is now largely limited by dewatering and biosolids disposal capabilities.

## Project Costs

Table ES-1 summarizes estimated project costs. All construction costs include a contingency and have a planning level accuracy of plus or minus 20 percent. Engineering costs are estimated at 15 percent of construction costs.

**Table ES-1 - Estimated Project Costs**

<i>Item</i>	<i>Amount</i>
Digesters	\$3,500,000
Digester Building	1,500,000
Digestion Equipment	1,000,000
Biogas Utilization	3,000,000
Site Work/Yard Piping	350,000
Instrumentation and Controls	1,000,000
Electrical	2,100,000
Gravity Belt Thickening	600,000
Engineering	1,950,000
<b>Total</b>	<b>\$15,000,000</b>

## Projected Cost Savings

Table ES-2 summarizes projected cost savings attributed to: reduced quantities of biosolids to thicken and dewater, elimination of lime stabilization, reduction in composting, reduction in electricity usage, less land application expenses and elimination of landfilling. Total operating cost savings are approximately \$640,000 per year. This does not include any labor cost savings. It is anticipated that any labor requirements due to the digestion facility will be offset by the reduction in labor needed to operate the dewatering facility and associated biosolids handling and trucking equipment.

**Table ES-2 - Annual Estimated Operating Costs**

<i>Annual Estimated Operating Costs</i>	<i>Current Biosolids Management</i>	<i>Biosolids Management With Anaerobic Digestion</i>	<i>Difference</i>
<b>WAS Thickening and Dewatering</b>	\$49,800	\$25,800	\$24,000
<b>Lime Stabilization</b>	\$120,000	\$0	\$120,000
<b>Composting Facility</b>	\$461,600	\$297,000	\$164,600
<b>Treatment Facility</b>	\$583,000	\$489,400	\$93,600
<b>Residual Disposal</b>	\$448,000	\$175,000	\$273,000
<b>Digester Equipment</b>	\$0	\$33,000	(\$33,000)
<b>Total Estimated Annual Biosolids Management Costs</b>	\$1,660,000	\$1,020,000	\$640,000

Significant cost savings also result from the value of the electricity generated by the reciprocating engines. In the first year of operation, at the current rate of \$0.12 per kWh, the savings is approximately \$282,000. Savings will increase by \$45,000 annually if the Authority is able to take advantage of the additional 15% capacity available in the anaerobic digester system.

## Financial Analysis

If no grants are received for the implementation of the project, the net average annual cost savings to the Authority are approximately \$50,000. Therefore, the project is economically feasible within the cost estimating accuracy of this study. With a 50 percent grant equivalent, the net average annual cost savings is approximately \$650,000. See Table ES-3.

**Table ES-3 - Financial Analysis of  
Anaerobic Digester/Energy Recovery Project**

<i>Item</i>	<i>Project With No Grants</i>	<i>Project With 50 Percent Grant Equivalent</i>
Estimated Capital Costs	\$15,000,000	\$7,500,000
Annual Bond Cost	\$1,200,000	\$600,000
Annual Operating Cost Savings	\$1,250,000	\$1,250,000
Net Annual Savings	\$50,000	\$650,000

## Greenhouse Gas Emissions Comparison

In recent years, interest in analyzing the greenhouse gas (GHG) emissions from various biosolids management practices has increased. The gases of most concern are carbon dioxide, methane and nitrous oxide. Greenhouse gases differ in their influence on trapping heat in the atmosphere. For ease of comparison, protocols require reporting of GHG emissions in CO<sub>2</sub> equivalents. Based on the evaluation, by utilizing anaerobic digestion to manage biosolids, GHG emissions will be reduced by approximately 83% as compared to existing biosolids management practices, as shown in the Table ES-4.

**Table ES-4 - Estimated Greenhouse Gas Emissions  
(Mg CO<sub>2</sub> equivalents per year)**

<i>Source</i>	<i>Existing Practices</i>	<i>With Anaerobic Digestion and Energy Recovery</i>
Direct Emissions	2,240	725
Purchased Heat and Power	302	(-185)
Indirect Supply Chain and Product Use	814	23
<b>Total</b>	<b>3,356</b>	<b>563</b>

## Project Conclusions

This feasibility study indicates that the project is economically viable and provides significant benefits to LAWPCA in terms of operations and capacity.

# Section 1

## Background and Introduction

### 1.1 Facility Background

The Lewiston Auburn Water Pollution Control Authority (LAWPCA) owns and operates the Lewiston Auburn Water Pollution Control Facility (LAWPCF). The facility is permitted to discharge an average daily flow of 14.2 million gallons per day (MGD) and currently operates at an average daily flow of approximately 12.7 MGD.

The influent wastewater is a mixture of residential, commercial and industrial wastewater, generated in the cities of Lewiston and Auburn. Approximately half of the total organic load to the facility is generated by the Cascades Auburn-Fiber deinking facility. The LAWPCF has a secondary level treatment process, with two primary sedimentation basins, two aeration basins and two secondary clarifiers. Final effluent is disinfected with chlorine and then dechlorinated prior to discharge in the Androscoggin River.

The solids handling process at the treatment plant thickens and dewateres solids removed in the primary and secondary treatment process. Primary and secondary solids are thickened separately prior to co-dewatering in a belt filter press (BFP). Following dewatering, the sludge cake is beneficially reused by either composting or lime stabilization. During the spring and summer months, biosolids are stabilized to a Class B product by lime addition and land applied. In the fall and winter months, the biosolids are trucked to an in-vessel composting facility, owned and operated by the LAWPCA. The product is sold for various uses.

### 1.2 Project Drivers, Goals and Objectives

The composting facility has served the LAWPCA well during its 15 years of operation. However, composting operation costs have increased, especially the cost of amendments (woodchips, sawdust, chopped hay or horse bedding that is mixed with the dewatered sludge) and the facility is unable to manage peak seasonal biosolids production, necessitating costly long distance disposal. As such, the LAWPCA is considering anaerobic digestion for biosolids stabilization and volume reduction.

Anaerobic digestion of biosolids before dewatering and land applying or composting offers several advantages that may justify the capital and operating costs of an anaerobic digestion system. Based on CDM's experience and current understanding of the LAWPCF's operations, the potential advantages of anaerobic digestion include:

- Reduction of total solids by approximately 40%. This reduction in solids will reduce subsequent costs for conditioning, dewatering, trucking and disposal.

- Elimination of the cost to transport “excess” biosolids that currently exceed the capacity of the composting facility. Associated tipping fees will also be eliminated.
- Reduction of biosolids odors, thereby making the LAWPCA’s existing Class B land application program more acceptable to nearby property owners.
- Potential to utilize the biogas from the anaerobic digestion process in a combined heat and power (CHP) application to produce electricity and heat. The electricity produced would offset a portion of power currently purchased from the utility and the heat would be used for digester and building heating.
- The wastewater treatment plant is limited by the capacity of the existing dewatering and biosolids stabilization equipment. By reducing the volume of sludge through anaerobic digestion, the overall capacity of the plant will increase.

### **1.3 Evaluation Approach**

To assess the technical and economic feasibility of installing an anaerobic digestion system to manage biosolids, the report is divided into the following sections:

#### **Section 1**

- Introduction and project background.

#### **Section 2**

- Brief description of anaerobic digestion and digester gas utilization systems in use in New England and other areas with similar climates.

#### **Section 3**

- Summary of current sludge quantities and characteristics based on operating data; estimation of future sludge quantities; recommended basis of design for an anaerobic digestion system.

#### **Section 4**

- Description of existing sludge management practices at the treatment and composting facilities and associated costs.

#### **Section 5**

- Summary of energy usage and associated costs at the treatment and composting facilities.

#### **Section 6**

- Evaluation of anaerobic digestion system: volume requirements, number of digesters, digester control system, building sizing, equipment layout and facility siting.

### **Section 7**

- Evaluation of using the biogas generated during the digestion process: methods of collection and storage, treatment requirements, cogeneration equipment (microturbines, reciprocating engines).

### **Section 8**

- Evaluation of replacing the existing waste activated sludge dissolved flotation thickeners with gravity belt or rotary drum thickeners.

### **Section 9**

- Summary of existing costs for current biosolids management; engineer's opinion of probable cost for digester system; life cycle cost analysis (current practice versus anaerobic digestion system); greenhouse gas comparison; conclusions and recommendations.

## Section 2

# Representative Anaerobic Digester and Digester Gas Utilization Programs

Following are brief descriptions of anaerobic digestion and digester gas utilization systems in use in New England and other areas with similar climates. See Appendix A for more information on plants surveyed. These particular wastewater treatment facilities were chosen because they are of similar size (influent flow volume) to the LAWPCF. The information presented was gleaned from project reports, conference presentations, facility websites, and interviews with facility managers and operators during late May 2009. Copies of sources are available upon request.

### 2.1 Summary AD & Digester Gas Utilization Program Reports

Following are short summaries of key findings regarding each of the anaerobic digester and heat and power systems investigated. Detailed tabulated data regarding each program can be found in Appendix A.

#### *Lewiston, NY*

Lewiston is the smallest of the wastewater treatment facilities investigated, but it also has one of the longest experiences with combined heat and power systems, using some form of CHP since 1985. This is a pioneer and leader in the field, helping other pioneers like Jim Jutras at Essex Junction. The digester system was built in the mid-1970's and is two tanks with the primary being heated to mesophilic range and the secondary unheated and used to store digester gas (using a floating cover). The first two generations of CHP systems were combustion engines, 51 kWh and 100 kW (likely derated) respectively. The third generation of CHP system is 2 Capstone C30's, installed in 2001.

The Capstone system is already on its first replacement. Both the initial installation and the replacement were 100% grant-funded through various sources (NYPA, NY Governor's office, NYSERDA). One initial challenge for the Lewiston plant was the air-to-liquid heat exchanger. A modification was installed in 2003, which added a plate and frame-style heat exchanger and closed the loop on the liquid circulation. Another key observation by Tim Lockhart, the Chief Operator, is to have ample digester gas storage. There will be digester downtime due to events such as maintenance and ebbs and flows in digester gas production due to stormflows, so in order to produce a steady output from the CHP system, the digester gas storage needs to account for these events.

#### *Essex Junction, VT*

Essex Junction, VT installed their CHP system in 2003, with much assistance from Lewiston, NY, who had a similar average daily flow. Their system is using digester gas that was formerly used in a boiler to heat the digester and now goes through 2

Capstone C30 engines. Their digesters are two mesophilic digesters, each with 350,000 gallon capacity. One initial start-up challenge was due to a missed dew-point calculation by the manufacturer, and it was handled quickly.

Other operational challenges were related to the age of the digester and the system maintenance with the headworks in need of repair for a period of time. The system's payback (7 years) was calculated solely on the basis of kWh produced and therefore not purchased. One charge that the utility started to charge after the system was in place was a power factor charge, due to the decrease in the power factor rating.

Essex Junction also takes in some brewery waste and FOG in addition to the normal flow to the plant. To date, this material has been accepted into the primary scum pit, and the additional revenue has not justified investments in a receiving station.

The total cost of the system was \$303,000, after grant funding of about \$80,000. The initial funders were: Efficiency Vermont, Native Power, Dept of Energy, BioMass Energy Resource Center. The system is fully owned by the Village of Essex Junction.

The electricity savings are summarized as follows:

Average electricity use for entire WWTP, 1997-2002 = 77,096 kWh/month

Average electricity use for entire WWTP, 2004 - May 2008 = 68,574 kWh/month

### ***Chippewa Falls, WI***

Chippewa Falls, WI has a similar average daily flow to Lewiston and Essex Junction (although a higher design flow). It has 3 digesters, the first with a 650,000 gallon capacity and the second two with each 250,000 gallon capacity and floating covers for gas storage. It also has two C30 Capstone microturbines. One operational challenge highlighted for this plant was the "tightness" of space in the gas cleanup skid. If they had to do something over again, it would be to get the cleanup system to not be skid-mounted so that there's more room for routine maintenance.

Chippewa Falls achieves a total VS destruction of 52% and is looking into "OpenCEL" technology to see if it makes sense to make further investments to improve VS destruction.

### ***South Monmouth, NJ***

South Monmouth, NJ has an average daily flow of 6 MGD and has seasonal digester gas output that varies from 65,000 cubic feet per day (cfd) in the winter to 150,000 cfd in the summer, due to the fact that it services beach communities. The system has two digesters with a total capacity of 1,500,000 gallons. The latest generation of CHP system is expected to be installed by the end of 2009. The first generation of CHP was a microturbine system and they've decided to go with an IC engine this time around due to serviceability and the need for more heat recovery. Two, 140 kW

reciprocating engines are being installed, along with a new gas conditioning system for hydrogen sulfide, moisture and siloxane removal.

### ***Fairfield, CT***

The Fairfield, CT WWTP has been digesting since 1952 and has an average daily flow of 7 MGD. They are currently using their digester gas in existing boilers for both the digester and the building and are looking into IC engines as their “next generation” CHP system. The plant did have 60kW of microturbines installed; however, had operational problems from the start, due to inadequate cleanup of the digester gas. They went through 3 engine replacements (at \$16K each) and were faced with an expensive retrofit of the gas cleanup skid, so are opting to go with IC engines. Also, they replaced the cover and the mixing system in 2001. The current mixing system pumps digester gas through the digester. One comment from the Assistant Superintendent is that they may have gone with Rota-Mix system had they known how aggressive/touchy the cannon mixing system was.

### ***Franklin, NH***

The Winnepesaukee River Basin Program, a state-owned and -operated system, collects wastewater from numerous towns in central New Hampshire and processes it at the Franklin Wastewater Treatment Facility. Built in the 1980s, the facility has had anaerobic digesters from the beginning, and the digester gas has been flared. Currently, options for digester gas utilization are being explored. Additional information regarding plans for Franklin is available upon request.

### ***Pittsfield, MA***

The Pittsfield, MA plant has an average daily flow of 12 MGD, is currently using the 98,000 cfd of digester gas to heat the digester and the building and is in the preliminary design stages of installing a CHP system. The digestion system is two mesophilic digesters constructed in 1963, each with covers replaced in 1997 (secondary) and 2005 (primary). The secondary digester has a spiral cover that has a digester gas holding capacity of 35,000 cf.

The expected total installed capacity of the CHP system is 295 kW and the equipment installed is expected to be 3, 65 kW Capstone microturbines, with an expected installation date of early 2010. The heat recovered will feed into the existing sludge heating loop for the digester and digester building. One issue that is currently a priority over the CHP installation is replacing the bar screens in the headworks that is clogging pumps (with rags and other debris) and reducing the flow of solids to the digester, thereby reducing the digester gas output. The plan is to replace that and then move forward with the CHP project.

The Pittsfield, MA WWTP received funding for feasibility work from the Massachusetts Technology Collaborative (MTC) and was awarded \$400,000 from MTC for design and construction of the project.

### ***Nashua, NH***

Nashua has the only egg-shaped anaerobic digester in New England outside of Boston. It was installed in 1999 and the combined heat and power (CHP) system was installed at the same time. The operators have been very pleased with the system overall. The egg-shaped digester is very efficient and easy to operate; it did develop a crack and leak in the summer of 2007, but that was fixed. The operators stress the fact that the engine generator requires a lot of maintenance. The facility has saved about \$10,000/month in energy costs. Compared to its prior sludge utilization program, the operators estimate that the city saves close to \$1 million a year in solids end use costs with the reduced volume of solids and their increased quality, which makes land application desirable.

### ***Gresham, OR***

The Gresham, OR WWTP is currently on its second generation CHP system using digester gas from the facility. The former system used a 250kW engine and flared 41% of the digester gas. The current system is a 395 kW Caterpillar that uses all of the digester gas and recovers heat from the engine coolant and exhaust to be used for digester and building heating. One reason why Caterpillar was selected was the ability to get parts and service (they had problems with servicing with the first one). In addition, a gas cleanup system that takes out H<sub>2</sub>S, water vapor, and siloxanes was installed, resulting in fewer maintenance problems compared to the original system.

The system was installed in 2005 at a cost of about \$1.3 million before incentives. One startup challenge was the integration of the CHP control system with the facility's overall SCADA system. Once that was addressed, the availability of the CHP system was 98%. The project received a total of about \$370,000 in incentives, which included a grant from the Energy Trust of Oregon and a Business Energy Tax Credit pass-through that allowed CostCo to give the City of Gresham a lump-sum amount and then take the tax credit over a five-year period. This brought the payback on the system down from 8 years to 5.9 years.

### ***Janesville, WI***

Janesville, WI has an average daily flow of 13 MGD. The facility has been using digester gas for CHP since 1985 and is currently producing about 12% of its electricity needs. Janesville uses three digesters, with a total capacity of 2,510,000 gallons and a digester gas output of 102,000 cfd. The first tank is thermophilic and the second two tanks are mesophilic (with gas storage/sludge storage capacity). The current CHP system, installed in 2002, is using 2, 200 kW Waukesha gen-sets (derated to 120-150 kW) with a total annual output of 719,000 kWh. Two observations made by the operator were that the space around the Waukesha is cramped because they went into an existing building where smaller Caterpillars used to be and also that heat recovery could be optimized (e.g. on winter days where the temperature gets up to 35-40 degrees F, the radiators outside the building that are used as heat sinks are running.)

The fuel conditioning system is removing H<sub>2</sub>S and water vapor (through accumulators in the tunnel below), but not siloxanes. The engines have not had a major overhaul yet, despite the manufacture recommendations of a rebuild at 16,000 hours. Engine #1 has 24, 519 hours of runtime, and engine #2 has a total of 14, 883 hours of runtime completed.

### ***Schenectady, NY***

The Schenectady, NY plant has an average daily flow of 14.5 MGD and produces about 80,000 cfd of digester gas. Its two mesophilic digesters have a combined capacity of 1,200,000 gallons and an HRT of 4.5 days. The CHP system has not been installed yet, but they are expecting to install one with an installed rating of around 100 kW. They are expecting to provide recovered heat to the digester only. They are currently introducing a solvent to the digester from a local industrial source and are expecting an increase in digester gas output as a result.

### ***Greater Lawrence Sanitary District, No. Andover, MA***

GLSD receives two and a half times the flow of LAWPCA, but its situation and experiences are similar. Its three 1.4 million gallon anaerobic digesters came online in late 2002/early 2003. At that time, GLSD had been facing extreme challenges with solids management and was trucking belt-filter-press-dewatered cake to northern Maine and elsewhere for landfill disposal or composting - at considerable cost. The main driver for the entire new solids management process (thickening, AD, and heat drying/pelletizing) was cost and hassle.

The integrated solids management system, which included a marketable end product with diverse uses, led to an obvious choice for how to use the digester gas. Heat drying facilities usually use copious quantities of natural gas. GLSD substitutes digester gas. The publicly-operated wastewater treatment plant is required, by contract, to provide digester gas to the drying facility, which is operated privately by New England Fertilizer Company (NEFCO). After the drying facility's needs are met, additional digester gas is used in boilers to heat the digesters (but no buildings are heated with it). Excess digester gas is flared.

Another similarity between GLSD and LAWPCA is the fact that major industrial contributors to the influent flow are paper fiber mills. GLSD's new solids management operation was designed for flow that included two paper mills, both of which have now shut down. This has resulted in a dramatic reduction in final solids, which means that, some weeks, the NEFCO drying facility operates just a day and a half a week. This results in there being excess digester gas that is flared.

Another lesson learned at GLSD is the importance of paying attention to the potential for foaming in the digesters.

### ***Allentown, PA***

Allentown, which has 3 times the flow of LAWPCA, has long experience with anaerobic digestion. They have two primary digesters and one secondary that is mostly used for digester gas storage. Their advice for AD operations is to monitor the digesters routinely and make only gradual changes in temperature, feed rates, etc. - never anything abrupt. They also stress the importance of digester cleaning, which they do religiously every five years; they do this job with in-house staff and consider themselves highly skilled at it.

Allentown is currently using a second set of 13 microturbines, the first set having failed due to inadequate gas cleaning and other maintenance issues. The operators stress that microturbines can be finicky and gas clean-up is critical. An interesting aspect of Allentown's operation is the financial arrangement: the CHP work was driven by the utility, Pennsylvania Power & Light, which owns the CHP system and contracts with a third party for maintenance. The maintenance company has not kept up on the maintenance, so several turbines are off-line and the overall efficiency of the system is reduced.

### ***Akron, OH***

This WWTP is six times larger than LAWPCA, and it was not investigated thoroughly for this report. However, the story of its recently-installed German high-solids AD and CHP systems is detailed in a paper from the proceedings of the 2009 WEF Residuals and Biosolids Conference (A. Berger, 2009; copy available upon request).

Notably, the same company that promoted the Akron facility, Kurz Bros., is now planning and permitting a similar facility in Columbus, OH.

### ***New York, NY***

There are 14 wastewater treatment plants in New York City (overseen by NYC DEP), 13 of which are supplied electricity by the New York Power Authority (NYPA). NYPA has so far invested in 8 fuel cells in 4 of the WWTPs, with the help of funding from the US Department of Defense and NYSERDA. NYPA is currently investing in ways to improve the production of digester gas before it continues to invest in the CHP systems themselves. Its long-term goals are to continue installing CHP systems at these plants in order to improve neighborhood emissions levels and the economics of the plants. The treatment plant at Yonkers, NY was one of the first to pilot fuel cells run on digester gas.

### ***Groton, CT***

Groton, CT is too early in its project development to discuss design parameters of their project; however, it is worth mentioning because of their plans for future ownership of the CHP system. The digesters are existing and owned by the treatment plant, and the *engineering firm* that is working with them is also planning to provide financing for the CHP system and own and operate the CHP system, selling the kWh back to the plant. Although it is likely not an option for the Lewiston-Auburn digester

to get financed this way, it is a possibility with a CHP system if the municipality and a private partner are interested in this type of arrangement.

## **2.2 General Summary and Comparisons**

The following observations and conclusions are drawn from the information collected.

- Nine of the facilities investigated had considerable experience with both anaerobic digestion and energy recovery from digester gas. Lewiston, NY has decades of experience with both, while Greater Lawrence Sanitary District has a few years experience with both. This variety of experiences is worth reviewing closely during planning and design of a new system.
- Microturbines, especially Capstone microturbines, are in widespread use. They, and reciprocating engines, especially Waukesha engines, dominate the electricity production systems at facilities similar to the LAWPCF size range. Fuel cells have been used at several large facilities (e.g. Yonkers, New York and Boston's Deer Island WWTF), perhaps because they are more expensive and most useful in air non-attainment areas where ultra-low emissions are important.
- Heating digesters with digester gas is nearly universal. Older systems use the digester gas in dual-fuel boilers. The most recently-installed systems utilize heat recovered from engines (most common) or microturbines.
- Most systems prioritize use of digester gas, with the top priority being electricity generation (keeping the turbines running). If electricity generation is not installed, then the priority for digester gas use is heating the digesters (this was the common standard in older systems). Heating buildings with digester gas is done only when excess heat is available and readily recovered. In a few rare cases, facilities set the priority of cleaning digester gas and using it in city vehicles (Columbus, OH is planning to do this, and it is done in Europe) or selling it to the natural gas distribution system (e.g. King County/Seattle).
- Gas cleanup systems are improving. It is absolutely necessary for digester gas to be cleaned before use in Capstone microturbines and fuel cells, and cleaning the gas is understood to extend the life of all equipment and minimize maintenance needs. However, gas clean-up systems are still being optimized and innovations continue. Plus, the costs of gas clean-up systems are still quite high, both in terms of installation and operations & maintenance.
- With at least two facilities, old headworks issues affected the digesters' ability to produce digester gas, simply from clogging pumps, and filling up digester capacity (shortening HRT). Maintenance of the entire treatment system is key.

- Adequate gas storage allows for normal fluctuations in digester gas production that are caused by multiple factors.

Some facilities have recognized the importance of optimizing digester gas production before focusing on maximizing energy extraction via CHP systems. The CHP system's capacity is wasted if digester gas production is not consistent and maximized.



# Section 3

## Sludge Quantities and Characteristics

### 3.1 Existing Flows and Loads

In order to assess the viability of anaerobic digestion at the treatment facility, sludge quantities and characteristics must be established. To establish wastewater solids quantities and characteristics, LAWPCA recommended that CDM utilize the results of the calibrated BioWin model, presented in the 2008 *Capacity Evaluation of the Water Pollution Control Facility for the Lewiston Auburn Water Pollution Control Authority* prepared by Wright-Pierce.

The following sludge quantities and characteristics are based on plant flows and loadings data from 2007 (referred to as Current Conditions or Base Scenario in Wright-Pierce Report) and Scenario 2B in the Wright-Pierce report, which considers additional loadings from the Cascade Auburn-Fiber de-inking facility.

Scenario 2B models the treatment facility with no additional pretreatment installed at the Cascade Auburn-Fiber facility. The sludge quantities and characteristics for Scenario 2B are being evaluated because the Cascade Auburn-Fiber facility will not be adding pretreatment. Thus, any additional loads from the Cascade-Auburn facility will be treated at the treatment plant.

#### 3.1.1 Existing Sludge Quantities and Characteristics

Primary clarifier influent information (sum of influent from Lewiston and Auburn, Cascade-Auburn Fiber, septic waste and recycled solids) is summarized in Table 3.1. The sludge production volumes and characteristics from the primary sludge gravity thickeners and the dissolved air flotation (DAF) thickeners, which thicken waste activated sludge (WAS) from the secondary clarifiers, are shown in Table 3.2 and Table 3.3. Currently, the combined primary and WAS sludge is dewatered using a belt filter press (BFP). The characteristics of the combined sludge being fed to the BFP are given in Table 3.4 (base scenario).

If anaerobic digestion is deemed feasible the combined sludges under the base scenario will be digested and then dewatered in the existing belt filter presses.

**Table 3.1 - Existing Primary Clarifier Influent**

	<i>Average Day</i>	<i>Max Month</i>
Influent Flow (MGD)	13.21	23.39
Peak Day Flow (MGD)	32	32
BOD (lbs/day)	25,129	38,269
TSS (lbs/day)	23,274	32,476
VSS (lbs/day)	18,425	29,975

**Table 3.2 - Existing Primary Sludge Gravity Thickeners**

	<i>Average Day</i>	<i>Max Month</i>
Influent Sludge (MGD)	0.07	0.07
Effluent Thickened Sludge (MGD)	0.024	0.035
Thickened Sludge (Dry Solids, lbs/ day)	12,852	18,884
Thickened Sludge, % Solids	6.3	6.5

**Table 3.3 - Existing WAS Flotation Thickeners**

	<i>Average Day</i>	<i>Max Month</i>
Influent Sludge (MGD)	0.20	0.27
Effluent Thickened Sludge (MGD)	0.051	0.066
Thickened Sludge (Dry Solids, lbs/ day)	10,865	18,621
Thickened Sludge, % Solids	2.6	3.4

**Table 3.4 - Existing Combined Thickened Sludge (BFP Influent)**

	<i>Average Day</i>	<i>Max Month</i>
Sludge Volume (MGD)	0.075	0.101
Percent Solids	3.8	4.5
TSS (lbs/ day)	23,717	37,505
VSS (lbs/ day)	17,788	28,129
Inert Solids (lbs/ day)	5,929	9,376

### 3.1.2 Existing Sludge Quantities and Characteristics with DAF Replacement

Because the current method of thickening WAS using DAF thickeners consumes a significant amount of power and because the equipment has reached the end of its useful life, a preliminary evaluation of technologies to replace the DAF thickeners is included as part of this study. Technologies to be evaluated include gravity belt and rotary drum screen type thickeners. For the purpose of the evaluation, 100% TSS capture across the thickening equipment was assumed.

As part of the design criteria for the equipment that will replace the existing DAFs, the new equipment will have the capability to thicken the WAS to 5% solids.

The existing gravity thickeners are operating well and it is assumed that they will not be modified to increase the primary sludge solids percentage. With new WAS thickening equipment and the existing primary thickeners remaining in place, the combined thickened sludge will have the quantities and characteristics given in Table 3.5. For anaerobic digestion, influent sludge with a solids content between 5-6% is ideal. If the sludge is above 6% solids, mixing the contents of the digester becomes more difficult.

**Table 3.5 - Combined Thickened Sludge, WAS thickened to 5%**

	<i>Average Day</i>	<i>Max Month</i>
Sludge Volume (MGD)	0.050	0.080
Percent Solids	5.7	5.6
TSS (lbs/day)	23,717	37,505
VSS (lbs/day)	17,788	28,129
Inert Solids (lbs/day)	5,929	9,376

### 3.1.3 Summary of Sludge Quantities and Characteristics for Base Scenario

Table 3.6 compares the sludge quantities and characteristics using existing equipment to thicken primary and WAS sludge vs. retaining the existing gravity thickeners and replacing the DAF units with a belt or screen type thickener.

**Table 3.6 - Combined Thickened Sludge Comparison**

	<i>Using Existing Equipment</i>		<i>DAF Equipment Replaced</i>	
	<i>Average Day</i>	<i>Max Month</i>	<i>Average Day</i>	<i>Max Month</i>
Sludge Volume (MGD)	0.075	0.101	0.050	0.080
Percent Solids	3.8	4.5	5.7	5.6
TSS (lbs/day)	23,717	37,505	23,717	37,505
VSS (lbs/day)	17,788	28,129	17,788	28,129
Inert Solids (lbs/day)	5,929	9,376	5,929	9,376

By replacing the existing DAF thickeners with a belt or screen type thickener capable of increasing the solids percentage of the WAS to 5%, the volume reduction of combined sludge to the anaerobic digester is estimated to be reduced by approximately 25,000 and 21,000 gallons per day for average day and maximum month, respectively.

With a typical solids retention time of 20 days for a high rate anaerobic digester, the volume of the anaerobic digester would be reduced by 500,000 gallons if the WAS is thickened to 5% based on average daily sludge production. Based on the preliminary digester sizing calculations (Section 6), this represents approximately a one-third reduction in digester volume. From a cost perspective, this reduction in digester volume would offset the additional costs associated with improved WAS thickening. Therefore all digester sizing in this evaluation is based on new WAS thickening equipment.

## 3.2 Future Additional Loading

Scenario 2B, as presented in the Wright-Pierce report, considers the projected loadings associated with increased production at Cascade-Auburn Fiber, assuming no pretreatment is added at Cascade-Auburn Fiber. With no pre-treatment at the de-

inking facility, the additional loads from the Cascade-Auburn facility will be treated at the LAWPCF. The increased loading from the de-inking facility primarily affects organic loading to the treatment plant.

When considering additional future loadings to the treatment plant from the de-inking facility, it is assumed that the existing DAFs have been replaced with thickening equipment capable of thickening the WAS to at least 5%, as shown in Table 3.7.

**Table 3.7 - WAS Sludge Quantities and Characteristics, Thickened to 5%**

	<i>Average Day</i>	<i>Max Month</i>
Influent Sludge (MGD)	0.20	0.30
Effluent Thickened Sludge (MGD)	0.029	0.051
Thickened Sludge (Dry Solids, lbs/ day)	12,146	21,165
Thickened Sludge, % Solids	5.0	5.0

Assuming that the gravity thickeners are not modified to increase the primary sludge solids percentage, the combined thickened sludge, with the WAS sludge thickened to 5% solids, will have the quantities and characteristics given in Table 3.8.

**Table 3.8 - Combined Thickened Sludge to Digester, WAS thickened to 5%**

	<i>Average Day</i>	<i>Max Month</i>
Sludge to Digester (MGD)	0.053	0.086
Percent Solids	5.7	5.6
TSS (lbs/ day)	25,344	40,348
VSS (lbs/ day)	19,008	30,261
Inert Solids (lbs/ day)	6,336	10,087

### 3.2.1 Scenario 2B Sludge Quantities and Characteristics with Additional Loading

Table 3.9 compares the Scenario 2B projected sludge quantities and characteristics using existing equipment to thicken primary and WAS sludge vs. retaining the existing gravity thickeners and replacing the DAF units with a belt or screen type thickener.

By replacing the existing DAF thickeners with a belt or screen type thickener capable of increasing the solids percentage of the WAS to 5%, the volume reduction of combined sludge to the anaerobic digester is reduced by approximately 18,000 and 22,000 gallons per day for average day and maximum month, respectively.

**Table 3.9 - Combined Thickened Sludge Comparison with Additional Loadings from Cascade Auburn-Fiber**

	<i>Using Existing Equipment</i>		<i>DAF Equipment Replaced</i>	
	<i>Average Day</i>	<i>Max Month</i>	<i>Average Day</i>	<i>Max Month</i>
Sludge to Digester (MGD)	0.071	0.108	0.053	0.086
Percent Solids	4.3	4.5	5.7	5.6
TSS (lbs/day)	25,344	40,348	25,344	40,348
VSS (lbs/day)	19,008	30,261	19,008	30,261
Inert Solids (lbs/day)	6,336	10,087	6,336	10,087

With a typical solids retention time of 20 days for a high rate anaerobic digester, the volume of the anaerobic digester would be reduced by 360,000 gallons if the WAS is thickened to 5%, based on average daily sludge production. It is likely that the reduction in cost due to reduced digester volume would offset the costs to replace the existing DAF thickeners. The sludge quantities and characteristics are summarized in Table 3.10.

**Table 3.10 - Combined Thickened Sludge to Digester**

	<i>Average Day</i>	<i>Max Month</i>
Sludge to Digester (MGD)	0.053	0.086
Percent Solids	5.7	5.6
TSS (lbs/day)	25,344	40,348
VSS (lbs/day)	19,008	30,261
Inert Solids (lbs/day)	6,336	10,087

### 3.3 Summary

Table 3.11 compares the sludge quantities and characteristics for the Base Scenario and the scenario considering additional loading from Cascade Auburn-Fiber.

**Table 3.11 - Base Scenario and Scenario 2B:  
Combined Thickened Sludge to Digester**

	<i>Base Scenario</i>		<i>Base Scenario + Additional Loading From Cascade Auburn-Fiber (2B)</i>		<i>Percentage Difference</i>	
	<i>Average Day</i>	<i>Max Month</i>	<i>Average Day</i>	<i>Max Month</i>	<i>Average Day</i>	<i>Max Month</i>
Sludge to Digester (MGD)	0.050	0.080	0.053	0.086	5.6%	6.9%
Percent Solids	5.7	5.6	5.7	5.6	0	0
TSS (lbs/day)	23,717	37,505	25,344	40,348	6.4%	7.0%
VSS (lbs/day)	17,788	28,129	19,008	30,261	6.8%	7.0%
Inert Solids (lbs/day)	5,929	9,376	6,336	10,087	6.8%	6.4%

### 3.4 Basis of Design

The Wright-Pierce report considers additional loading to the treatment plant from Cascade Auburn-Fiber only and does not consider the addition of waste from other sources. Because the report does not include future flows and loading from other commercial, residential and industrial sources, LAWPCA has concurred that the basis of design for digester system sizing shall be the Base Scenario plus 15 percent. See Table 3.12 for the basis of design.

There are several factors that may impact future flows and loads to the treatment plant including: residential, commercial and industrial growth or decline in Lewiston and Auburn; operations of Cascade Auburn-Fiber; ability of LAWPCA to accept outside wastes.

From the data presented in the Wright-Pierce report, the TSS loading from Cascade Auburn-Fiber to the treatment plant accounts for only 1% of the total TSS loading to the plant. Thus, if Cascade Auburn -Fiber were to reduce TSS loadings to the plant, the impact to the anaerobic digestion system would be minimal. In the event that loadings from residential, commercial and industrial sources decreases in the future, the solids retention time in the digester may be increased, resulting in higher volatile solids reduction.

**Table 3.12 - Basis of Design:  
Combined Thickened Sludge to Digester**

	<i>Base Scenario</i>		<i>Bases Scenario + 15%</i>	
	<i>Average Day</i>	<i>Max Month</i>	<i>Average Day</i>	<i>Max Month</i>
Sludge to Digester (MGD)	0.050	0.080	0.058	0.092
Percent Solids	5.7	5.6	5.7	5.6
TSS (lbs/day)	23,717	37,505	27,334	42,967
VSS (lbs/day)	17,788	28,129	20,500	32,226
Inert Solids (lbs/day)	5,929	9,376	6,834	10,471

# Section 4

## Existing Sludge Management Practices and Associated Costs

### 4.1 Sludge Thickening and Dewatering Facility Description

The solids handling facilities at the Lewiston Auburn thicken and dewater solids removed in the primary and secondary treatment process. The dewatered sludge cake is stabilized by either composting for sale and distribution or lime stabilization for beneficial reuse on agricultural land. The solids handling system consists of gravity thickeners for primary solids and dissolved air floatation (DAF) thickeners for secondary solids, followed by belt filter presses (BFPs) for dewatering. Primary and secondary sludge is stored and thickened separately, then co-dewatered in two BFPs.

Primary sludge is pumped from the primary clarifiers to two gravity thickeners, which thicken and store primary solids. In the gravity thickeners, the primary sludge is thickened to approximately 6% solids. Secondary sludge is pumped to two dissolved air floatation units for thickening, where waste activated sludge (WAS) is thickened to between 2.6% to 3.3% solids. Thickened secondary sludge flows by gravity from the DAF units to four thickened waste activated sludge (TWAS) holding tanks. Facility operators have reported that when both DAF units are operating, the TWAS should be approximately 3% solids or less to allow it to flow by gravity to the TWAS holding tanks.

The thickened sludge are mixed in-line prior to dewatering using BFPs. The dewatered cake is then either transferred to a pug mill mixer for lime addition prior to land application or is hauled in raw cake form to the LAWPCA composting facility for composting or is transferred to disposal sites. Composting is used primarily in the winter and early spring months to stabilize biosolids while lime addition is used primarily in the late spring, summer and early fall months.

On average, the solid content of the dewatered cake exiting the BFPs is 17%. Under existing operations, both BFPs are operated with a maximum hydraulic loading rate of 3,000 lbs/hr and a maximum hydraulic loading rate of 150 gpm. The belt filter press typically operates 5 days a week for 6-8 hours a day, with a maximum of 10 hours a day.

#### 4.1.1 Estimated Annual Operations and Maintenance Costs Associated with Sludge Handling Systems

##### 4.1.1.1 Chemicals

Polymer is used as a coagulant/flocculent for WAS thickening and biosolids dewatering. LAWPCA typically accepts bids from polymer suppliers every two years and requires the supplier to visit the site and “jar test” their products to determine which product provides the lowest cost per dry ton of solids dewatered. The facility

currently uses polymer that costs \$1.49 per pound and, with an estimated 23,000 pounds of polymer used annually; the estimated annual polymer cost is \$34,300.

From the plant's operating data, approximately 8,000 and 15,000 pounds of polymer are used for WAS thickening and BFP dewatering, respectively. Thus, the cost of polymer associated with WAS thickening is approximately \$12,000/year and the cost of polymer used for BFP dewatering is approximately \$22,300/year.

#### **4.1.1.2 Energy Usage**

In order to operate the DAF thickeners, the following equipment is used:

- 1 re-aeration pump: 5 hp
- 1 recirculation pump: 25 hp
- 1 drive motor (rake drives): 2 hp
- 1 duplex air compressor: 15 hp

From the plant operating data, the facility runs the DAF units approximately 10 hours/day, 5.5 days/week. With the cost of electricity (supply and demand charges) being approximately \$0.12/kWh, the cost of electricity to run the DAF units is approximately \$12,000/year.

When the DAFs are operating, both BFPs typically operate. For the BFPs, the following equipment is used:

- 2 BFP motors: 10 hp
- 2 wash water pumps: 80 hp
- Plunger pumps: 20 hp
- 2 discharge belt drive motors: 6 hp
- 2 polymer feed pumps: 4 hp
- 2 air handling fans: 22.5 hp (1-15 hp; 1-7.5 hp)

With the motors operate the BFP dewatering system being approximately 143 hp, the cost of electricity to operate the BFPs is approximately \$37,000 annually.

Natural gas is utilized for facility heating only and is not affected by the operations of the DAF or BFP units.

#### **4.1.1.3 Operations and Maintenance Personnel**

When the WAS thickening and BFP dewatering equipment is operating, approximately 10 hours a day, 5.5 days a week, a plant operator and maintenance person supervise the process. The approximate hourly rates of a lead operator and

maintenance person are \$20/hour and \$17/hour, respectively. With each employees' annual benefits costing approximately \$16,000, the annual value of the time spent by the operator and maintenance person running the thickening and dewatering process is approximately \$73,200 and \$64,600, respectively.

As the sludge cake exits the BFP following dewatering, the cake is discharged by gravity into a truck for transport. When the dewatering system is operating, an average of approximately 5 truck loads of cake are taken offsite per day, with each truckload consuming an average of approximately two hours of the driver's time. When driving to the compost facility, the round trip is roughly 40 minutes. When driving to farms, however, the round trip time runs between an hour and three and one half hours). With the average hourly rate of a truck driver being \$16.50/hour and the value of annual benefits being \$16,000, the approximate annual value of the time a truck driver spends trucking sludge cake offsite is approximately \$63,200.

Because labor performed by operations and maintenance personnel is considered a "soft cost", it will not be included when evaluating savings by utilizing anaerobic digestion to stabilize biosolids vs. existing practices.

#### 4.1.1.4 Annual Operations and Maintenance Cost Summary

Table 4.1 summarizes the operations and maintenance cost associated with using the existing DAF for WAS thickening and belt filter presses for dewatering.

**Table 4.1 - Estimated Annual Thickening/Dewatering Costs**

<i>Item</i>	<i>Estimated Annual Cost</i>
Polymer Usage	\$34,000
DAF and BFP Energy Usage	\$49,000
Operations and Maintenance Personnel	\$201,000
Total Estimate Annual Cost	\$250,800

## 4.2 Compost Facility Description

The compost facility, which began operations in 1993, utilizes a horizontal agitated bin system, comprised of 6 aerated bins. Each bin is 10' wide, 7' deep and 210' long. Dewatered sludge is delivered from the WWTP and is mixed with amendments (woodchips, sawdust, chopped hay, horse bedding) and loaded into the bids. Large tillers, mounted on rails, move and mix the compost with each pass, moving the compost toward the discharge pit. When the compost reaches the discharge pit, it is put in a curing area for 30-40 days for further stabilization before being sold.

### 4.2.1 Estimated Annual Operations and Maintenance Costs

#### 4.2.1.1 Composting Amendments

The need for amendment is based on the historical average of approximately 1.8 yards of amendment for every yard of solids composted. To estimate the cost of amendments, historical information was used to approximate the volume of amendment required. The cost estimate, presented in Table 4.2, is based on LAWPCA aggressively substituting less expensive amendment material for woodchips and

sawdust, including the use of horse bedding at \$4.50 per cubic yard and possibly fly ash at \$7.00 per cubic yard. Historically, LAWPCA has paid from \$11.00 to \$16.00 per cubic yard of sawdust and shavings.

The amendment market has been extremely volatile with price spikes and low availability. This is likely due to demand for shavings and sawdust from alternative markets (pet bedding, wood pellet makers, biomass burners, and plastic wood for decks). LAWPCA is considering a number of alternatives to keep amendment costs as low as possible, including storing amendment material in the compost curing building during the summer or using the compost stacking pad and tarps to store sawdust for later use.

**Table 4.2 - 2009 Estimated Composting Volume and Amendment Costs**

<i>Month</i>	<i>Volume of Solids Delivered to CF (Cubic Yards)</i>	<i>Amendment Cubic Yards of Shavings + Cubic Yards of Horse Bedding or Ash</i>	<i>Cost of Shavings + Bedding/Ash</i>
January	2350	3900 (500)	\$46,800+\$2350
February	2050	3800 (500)	\$45,600+\$2350
March	2150	4000(500)	\$48,000+\$2250
April	1800	2800(500)	\$33,600+\$2350
May	1000	1800 (200)	\$21,600+ \$900
June	200	360	\$3,200
July	100	180	\$2,500
August	0	0	\$0
September	100	180	\$2,500
October	300	540 (300)	\$6,480 + \$1,350
November	1200	2000 (400)	\$24,000 + \$1800
December	1800	3800 (400)	\$45,600 + \$1800
<b>Total Annual Cost = \$295,000</b>			

#### 4.2.1.2 Energy Usage

At the compost facility, the following equipment is utilized:

- 2 compost turners: 100 hp
- 30 aeration blowers: 150 hp
- 2 curing blowers: 1 duty, 1 standby; 5 hp each
- 3 exhaust fans: 2 typically operational, 100 hp each

With the composting facility typically operating 8 hours/day, 5.5 days/week and the cost of electricity (supply and demand charges) being approximately \$0.12/kWh, the cost of electricity to run the composting equipment is approximately \$92,000/year.

According to the budgetary information provided by LAWPCA, the budget for total annual electricity costs at the composting facility is \$90,000. This coincides with the estimated electricity used by the composting equipment, as described above.

Propane is used for building and process heat. It estimated that 36,000 gallons of propane, at \$1.85 per gallon will be used from January to May. From September to December, it is estimated that 23,000 gallons of propane, at \$2.00 gallon will be utilized. Thus, it is estimated that the total cost of propane in 2009 is estimated to be \$113,000. See Section 4 for more information pertaining to the facility’s energy needs.

#### 4.2.1.3 Operations and Maintenance Personnel

At the compost facility, one supervisor and two technicians operate the facility. The facility operates approximately 8 hours/day, 5 days a week and 5 hours/day on Saturday during the winter. The approximate hourly rates of the Supervisor and technicians are \$23/hour and \$17/hour, respectively. With the annual cost of benefits being approximately \$16,000 per employee, the annual value of the supervisor’s and each technician’s salary is approximately \$70,000 and \$56,000, respectively.

Because labor performed by operations and maintenance personnel is considered a “soft cost”, it will not be included when evaluating savings by utilizing anaerobic digestion and composting to stabilize biosolids vs. composting only.

#### 4.2.1.4 Annual Operations and Maintenance Cost Summary

Table 4.3 summarizes the operations and maintenance cost associated operating the compost facility.

**Table 4.3 - Estimated Annual Composting Costs**

<i>Item</i>	<i>Estimated Annual Cost</i>
Amendments	\$295,000
Energy Usage	\$203,000
Operations and Maintenance Personnel	\$182,000
Total Estimate Annual Cost	\$680,000

### 4.3 Lime Stabilization Description

During the warmer months, LAWPCA uses lime stabilization to produce Class B biosolids for agricultural land application. Several years ago, the Class B material was also used to cover landfills or to manufacture “synthetic topsoil” at a farm site. Neither of these alternative uses appears to offer much opportunity for the Authority’s class B program for the near future. The parameters for the lime stabilization process are tailored to meet local farmer’s demand for Class B material.

There is a small demand for the Class B product beginning in late April, running to early June for corn planting. Significant demand for the product begins in early July and continues through late September/early October. Peak demand occurs from mid-August through mid-September when the material is used for top dressing on the hay fields.

Table 4.4 is a summary of the volumes of lime stabilized biosolids (in cubic yards) sent to farms for the last two years:

**Table 4.4 - 2007-2008 Volume of Lime Used (cubic yards)**

<i>Year/month</i>	<i>April</i>	<i>May</i>	<i>June</i>	<i>July</i>	<i>August</i>	<i>Sept</i>	<i>Oct</i>	<i>Nov</i>
2007	252	2057	2160	2050	1940	1956	1725	395
2008	866	1964	2220	1983	467	1828	823	207

It should be noted that the land application program is highly dependent on weather. In 2008, LAWPCA had to begin operations of the compost facility in August due to extreme rainfall. The demand for Class B biosolids from farmers was strong in 2008, but there are many limitations on spreading and stockpiling, including the depth to groundwater. For spreading and stockpiling, the distance from the surface to the ground water level has to remain 15-inches and 24-inches, respectively. During extreme weather events, there are also access issues that can limit the availability of a given spreading or stockpiling site.

### **4.3.1 Estimated Annual Operations and Maintenance Costs**

#### **4.3.1.1 Lime**

In 2008, LAWPCA received 23 deliveries of 30% quicklime/70% kiln dust blend, costing \$70,700. Each delivery to the WWTP is about 29 tons at \$106.01 per ton. For 2009, the unit cost for lime is \$113.40 per ton and it is estimated that 800 tons of lime will be needed. Thus, the budgeted amount for lime in 2009 is \$90,000.

The unit cost for the kiln dust/quicklime mix is roughly half what LAWPCA would pay on a per ton basis for straight high calcium quicklime and approximately 40% of the cost for dolomitic quicklime. When utilizing high calcium products, LAWPCA can be subject to significant costs for supplemental nutrients on some farms, as required by the Maine DEP. The supplemental nutrient requirement applies when the pH of the soil is between 6.5 and 7.5 and the base saturation of the soil is less than 2.5% potassium and/or 10% magnesium. LAWPCA estimates that approximately \$30,000 was paid in 2008 for these regulatory driven nutrient costs.

#### **4.3.1.2 Energy Usage**

Energy usage to operate the lime stabilization process is minimal.

#### **4.3.1.3 Operations and Maintenance Personnel**

The lime stabilization operation does not require significant LAWPCA operator personnel attention when running. The system is maintained as needed and it is estimated that approximately \$1,000/year is spent on maintenance.

#### **4.2.1.4 Annual Operations and Maintenance Cost Summary**

Table 3.5 summarizes the operations and maintenance cost associated producing Class B biosolids using lime stabilization.

**Table 4.5 - Estimated Annual Lime Stabilization Costs**

<i>Item</i>	<i>Estimated Annual Cost</i>
Lime	\$90,000
Supplemental Nutrients (fertilizer)	\$30,000
Operations and Maintenance Personnel	\$1,000
<b>Total Estimate Annual Cost</b>	<b>\$121,000</b>

#### **4.4 Trucking and Hauling Costs**

Table 4.6 summarizes annual trucking and hauling costs associated with biosolids at the WWTF. Three wheeler trucks, operating on diesel, are used to truck biosolids to distant farms, Hawk Ridge Composting Facility and landfills. A backhoe loader, also operating on diesel, is used at the treatment plant For loading compost, removing grease from the grease pit, snow plowing and other miscellaneous material handling tasks.

More diesel fuel has been used in the wheelers and backhoe in recent years due to trucking more material to alternative disposal locations. The extra hauling distance has also increased maintenance and tire costs. From budgetary information provided by the LAWPCA, it was estimated that the cost of diesel for the wheelers is \$40,950 per year (11,700 gallons at \$3.50 per gallon) and the diesel cost for the loader/backhoe is \$1,260 per year (350 gallons at \$3.60 per gallon).

At the compost facility, two front end loaders and a truck are used to manage biosolids on site. Table 4.7 summarizes the estimated annual vehicle cost, as detailed in the 2009 Budget Account Summary.

**Table 4.6 - 2009 Budget Account Summary for  
Trucking and Hauling of Biosolids**

<b><i>Fuel Usage - Diesel Cost</i></b>	
Wheelers (11,700 gallons at \$3.50/gallon; diesel from Public Works garage)	\$40,950
Loader/Backhoe (350 gallons at \$3.60/gallon)	\$1,260
<b><i>Budget Repair &amp; Maintenance Cost -Vehicle Description and ID</i></b>	
Volvo Wheeler #405	\$1,200
Volvo Wheeler #408	\$2,400
Wheeler, New	\$800
Kobelco Loader/Backhoe, #410	\$1,000
<b><i>Miscellaneous Costs</i></b>	
Tires	\$2,500
Tailgate seals, load covers, body work	\$1,000
EZ Pass	\$2,800
<b>Total</b>	<b>\$54,000</b>

**Table 4.7 - Compost Facility 2009 Vehicle Budget Account Summary**

<b><i>Fuel Usage - Diesel Cost</i></b>	
Front end loaders (3,650 gallons of diesel at \$3.60/gallon; diesel from local heating supplier)	\$13,140
Truck (250 gallons at \$3.25/gallon for gasoline)	\$815
<b><i>Budget Repair &amp; Maintenance Cost -Vehicle Description and ID</i></b>	
John Deer Front End loader	\$950
Komatsu Front End Loader	\$600
Dodge Dakota pick up , #407	\$550
<b><i>Miscellaneous Costs</i></b>	
Lubrication and Filters	\$1,800
Cutting Edges and Attachments	\$600
Misc.	\$100
<b>Total</b>	<b>\$18,600</b>

## 4.5 Residuals Disposal Cost Summary

Table 4.8 summarizes all costs related to the utilization or disposal of biosolids (excluding composting costs). Cost includes biosolids quality testing, farm permitting and farm field maintenance, land application fees, alternative disposal of biosolids at landfills and Hawk Ridge Composting facility, and taxes at Gauthier Farm.

**Table 4.8 - Residuals Disposal Cost Summary for 2007**

<i>Item</i>	<i>Cost</i>
Land Application (New England Organics, 11,800 cubic yards at \$24.66/cubic yard)	\$291,000
Site License and Program Approval Fees	\$9,800
Alternate Disposal of "Excess" Biosolids	
CWS Landfill (120 yards = 102 tons at \$52/ton)	\$5,300
Hawk Ridge Compost Facility (600 yards = 510 tons at \$50.44/ton)	\$25,700
Juniper Ridge Landfill (includes transportation, 1,700 tons at \$61.71/ton)	\$125,900
Field Maintenance (Barker pad, field repairs, stuck trucks, pump leachate)	\$16,500
Biosolids Analysis	
Metals	\$5,300
Dioxins	\$1,400
Miscellaneous	\$800
Gauthier Spreading Payments (equal to taxes)	\$18,500
Trucking and Hauling	<b>\$54,000</b>
<b>Total Estimated Annual Cost</b>	<b>\$554,000</b>

In 2007, approximately 27,000 cubic yards of biosolids were produced. Approximately 15,000 cubic yards of biosolids was managed of through land application or alternative disposal. Thus, approximately 12,000 cubic yards of biosolids was composted.

## 4.6 Compost Facility Revenue

Table 4.9 summarizes revenue generated by the selling of compost from 2001-2008. In 2005, the price per yard was raised from \$6.00 to \$7.00 and volume discounts were reduced. Currently, the largest discount of 25% is offered for purchases over 2,001 yards. A discount of \$1.00 per yard is offered for compost purchased during the winter season. In 2005 and 2006, the customer demand for compost exceeded the supply, while in 2007, compost sales to contractors were down and 2007 ended with approximately 700 yards in inventory. With the land application program requiring nearly 10,000 cubic yards of biosolids in 2006 and nearly 12,000 cubic yards in 2007, LAWPCA was faced with the challenge of not having enough feed stock to make compost.

Due in part to the reduced demand for compost in the home sales and landscaping market, the economic outlook for the composting facility is questionable. LAWPCA is considering offering price incentives, alternative outlets for selling compost and longer term storage of compost. However, 2009 sales for compost are doing well, with 6,000 cubic yards sold by June, 2009.

**Table 4.9 - Compost Facility Revenue, 2001-2008**

<i>Year</i>	<i>Budget</i>	<i>Actual Revenues</i>	<i>Comments</i>
2001	\$55,000	\$62,143	Revenue exceed budget by 7%
2002	\$52,000	\$62,551	Revenue exceeded budget by 20%
2003	\$65,000	\$59,798	Wet fall, 11% under budget
2004	\$65,000	\$89,420	Sold compost left over from 2003
2005	\$81,000	\$80,486	On budget
2006	\$85,000	\$84,707	On budget
2007	\$85,000	\$78,272	8% below budget
2008	\$82,000	\$55,003	33% below budget

# Section 5

## Energy Usage and Associated Costs

### 5.1 Electricity Usage and Associated Costs

The amount of electricity used at the treatment facility and the Composting Facility is summarized in Table 5.1. Currently, LAWPCA has a contract with Maine Power Options for the supply portion of the electricity bill and will purchase electricity at \$0.09/kWh at the wastewater treatment facility through 12/1/11 and \$0.0954 at the composting facility through 12/1/2010. Transmission and distribution is supplied by Central Maine Power and adds approximately \$0.01/kWh. As a time of use customer, demand charges make up as significant percentage of the total electricity costs at approximately \$0.025 per kWh.

**Table 5.1 - Electrical Usage and Cost Summary**

	<i>Total kWh Used</i>	<i>Demand Charge</i>	<i>Supply Charge</i>	<i>Total Cost</i>	<i>Total Cost Per kWh</i>
<b>Treatment Plant</b>					
2006	3,754,800	\$83,820	\$325,019	\$408,839	\$0.11
2007	3,432,000	\$78,162	\$328,566	\$406,728	\$0.12
2008	3,570,000	\$69,057	\$357,161	\$426,218	\$0.12
<b>Composting Facility</b>					
2006	643,416	\$16,156	\$69,384	\$85,540	\$0.13
2007	540,595	\$15,008	\$59,765	\$74,773	\$0.14
2008	638,724	\$16,505	\$65,817	\$82,322	\$0.13

According to the budgetary information, the anticipated total costs for electricity in 2009 are \$445,000 and \$90,000 for the LAWPCA Treatment Plant and the Composting Facility, respectively.

### 5.2 Fuel Oil and Natural Gas Usage and Associated Costs

In the past, the treatment plant used two boilers (Boiler #1 and Boiler #2) for heating. During most of the heating season, only one boiler was in operation. The second boiler was used only during extremely cold periods in the winter. Table 5.2 summarizes the amount of fuel oil used from 2005 through 2008 and the associated costs.

Both boilers originally used fuel oil, which is delivered to the site and stored. In 2008, the burner serving Boiler #2 was replaced with a dual fuel modulating burner (fuel oil and natural gas). In spring 2009, both Boiler #1 and Boiler #2 were removed, as they had reached the end of their operating life. In early June LAWPCA's mechanical

contractor completed the installation of a new boiler. The dual fuel burner from Boiler #2 was installed in the new boiler. In the course of the project, both of the obsolete boilers were removed and all asbestos connected to each boiler and inside each boiler was removed. The new boiler was placed in the #1 position to facilitate installation of a second boiler in the future.

The LAWPCF connected to the natural gas utility in the fall of 2008. For the 2008-2009 winter heating season, Boiler #2 utilizing natural gas was used exclusively for heating.

**Table 5.2 - WWTP Fuel Oil Use 2005 - 2008**

<i>Year</i>	<i>Quantity - gallons of oil, (cubic feet of natural gas)</i>	<i>Facility Heating Load<sup>1</sup>: BTU Value (in millions)</i>	<i>Unit price</i>	<i>Total Cost</i>
2005	44,859	5,158	\$1.59	\$72,000
2006	38,599	4,438	\$1.18	\$70,000
2007	46,924	5,396	\$2.19	\$103,000
2008 (through 10/31)	30,590	3,517	\$2.77	\$86,000
2008 -2009 (Dec - May)	(30,131)		\$195 (\$1.02 - \$2.36)	\$58,883

(1) Fuel oil #2 has approximately 115,000 BTUs per gallon.

Per CDM's conversation with LAWPA personnel, the natural gas usage and cost data available for the 2008-2009 heating season is both incomplete and only covers a single part of one heating season. As such, LAWPCA recommended utilizing the fuel oil consumption data in Table 5.2 to estimate the facility's heating load during the winter.

Because of the lack of long term natural gas consumption data, historic fuel oil consumption was used to estimate that approximately 43,000 gallons of fuel oil is needed to meet heating demands at the LAWPCF. From the 2009 budget, it is estimated that approximately \$105,000 will be spent on facility heating. Due to the improved efficiency of the new boiler and modulating burner, it is estimated that the cost for facility heating using natural gas will be reduced by 20%. As such, it is estimated that the cost for facility heating will be approximately \$84,000.

### 5.3 Propane Usage and Associated Costs

At the Compost Facility, propane is used for building and process heat. From budgetary estimates prepared by the LAWPCA, it is estimated that 36,000 gallons of propane, at \$1.85 per gallon will be used from January to May. From September to

December, it is estimated that 23,000 gallons of propane will be consumed at \$2.00 gallon. Thus, it is estimated that the total cost of propane in 2009 will be \$113,000.

## 5.4 Energy Usage Summary

Table 5.3 summarizes the total estimated annual cost of energy for the LAWPCF and the Composting Facility.

**Table 5.3 - Estimated Total Annual Energy Costs**

	<i>LAWPCF</i>	<i>Compost Facility</i>
Electricity Costs	\$445,000	\$90,000
Natural Gas or Propane Cost	\$105,000	\$113,000
Total Energy Costs	\$550,000	\$203,000

# Section 6

## Evaluation of Anaerobic Digestion

### 6.1 Introduction

Anaerobic digestion has been practiced for decades and is one of the most common forms of biosolids stabilization utilized in the United States. During the last 10 years there has been renewed interest and research in anaerobic digestion for the following reasons:

- Solids quantities are reduced by approximately 40 percent;
- The digester gas produced can be converted to electricity to reduced purchased power costs;
- The digested biosolids produced exhibit less odor; and
- The carbon footprint of facilities with anaerobic digestion is significantly less than competing biosolids management technologies.

Recent research in anaerobic digestion has focused on improved solids pre-treatment, improved digestion efficiency and maximization of digester gas production. For the purpose of this feasibility study, the anaerobic digestion system is based on complete-mix, single-stage mesophilic (95°F) digesters, which are fed with a mixture of thickened primary and waste activated sludge.

There are many technologies that are being developed to improve sludge quality, making it more amenable to digestion. These technologies disrupt the cell membranes with chemical, heat or pressure to accelerate the digestion process. None of these technologies have enough demonstrated, successful installations to be considered at this time for the LAWPCA facility.

There are also several variations of the anaerobic digestion process itself which have been employed by some municipalities. These include staged systems (acid-phase digesters followed by gas-phase digesters), high temperature thermophilic digesters (140°F) and other combinations. These systems have been utilized in an attempt to increase solids reduction and/or produce a biosolids product that meets the EPA Class A pathogen standards.

For the LAWPCA digestion facility, the conceptual design plans for adequate heating, mixing and detention times that have been shown to achieve high volatile solids reduction in similar facilities. Since LAWPCA has an existing composting facility that is capable of producing a Class A product, it is not necessary to produce a Class A product directly from the digesters.

Finally, as described in Section 7, the LAWPCA digestion facility will be equipped with energy recovery equipment to maximize digester gas utilization.

## 6.2 Preliminary Digester Sizing Criteria

Anaerobic digesters are sized based upon solids retention time (SRT) and hydraulic retention time (HRT). Because the proposed high rate digester system at LAWPCA will not include supernatant decant, the HRT is equivalent to the SRT for this application and the terms may be used interchangeably. It is CDM’s design practice to size the digester system for a minimum SRT of 14 to 15 days for maximum month conditions and 20 days for average day conditions.

## 6.3 Digester System Sizing

LAWPCA digester sizing is based on a minimum SRT of 14 days at maximum month conditions, in accordance with CDM’s practice of applying a 14 to 15 day SRT for maximum month conditions. Table 6.1 summarizes the recommended basis of design used to size the digester system, as detailed in Section 3. The peaking factor (maximum month/average day) is 1.57. From plant operating data, volatile solids account for approximately 75% of total solids.

**Table 6.1 - Combined Thickened Sludge to Digester System,  
Recommended Basis of Design**

	<i>Average Day</i>	<i>Max Month</i>
Flow (MGD)	0.058	0.092
TSS Concentration (mg/l)	56,267	56,455
TSS (lbs/day)	27,275	43,131
VSS (lbs/day)	20,456	32,348
Inert Solids (lbs/day)	6,819	10,783

Based on a maximum month SRT of 14 days and a peaking factor of 1.57, the average SRT will be 22 days. Under the design conditions summarized in Table 6.2, the volume of sludge pumped to the digester during average day and maximum month conditions is estimated to be 58,000 gallons per day (gpd) and 92,000 gpd, respectively. Applying the 14 day SRT size criteria at maximum month conditions, the required effective digester volume is approximately 1,288,000 gallons (172,200 cubic feet).

LAWPCA is served by a combined collection system and experiences grit loading. Wastewater is screened using two ¾” mechanical screens and pumped to the aerated grit chambers. However, it is still likely that some grit will accumulate within the digesters. The Water Environment Federation Manual of Practice #8 (MOP-8) recommends sizing the digesters to include a 10% allowance for grit accumulation, in addition to the digester bottom cone volume which is not considered part of the digester working volume. As such, the recommended volume of the digester system is approximately 1,420,000 gallons (190,000 cubic feet). As two, 50% anaerobic digesters are proposed, the volume of each tank is estimated to be 710,000 gallons.

### 6.3.1 Digester Dimensions and Volatile Solids Reduction

Tank dimensions have been based on the following guidelines:

- Digester diameter should be in 5 foot increments to allow for standard floating or fixed cover sizes.
- Typical conical bottom slope is 1:4 or 1:6.
- Ratio of sidewall depth (SWD) to tank diameter should be 0.3 to 0.7. SWD is the depth of water at the sidewall of the tank.

Two 65-foot diameter digesters with a SWD of 30 feet are recommended, with a total volume of 1.42 million gallons. The combined thickened sludge flow will be split equally between the two digesters (29,000 gpd to each digester on average day, 46,000 gpd to each digester at maximum monthly flow).

For this report, we have based our analysis on the design criteria shown above which represent standard digester vessel configurations. We believe the vessel shapes are cost-effective based on other projects. However, as a future optimization task other shapes could be evaluated including tall digesters or egg-shaped digesters.

For high rate anaerobic digestion, the theoretical amount of volatile solids destruction, as outlined in MOP-8 can be estimated by the following equation:

$V_d = 13.7 \ln(\text{SRT}_{\text{design}}) + 18.94$ , where:

$V_d$  = volatile solids destruction, percent

$\text{SRT}_{\text{design}}$  = SRT, days

With the design average SRT of 22 days, the estimated volatile solids destruction is 61%. However, to be conservative, a volatile solids destruction rate of 55% is used to determine the characteristics of solids exiting the digester and biogas production.

### 6.3.2 Digester Sizing Summary

Sizing for the recommended digester system is summarized in Table 6.2.

### 6.3.3 Digested Sludge Characteristics

With an average day SRT of 22 days and a maximum month SRT of 14 days and assuming 55% volatile solids destruction in the digester to be conservative, the anticipated characteristics of the digested sludge are summarized in Table 6.3. For the average day and maximum month scenarios, the anaerobic digestion process would reduce total solids by approximately 40%.

## 6.4 Digester System Equipment

Anaerobic digestions systems comprise of the following four subsystems:

1. Heating system
2. Mixing system
3. Digester covers

4. Digester biogas handling equipment

**Table 6.2 - Digester System Sizing Summary**

Number of Digesters	2
Tank Dimensions	
-Diameter, feet	65
-Sidewater Depth, feet	30
Effective Tank Volume (each tank)	
-Gallons	644,000
-Cubic Feet	86,100
Total Tank Volume (each tank, 10% additional volume for grit)	
-Gallons	710,000
-Cubic Feet	95,000
Total Tank Volume (2 Tanks)	
-Gallons	1,420,000
-Cubic Feet	190,000
Design SRT	
-Average	22
-Maximum month	14

**Table 6.3 - Characteristics of Digested Sludge**

	<i>Average Day</i>	<i>Max Month</i>
Flow (MGD)	0.058	0.092
TSS (lbs/day)	16,024	25,339
VSS (lbs/day)	9,205	14,557
Inert Solids (lbs/day)	6,819	10,783
Percent Solids	3.3	3.7

### 6.4.1 Digester Heating

Anaerobic digesters are heated to maintain an environment conducive to methane forming microorganisms and to ensure greases and fats within the digester remain in an emulsified state so they can be broken down biologically. There are two main types of heating systems, internal and external.

With an internal arrangement, heat is applied to the sludge while it remains in the digester tank. Older digester heating arrangements included mounting pipes to the interior of the digester wall in which hot water circulates and draft tube mixers equipped with hot water jackets. In recent years, these arrangements have become less popular due to operational issues, including the buildup of sludge on the heating surface and access restrictions. Because all internal heating systems rely on the digester mixing system to circulate heat within the digester, the mixing system must be operated on a continuous basis. Without continuous mixing, heat gradient will develop in the tank and create biologically inactive zones.

Newer digesters typically use external heating systems that recirculate sludge through an external heat exchangers using a recirculation pump. Most external heating systems incorporate means to heat the sludge before it enters the digester. The feed sludge is typically interlocked with the sludge recirculation pumps, allowing the blending and preheating of the feed and active digester sludge before it enters the digester. There are three types of heat exchangers commonly used today: tube in bath, tube in tube and spiral plate.

A tube in tube heat exchanger consists of a steel pipes that are surrounded by a hot water bath. Operation of a water bath heat exchanger involves the circulation of sludge through the piping and the heat transfer rate is increased by pumping hot water into and out of the bath.

The tube in tube, or jacketed pipe, heat exchanger and the spiral plate heat exchanger are similar in design and concept. A jacketed pipe exchanger typically consists of two concentric pipes, one containing sludge and the other containing hot water. The hot water and the sludge flow counter currently to optimize the exchange of heat.

A spiral plate heat exchanger is essentially two flat plates wound into a double spiral. Alternate edges of the plates are closed to form separate channels for sludge and heating water.

Hot water for the digester heating systems is typically supplied by a boiler that utilizes biogas from the anaerobic digester. Natural gas can be used as a supplemental fuel when not enough biogas is produced to heat the digester or if all of the digester gas is used in cogeneration.

### **6.4.2 Digester Mixing**

Mixing in high rate digestion systems is important to maintain uniformity within the digester and to prevent scum accumulation in the digester tank. Presently, the most common mixing systems are: recirculation pumps, compressed biogas and mechanical mixing. Digester mixing is a crucial component and poor mixing typically results in lower volatile solids destruction and decreased biogas production.

Pump systems use external pumps to recirculate the sludge for mixing. Sludge is pumped from the digester tank and is typically reintroduced through several ports located around the circumference of the digester or discharged through nozzles. Depending on tank diameter, pumping rates typically turn over the contents of the digester every 3 to 12 hours.

Gas recirculation systems include draft tubes, floor mounted diffusers, discharged lances and bubble guns. A draft tube system consists of a compressor and a large diameter tube into which digester gas is released from gas injector pipes, causing sludge to rise and mix as it approached the liquid surface in the tank. The multiple lance gas recirculation system consists of vertically mounted gas injector pipes located approximately two-thirds out from the center of the digester. Compressed gas may be discharged sequentially from one injector pipe and then through another by means of a valve or may be discharged continuously through all pipes.

Floor mounted diffusers are mounted onto short concrete pedestals and arranged in a circular pattern around the interior of the digester tank. The number of diffusers depends on the volume of the digester tank. Compressed gas is supplied to each diffuser by a separate gas line from the compressor. This type of system is difficult to maintain and repair because unlike the lances and drop tube system, the digester tank has to be taken offline to remove the diffusers.

In the bubble gun system, compressed gas accumulates in a bubble generator at the base of a vertical column and is released as a single, large bubble, forcing sludge upward through the base of the column and out the top. At the same time, sludge is drawn into the base of the column behind the bubble. The release of a bubble from the generator at the same time the previous bubble leaves the column provides a continuous flow of sludge, establishing a circulation pattern of sludge within the digester.

Mechanical mixing systems consist of a propeller, drive shaft and drive. Most mechanical mixing systems are mounted in a draft tube to direct sludge flow within the digester. Drives are typically reversible, allowing the sludge to discharge at the top or bottom of the draft tube. Mixer/draft tube assemblies may be located at the center of the digester tank, at the mid-radius point or outside the digester tank.

For the purpose of this feasibility study, a pump mixing system is utilized because the equipment consists mainly of easily serviceable pumps external to the digester.

### **6.4.3 Digester Covers**

Digester tanks require covers to maintain anaerobic conditions in the tank, collect biogas produced during the digestion process, reduce odors, retain heat to maintain internal temperatures and support some types of mixing equipment. There are three basic types of digester covers: floating, fixed, and gas membrane.

Floating covers have been widely used throughout the wastewater industry for years. They have typically been used to provide for some liquid storage (conventional floating covers), as well as some gas storage (gas holding covers). Conventional floating covers float directly on the sludge surface, which provides for fluctuations of the liquid sludge level with minimal change in biogas pressure.

Fixed steel covers are widely used throughout the wastewater industry as well. They have historically been the option with the lowest cost and least potential for operation and maintenance problems in comparison to floating covers. However, fixed covers offer minimal biogas storage and limited flexibility with regard to sludge liquid level. One advantage of the fixed steel covers is that they are compatible with all of the commonly used mixing systems. Both flat and dome-shaped covers have been used, but dome-shaped is the most common. The cover is supported on the top of the tank wall. With minimal gas storage volume, a fixed cover system must either rely on storage spheres, piping, flares, vacuum and pressure relief valves, or some other means of gas storage to keep the pressures consistent inside the tank.

Gas membrane covers are a relatively new product that was 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. This also allows for substantial changes in the depth of sludge in the digester.

#### **6.4.4 Gas Handling Equipment**

Gas handling equipment consists of gas storage, conveyance and safety equipment. The conveyance system brings biogas at the rate it is produced in the digesters to equipment for consumption, storage, or wasting. Most biogas conveyance systems are low pressure and operate at approximately 12 inches of water column (< 0.50 psig). Biogas may be stored based on production and utilization demands of the boiler or cogeneration equipment. Storage devices include digester tank gas holder covers which are part of the digester itself and membrane gasholders that are external to the digester and are typically located in close proximity to the digester on a concrete pad.

As biogas is explosive at low concentrations of approximately 1 volume of gas to 15 volumes of ambient air, it is of the utmost importance that the biogas handling system be fitted with appropriate gas-safety equipment, to protect against the risk of ignition and a potentially catastrophic explosion.

Any source of ignition, such as waste gas burners, engines, or boilers must be protected against flashback through the piping with a flame arrestor or flame traps. A flame arrestor works to quench the flame by dissipating any heat from a potential explosion in the piping. A flame trap is a combination of a flame arrestor and a thermal shutoff valve. If a propagating flame is stopped by the arrestor but continues to burn in the piping, a thermal element in the thermal shutoff valve will melt and seal off the remainder of the upstream piping from the fuel source.

Anaerobic digesters are provided with pressure/vacuum relief valves, typically mounted directly on top of the digester tank. These valves release any biogas to the atmosphere when the pressure rises above a set-point to protect from over-pressurization of the tank. Additionally, a vacuum relief valve will allow entry of ambient air into the tank during any vacuum conditions, to protect the tank from imploding.

### **6.5 Digester Heating Requirements**

For digestion, the heat requirements of the anaerobic digester include the amount of heat needed to:

1. Raise the incoming sludge to the digestion temperature (approximately 95 degrees F).
2. Compensate for heat losses through walls, floor and digester roof.

3. Make up the losses that may occur in the piping between the heat source and the digester tank. These losses are minimal and are not included in the digester heating requirements calculations.

### 6.5.1 Heat Requirement for Incoming Sludge

To calculate the energy required to heat the incoming sludge to the temperature of the digester, it is assumed that the specific heat of the sludge is close to that of water (1 BTU/lb/°F). To calculate the energy required to heat the sludge, the following equation is used:

$$Q_1 = W * C_p * (T_2 - T_1)$$

where:

W = Sludge to Digester, lbs/hour

Q<sub>1</sub> = Heating Required (BTU/hr)

C<sub>p</sub> = Specific Heat of Water (BTU/lb/°F)

T<sub>2</sub> = Heated Sludge Temperature (°F)

T<sub>1</sub> = Cold Sludge temperature (°F)

T<sub>1</sub> can be estimated from the geographical location of the digester. For the purpose of this evaluation, it is estimated that the temperature of the sludge entering the digester is 50 F in the winter and 70 F in the summer. Table 6.4 presents the design values used and the estimated energy required to heat the sludge entering the digester. Heating requirements are given in millions of British Thermal Units per hour (MBTU/hr).

**Table 6.4 - Sludge Heating Requirements**

	<i>Average Day</i>		<i>Maximum Month</i>	
	<i>Winter</i>	<i>Summer</i>	<i>Winter</i>	<i>Summer</i>
Sludge Volume to Both Digesters (gpd)	57,500	57,500	92,000	92,000
T <sub>2</sub> , Heated Sludge Temperature (°F)	95	95	95	95
T <sub>1</sub> , Cold Sludge temperature (°F)	50	70	50	70
Temperature Difference (°F)	45	25	45	25
W, Flow to both digesters (lb sludge/hr)	20,000	20,000	32,000	32,000
<b>Q<sub>1</sub>, Sludge Heating Required For Both Digesters (MBTU/hr)</b>	<b>0.90</b>	<b>0.50</b>	<b>1.44</b>	<b>0.80</b>

## 6.5.2 Digester Tank Heat Losses

Heat losses resulting from conduction through the digester tank roof, walls and floor are calculated using the following relationship:

$$Q_2 = U * A * (T_2 - T_1)$$

Where:

$Q_2$  = heat loss (BTU/hr)

$U$  = heat transfer coefficient (BTU/ ft<sup>2</sup>/°F/hr)

$T_2$  = operating Temperature of Digester (°F)

$T_1$  = air temperature outside of tank (°F)

$A$  = Area of exposed surface (ft<sup>2</sup>)

The design temperatures used in the heat loss analysis are summarized in Table 6.5. Design outside temperatures of -1 °F in winter and 72 °F in summer are based on HVAC design temperature data from the 2009 Plumbing Code, based on weather stations in Portland, ME.

**Table 6.5 - Winter and Summer Temperatures**

	<i>Winter</i>	<i>Summer</i>
$T_2$ , Internal Digester Temperature (°F)	95	95
$T_1$ , Outside Temperature (°F)	-1	72
Temperature Difference (°F)	96	23

The heat losses per digester, summarized in Table 6.7, were calculated based on the following digester tank configuration:

**Table 6.6 - Digester Tank Configuration**

Number of Digesters	2
Diameter	65 feet
Sidewater Depth	30 feet
Exposed digester concrete wall	20 feet above grade, 12-inch thick concrete
Buried digester concrete wall	10 feet below grade, plain concrete, surrounded by wet soil
Floor	1:4 slope, plain concrete, 12" thick, surrounded by wet soil
Digester Cover	Fixed Concrete, 4 inches thick

The digester configuration summarized in Table 6.6 has areas, composite U factors and heat losses shown in Table 6.7. U factors are from EPA's Process Design Manual for Sludge Treatment and Disposal (United States Environmental Protection Agency, 1979).

Based on the analysis above, the heat loss from both digesters is approximately 1.69 MBTU/hr in the winter and 0.40 MBTU/hr in the summer, if the digester cover and wall above grade are not insulated. If the digester cover and above grade wall are insulated, the heat loss from both digesters is 0.71 MBTU/hr in the winter and 0.17

MBTU/hr in the summer. Because heat loss is substantial during the winter months, it is assumed that the digester tanks and roof will be insulated.

**Table 6.7 - Conductive Heat Loss from Both Digesters**

	Heat Transfer Coefficient	Area (each, ft <sup>2</sup> )	Digester Heat Loss (MBTU/hr)	
			Winter	Summer
Digester cover				
Built up roofing, not insulated	0.88	3,300	0.56	0.13
Insulated with 1" board	0.28	3,300	0.18	0.043
Wall surface, above grade				
Not insulated	0.90	4,100	0.71	0.17
Insulated	0.14	4,100	0.11	0.026
Wall surface, below grade	0.25	2,050	0.098	0.023
Digester bottom	0.5	3,340	0.32	0.077
Heat Loss From Digesters (non-insulated)			1.7	0.40
Heat Loss Digesters (insulated)			0.71	0.17

### 6.5.3 Heating Requirement Summary

The estimated heating requirements needed to raise the incoming sludge to the digester operating temperature and the amount of heat needed to compensate for heat losses in both digesters are summarized in Table 6.8.

**Table 6.8 - Digester Heating Requirements**

	Average Day		Maximum Month	
	Winter	Summer	Winter	Summer
Q <sub>1</sub> , Heating Required to raise temperature of incoming sludge (MBTU/hr)	0.90	0.50	1.44	0.80
Q <sub>2</sub> , Heat required to compensate for conduction losses - insulated roof and walls (MBTU/hr)	0.71	0.17	0.71	0.17
<b>Total Heat Required - insulated roof and walls (MBTU/hr)</b>	<b>1.61</b>	<b>0.67</b>	<b>2.15</b>	<b>0.97</b>

## 6.6 Digester Facility Site Location

To minimize yard piping and pumping, it would be advantageous to locate the new digester system close to the existing process building, where WAS is thickened and combined primary and WAS is dewatered in BFPs.

Based on space available, two potential locations were identified for the digester system:

### **Option 1**

One potential location to construct the two digesters and digester control building is west of the existing secondary clarifiers. To avoid the plant effluent line and junction box that runs from the secondary clarifiers to the Chlorine Contact Chamber, the digester system could be installed south of the existing road that runs by the existing secondary clarifiers. See Figure 6.1 for this layout.

### **Option 2**

A second potential location for the digesters is west of the existing sludge thickener tanks and Process Building. Per CDM's conversations with LAWPCA personnel, it may be possible to modernize and relocate the existing screening equipment to the east side of the Process Control Building and install the digester equipment in the southwest of the building. By installing the digester equipment in an existing building, the need for a new digester control building would be eliminated. See Figure 6.2 for this layout.

For purpose of this feasibility study we have based the recommended plan on the cost associated with Option 1. It is possible that Option 2 with reuse of a portion of the processing building and change the location of the screenings truck loading may offer cost and operational advantages. However, the evaluation of screening replacement options, screening washing and compacting equipment and screenings transport is beyond the scope of this study.

## **6.7 Utility Requirements for Process Support**

For the anaerobic digestion system, it is anticipated that the following will be needed:

- **Utility power:** The digestion system will require 480v, 3ph, 60 HZ power necessary to operate the process equipment and meet the digester control building's electrical needs.
- **Potable Water:** The digester system will need potable water, primarily for boiler water make-up and other small domestic needs.
- **Plant water:** Plant water is necessary, primarily for gas compressor seal water (if a confined gas mixing system is used), hose bids and other minor water needs.
- **Natural Gas:** The boiler in the digester control building should be backed up with natural gas for digester and facility heating in the event that not enough biogas is created for digester and facility heating. The proposed boiler will be rated at approximately 2,500,000 - 3,000,000 BTU/hr.

## Figure 6-1

## Figure 6-2

## 6.8 Sidestream Considerations

Sidestreams from dewatered anaerobically digested biosolids may contain higher concentrations of nitrogen, phosphorus, suspended solids and BOD than is experienced with non-digested biosolids. Because the proposed digestion system is not decanted, it is assumed that the supernatants from the anaerobic digester will have the same characteristics as belt filter press filtrate.

Based on data collected at secondary treatment plants that utilize anaerobic digestion to manage biosolids, typically 1% of the influent BOD load, 5% of the TSS, 13% of the TKN and 9% of the phosphorus load is recycled back to the head of the plant.

Table 6.9 summarizes the influent loadings for average day conditions from plant operating data and the estimated loading if filtrate from anaerobically digested biosolids is added back to the liquid stream.

**Table 6.9 - Existing Loadings and Estimated Loadings with BFP Filtrate from Anaerobically Digested Sludge**

<i>Parameter</i>	<i>Primary Clarifier Influent , lbs/day (Existing Conditions)</i>	<i>Primary Clarifier Influent, lbs/day (With BFP Filtrate)</i>
BOD	25,100	25,350
TSS	23,300	24,500
TKN	3,100	3,500
P	650	710

As shown in Table 6.9, anaerobic digestion is expected to have minimal impact on the plant recycle loads.

## 6.9 Anaerobic Digester Conceptual Design Summary

Figure 6.3 and 6.4 are process flow diagrams depicting the existing biosolids management system and the biosolids management system utilizing anaerobic digestion. Following is a list of tankage and equipment (to be located in new digester control building or in existing Process Building) included in the conceptual design.

For the purpose of this feasibility study, insulated fixed steel covers are utilized due to their widespread use and number of installations. Although fixed covers limit the amount of biogas storage, fixed steel covers and an external biogas holder may be less costly than floating covers that offer biogas storage.

A pump mixing system to mix the contents of the anaerobic digester is considered in this feasibility study due to the relative ease of maintaining pumps over a compressed gas system. For digester heating in systems that utilize biogas in cogeneration, it is typical to reclaim heat in the form of hot water to heat the digester. Natural gas may be used to provide supplemental heating during cold weather periods.

- Digester tanks - Two, 65 foot diameter concrete tanks with insulation;
- Digester Roof - Fixed steel covers with insulation;

- Digester Mixing – Pumped mixing system;
- Digester Heating – Reclaiming heat from cogeneration system in the form of hot water utilizing heat exchangers; boiler utilizing natural gas used for supplemental heating in the winter; and
- Biogas Storage – Gas holder external to digester tanks.

A conceptual layout of the digester equipment building is shown in Figure 6.5.

Figure 6.3

Figure 6.4

Figure 6.5

# Section 7

## Biogas Production and Usage

### 7.1 Digester Gas Production

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, and reciprocating engines and microturbines for electricity production.

The amount of biogas produced during the anaerobic digestion process depends on the amount of volatile solids entering the digester and amount of biogas produced per pound of volatile solids destroyed. Table 7.1 summarizes biogas production rates based on the following assumptions:

- Digester feed volatile solids minimum concentration of 75%
- Volatile Solids Destruction of 55%
- Digester gas production typically ranges from 12-18 cubic feet per pound of volatiles destroyed. To be conservative, a value of 15 cubic feet per pound of volatile solids destroyed is used.
- Heating value of digester biogas typically ranges from 500 to 650 BTU/cubic foot. To be conservative, a design value of 550 BTU/cubic foot is used.

**Table 7.1 - Biogas Production Rates and Energy Value of Biogas**

	<i>Average Day</i>	<i>Max Month</i>
TSS to Digester (lbs/day)	27,300	43,100
VSS to Digester (lbs/day)	20,500	32,300
Inert Solids to Digester (lbs/day)	6,800	10,800
VSS Destroyed in Digester (lbs/day)	11,300	17,800
Biogas Produced (cubic feet/day)	170,000	266,700
Biogas Heating Value (MMBTU/day)	93	146
<b>Biogas Heating Value (MMBTU/hr)</b>	<b>3.88</b>	<b>6.11</b>

### 7.2 Digester Gas Usage

Digester biogas is typically used at wastewater treatment plants to heat the digester and facility buildings by using the biogas in a hot water boiler or using the biogas in a cogeneration system to produce heat and power.

#### 7.2.1 Digester and Building Heating

The estimated thermal needs of the digesters are outlined in Section 6.4.3. To estimate the facility heating requirements, the energy value of the fuel oil consumed in 2007 for facility heating was estimated to be 5,396 MBTU/year.

Assuming that the heating season runs 6 months out of the year, the average heating load for the facility is approximately 1.23 MMBTU/hr. Based on the digester system and facility heating requirements summarized in Table 7.2, the digester would produce enough biogas to meet the heating loads of both the digester system and the facility (Table 7.3).

**Table 7.2 - Digester and Facility Heating Requirements Summary**

	<i>Average Day</i>		<i>Maximum Month</i>	
	<i>Winter</i>	<i>Summer</i>	<i>Winter</i>	<i>Summer</i>
Digester System Heat Required - insulated roof and walls (MMBTU/hr)	1.61	0.67	2.15	0.97
Facility Heating Requirements (MMBTU/hr)	1.23	0	1.23	0

**Table 7.3 - Biogas Surplus**

	<i>Average Day</i>		<i>Maximum Month</i>	
	<i>Winter</i>	<i>Summer</i>	<i>Winter</i>	<i>Summer</i>
Energy Value of Biogas (MMBTU/hr)	3.88	3.88	6.11	6.11
Facility and Digester Heat Required (MMBTU/hr)	2.84	0.67	3.38	0.97
Biogas Surplus (MMBTU/hr)	1.04	3.11	2.73	5.14

### 7.2.2 Combined Heat and Power Applications

In cogeneration (cogen) system, 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. As such, this evaluation will evaluate cogen applications using microturbines and reciprocating engines.

Typically, cogen systems are sized to operate on average daily biogas flow. Additional units may be added for redundancy or to operate at peak conditions. For the purpose of this evaluation, cogen systems will be evaluated at average daily biogas production.

For both technologies, it is assumed that biogas cleaning (hydrogen sulfide, water, siloxane removal) and compression is required upstream of the cogen equipment. Typically, the parasitic load from biogas conditioning (cleaning and compression) is 10-15% of the power produced. To be conservative, a parasitic load of 15% is used.

### 7.2.2.1 Microturbines

Microturbines are small electricity generators that burn gaseous fuels to create high-speed rotation that turns an electrical generator to produce power. The electrical output for microturbines commercially available ranges from 30 to 250 kilowatts (kW). Because the 30 kW microturbine does not have an integral heat exchanger and is not UL listed, it is not a recommended technology and will not be evaluated further.

Table 6.4 summarizes the amount of power and heat produced if the biogas is used in the microturbine system. Waste heat from the microturbines, as well as biogas not used in cogeneration may be used to heat the digester and buildings.

For the purpose of this evaluation, a parasitic load of 15% is assumed, to provide energy for compression and gas boosting, if necessary. For example, a 65 kW unit will produce 55 kW assuming 15% of the power produced is consumed by the parasitic load of the equipment used to operate the cogeneration system.

Microturbines are typically more sensitive to impurities in the biogas such as hydrogen sulfide and siloxanes as compared to reciprocating engines.

**Table 7.4 - Utilizing Biogas in Microturbine Application**

Table 7.5 summarizes the heating needs of the digester system and facility versus the

<i>Biogas Production (MMBTU/hr)</i>	<i>Energy Input Per Microturbine (MMBTU/hr)</i>	<i>Number of Units</i>	<i>Net Electrical Output (Output - Parasitic Load) (kW)</i>	<i>Recoverable Heat from Microturbines (MMBTU/hr)</i>	<i>Energy Used in Cogeneration (MMBTU/hr)</i>	<i>Energy Remaining from Biogas Not Used in CHP (MMBTU/hr)</i>
<b>65 kW</b>						
3.88	0.765	5	276	2.05	3.83	0.05
<b>250 kW</b>						
3.88	2.94	1	213	1.2	2.94	0.94

amount of recoverable heat from the microturbine cogeneration system. Based on this evaluation, enough heat may be reclaimed in the summer months to heat the digesters. However, during the winter months, not enough heat is produced for digester system and facility heating. To make up the difference, it would be necessary to purchase natural gas or fuel oil to provide the remainder of the heat needed for digester and facility heating.

**Table 7.5 - Digester and Facility Heating Needs vs. Heat from Microturbine System**

	<i>Average Day</i>	
	<i>Winter</i>	<i>Summer</i>
Facility and Digester Heating Needs (MMBTU/hr)	2.84	0.67
Energy Available for Heating with 65 kW System (MMBTU/hr)	2.10	2.10
Energy Available for Heating with 250 kW System (MMBTU/hr)	2.14	2.14

### 7.2.2.2 Reciprocating Engines

Reciprocating internal combustion engines are a widespread and established technology. Reciprocating engines are available for power generation applications in sizes ranging from a 70 kW to over 5 MW. Reciprocating engine technology has improved over the past few decades, driven by economics, environmental regulations, increased fuel efficiency and reduced emissions. Table 7.6 summarizes the amount of power and heat produced if the biogas is utilized in a reciprocating engine. Waste heat from the engine, as well as biogas not used in the engine, may be used to heat the digester and buildings.

**Table 7.6 - Utilizing Biogas in Engine Application**

<i>Average Daily Biogas Produced (MMBTU/hr)</i>	<i>Rated Energy Input Per Engine (MMBTU/hr)</i>	<i>Number of Units</i>	<i>Net Electrical Output (Output - Parasitic Load) (kW)</i>	<i>Recoverable Heat from Units (MMBTU/hr)</i>	<i>Energy Used in Cogeneration (MMBTU/hr)</i>	<i>Energy Remaining from Biogas Not Used in CHP (MMBTU/hr)</i>
<b>140 kW</b>						
3.88	1.26	3 at full load	360	1.63	3.78	0.10
<b>270 kW</b>						
3.88	2.43	1 at full Load, 1 at 60% load	370	1.65	3.88	0.00

Based on average daily flow, there is enough biogas produced to operate three, 140 kW engines or two, 270 kW engines, one operating at full load and the other operating at 60% load.

The heating needs of the digester system and facility versus the amount of available heat from the engine system are summarized in Table 7.7. Based on this evaluation,

both the 140 kW systems and the 270 kW systems produce enough recoverable heat to heat the digesters in the summer (building facility heating not needed).

In the winter, both the 140 kW system and the 270 kW system would require supplemental heating from the boiler to provide addition heat to meet the thermal demands of the digester and buildings.

**Table 7.7 - Digester and Facility Heating Needs vs. Heat from Engine**

	<i>Average Day</i>	
	<i>Winter</i>	<i>Summer</i>
Facility and Digester Required (MMBTU/hr)	2.84	0.67
Energy Available for Heating with 140 kW System (MMBTU/hr)	1.63	1.63
Energy Available for Heating with 270 kW System (MMBTU/hr)	1.65	1.65

### 7.3 Recommended Cogeneration System

The recommended technology for cogeneration at the treatment plant is two, 270 kW reciprocating engines. At average day flow, enough biogas is generated to operate one engine at 100% load and the second at 60% load. At maximum month flow, enough biogas is generated to operate both engines at full load.

Accounting for estimated parasitic loads from biogas conditioning and compression, the system will generate approximately 370 kW of electricity. The 270 kW system can supply approximately 60% of the heating loads during the winter. The remaining 40% of the thermal load would be provided by the supplemental boiler operating on natural gas.

#### 7.3.1 Value of Electricity Generated from Cogeneration System

From Section 5, the total cost per kWh of electricity in 2008 was \$0.12. Not taking into account the price of electricity increasing over time and assuming the cogeneration system, producing approximately 370 kW, is operational 90% of the time, the estimated annual value of electricity produced is \$350,000.

#### 7.3.2 Estimated Cost for Supplemental Heating

In Section 5, it was estimated that the cost for facility heating using natural gas is \$84,000 annually. If approximately 60% of the heat demand for the facility buildings is met using waste heat from the cogeneration system, it is estimated that 40% of the heating load will be provided by supplemental natural gas, at an estimated annual cost of \$34,000.

# Section 8

## Evaluation of WAS Thickening

### 8.1 Background and Existing Conditions

At LAWPCA, the existing waste activated sludge (WAS) thickening system consists of two dissolved air flotation (DAF) units, four thickened waste activated sludge (TWAS) storage tanks and associated pumps. WAS is pumped from the secondary clarifiers to the DAF thickeners by three vertical, non-clog centrifugal pumps, which operate using VFDs. The DAF units thicken WAS only; primary sludge is thickened separately in gravity thickeners. Polymer is added to the DAF system. From plant operating data, approximately 4 pounds of polymer per pound of dry solids is used for WAS thickening.

From the DAF thickeners, which are located on the ground floor of the Process Building, the TWAS overflows into a discharge box and then flows by gravity to underground TWAS storage tanks. Facility operators have reported that the WAS must be thickened to 3% or less to allow it to flow by gravity from the DAF units to the TWAS storage tanks. Originally, the TWAS was pumped from the DAF units to the storage tank, but the pumps are no longer in use.

Currently, approximately 0.20 MGD of WAS is pumped from the secondary treatment system to the DAFs at average day conditions and 0.27 MGD of WAS is pumped at maximum month conditions. The solid loading to the existing DAF units is approximately 12,100 and 21,000 lbs/day for average day and maximum month conditions, respectively. Both DAF units typically operate 6-8 hours a day (10 hours a day maximum), 5-6 days per week, depending on the amount of waste solids in the secondary system.

Although the DAF thickeners are original to the plant and have reached the end of their anticipated life expectancy, the main driver for replacing the units is to increase the solids percentage of the sludge being fed to the anaerobic digester. By increasing the solids percentage, the volume of the digester decreases and less tankage is required.

### 8.2 Thickening Design Criteria

The design criteria for the thickening equipment includes residuals feed (loading) rate, sludge percent solids, desired thickened solids, duration of equipment operation, redundancy, and available space. To account for future loading to the plant, the WAS thickening system is designed to operate at current conditions plus 15%. Thus, the average day hydraulic loading is approximately 0.23 MGD and maximum month loading is 0.31 MGD. From operating data, the WAS is typically 0.71% and 0.92% solids at average day flow and maximum month flow, respectively.

For the purpose of this study, to be conservative, full scale redundancy will be provided for WAS thickening and each unit will be designed to handle maximum

month conditions. The following table provides the expected characteristics of the sludge conveyed to the WAS thickening equipment.

**Table 8.1 - Estimated Loading Rates For WAS Thickening**

<b>CONDITION</b>	<b>HYDRAULIC LOADING (GPD)</b>	<b>HYDRAULIC LOADING (GPM)</b>	<b>SOLIDS LOADING (DRY - LB/HR)</b>	<b>PERCENT SOLIDS (%)</b>
Average Day	230,000	510 (operating 7.5 hours/day)	1,850	0.71
Maximum Month (Operating 10 hours/day)	310,500	520 (operating 10 hours/day)	2,380	0.92

### 8.3 Thickening Alternatives Analysis

Technologies typically considered for thickening includes gravity belt thickeners (GBTs) and rotary drum thickeners (RDT). Continued use of the existing DAFs is not considered as an alternative for future thickening at LAWPCA, as the thickening system must be able to thicken the WAS to 5%, making it more amenable to anaerobic digestion.

The following provides advantages and disadvantages of the two mechanical thickening alternatives.

#### Advantages of Gravity Belt Thickening

- Low capital cost
- Low operating cost
- High solids capture
- High thickened solids concentrations and high quality filtrate
- Generally simple operation with straightforward maintenance requirements

#### Disadvantages of Gravity Belt Thickeners

- Polymer dependant
- Larger space requirements compared to RDT
- Potential odor problems
- General housekeeping requirements

#### Advantages of Rotary Drum Thickeners

- Small space requirements
- Low capital cost
- Low operating cost
- Simple operation with straightforward maintenance requirements
- Few moving parts
- Generally a "robust" machine
- Low odors (units are fully enclosed)

#### Disadvantages of Rotary Drum Thickeners

- Generally lower capture rates with potentially poor solids recovery
- Potentially poor quality filtrate
- General housekeeping requirements
- Polymer dependant; typically consume more polymer than GBTs due to the braking up of solid flocs inside the drum

### **8.3.1 Thickening Technology Recommendation**

From the technology comparison, the GBTs would provide operation and maintenance benefits and represent a better long term investment than the RDTs. The GBTs provide higher solids capture, which is important for the anaerobic digestion system. The preliminary recommended technology for future thickening at LAWPCA is by gravity belt thickener. Since there is no odor control system for the existing DAFs, an odor control system for the GBTs should not be required.

During the preliminary design of the thickening system to replace the existing DAF units, a final recommendation will be made to utilize GBTs or RDTs.

### **8.4 Gravity Belt Thickener Design Criteria**

The intent is for the new thickening equipment to operate on the same schedule as the existing equipment, approximately 6-10 hours a day, 5-6 days per week. The two WAS GBTs will be designed for duty and standby operation. Typical loading design criteria are a maximum hydraulic loading rate of 300 gpm/meter and a maximum solids loading rate of 1,100 lb/hr/meter. The GBTs will be designed for maximum month conditions.

The GBTs will have the following design criteria:

1. Belt width	2.2 meters
2. Operation	7.5-10 hours/day
3. Number of units	2 (1 duty and 1 standby)
4. Sludge feed concentration	0.71-0.92%
5. Sludge feed flow range	230,000 to 310,500 gpd (wet)
6. Sludge feed loading range	1,850 to 2,380 lb/hr (dry)
7. Thickened sludge range	5 to 5.5%
8. Minimum capture	95%
9. Polymer dose range	8-12 lbs/ton

Several manufacturers were contacted for details on equipment which could meet the design criteria provided above.

## 8.5 Process Location

Currently, DAF thickening is performed on the ground floor of the Process Building. Each 2.2 meter GBT is approximately 20' long and 10' wide. Because the existing DAF units are approximately 32' long and 12' wide, there is adequate space in the thickening room to replace the existing DAF units with GBTs.

## 8.6 Polymer Equipment

The existing DAF units have a polymer system. Although the existing polymer system may be reused with a GBT system, to be conservative, the cost of a new polymer system was included in the cost estimate. The possibility of using the existing polymer system in conjunction with a new GBT system should be evaluated further during the preliminary design phase.

### 8.6.1 Polymer Usage

From plant operating data, the average polymer usage in the DAF units is approximately 4 pounds of polymer per pound of dry solids. As detailed in Section 4, the cost of polymer associated with WAS thickening is approximately \$12,000/year. From the manufactures information, typical polymer usage in the GBT thickening system is between 8 to 12 pounds of polymer per pound of dry solids. Thus, the amount of polymer used for WAS thickening may increase to approximately \$24,000 (if 8 lbs/ton required) to \$36,000 year (if 12 lbs/ton) required.

During the preliminary design phase, it is recommended that the GBT technology be tested on the bench or pilot scale in order to more accurately determine solids capture and polymer usage. Most GBT manufacturers perform this test at no charge.

# Section 9

## Comparison of Options and Selection of Recommended Alternative

### 9.1 Digester Equipment and Cogeneration System Estimated Project Costs

For the purpose of this feasibility study, system supplier costs for the equipment described in Section 6 were solicited from digester equipment, thickening equipment and cogeneration system vendors.

The equipment is sized to operate an anaerobic digestion system with two, 50% single stage anaerobic digesters. It is estimated that the biogas generated from anaerobic digestion has enough energy to power two, 270 kW units. To be conservative, it is recommended that costs for biogas cleaning (moisture, hydrogen sulfide and siloxane) be included in this assessment as the quality of the biogas is unknown.

The main components are as follows.

1. Two 65' diameter digesters.
2. One 50,000 cubic foot double membrane gasholder.
3. Three sludge heat exchangers.
4. Four digester recirculation pumps.
5. Central dual-fuel boiler with individual hot water recirculation pumps for heat exchangers. Boiler is designed to burn either anaerobic digester gas or natural gas.
6. Four digester mixing system pumps.
7. Biogas cleaning system.
8. Two, 270 kW anaerobic digester gas driven reciprocating engine generators.
9. Two belt filter press feed pumps.
10. Two, 2 meter gravity belt thickeners.
11. Two polymer systems for gravity belt thickeners.

Table 9.1 summarizes estimated project costs. All construction costs include a contingency and have a planning level accuracy of plus or minus 20 percent. Engineering costs are estimated at 15 percent of construction costs.

**Table 9.1  
Estimated Project Costs**

<i>Item</i>	<i>Amount</i>
Digesters	\$3,500,000
Digester Building	1,500,000
Digestion Equipment	1,000,000
Biogas Utilization	3,000,000
Site Work/Yard Piping	350,000
Instrumentation and Controls	1,000,000
Electrical	2,100,000
Gravity Belt Thickening	600,000
Engineering	1,950,000
<b>Total</b>	<b>\$15,000,000</b>

## 9.2 Financial Analysis

### 9.2.1 Biosolids Quantities

Table 9.2 summarizes biosolids quantities with current biosolids management practices and biosolids quantities if anaerobic digestion is implemented to manage biosolids. The reduction in sludge quantities by utilizing anaerobic digestion is a key component to the financial analysis.

**Table 9.2, Summary of Biosolids Quantities**

<i>Biosolids Quantities</i>	<i>Current Biosolids Management</i>	<i>Biosolids Management With Anaerobic Digestion</i>
BFP Cake (cubic yards/year) <sup>1</sup>	27,000	13,500
BFP Cake (dry tons/year) <sup>1</sup>	5,130	3,078
BFP Cake (wet tons/year) <sup>2</sup>	30,176	15,390
Lime Stabilized Biosolids to Land Application <sup>3</sup>		
(cubic yards/year)	10,400	N/A
(tons of dry solids/year)	1,976	N/A
Composted Biosolids to Buyer <sup>3</sup>		
(cubic yards/year)	13,500	N/A
(tons of dry solids/year)	2,565	N/A
Raw Biosolids to Landfill <sup>3</sup>		
(cubic yards/year)	3,100	N/A
(tons of dry solids/year)	589	N/A
Digested BFP cake to compost <sup>4</sup>		
(cubic yards/year)	N/A	7,425
(tons of dry solids/year)	N/A	1,693
Digester BFP cake to land application <sup>4</sup>		
(cubic yards/year)	N/A	6,075
(tons of dry solids/year)	N/A	1,385
Digester BFP cake to landfill <sup>4</sup>		
(cubic yards/year)	N/A	0
(tons of dry solids/year)	N/A	0

1) Current based on 2008 operating data; anaerobic digestion will decrease volume of biosolids and improve dewaterability

2) Existing BFP cake ~17% solids; with digestion 20% cake is estimated

3) Based on plant data

4) Estimated that 55% of biosolids composted, 45% land applied and 0% landfilled

For this evaluation, it is assumed that approximately 55% of digested biosolids will be utilized for compost and 45% will be lime stabilized for land application. The volume of biosolids stabilized for land application is variable from year to year, as it is largely dependent on weather conditions and farmer demand. With the new digestion facility, there is no need to landfill biosolids.

## 9.2.2 Estimated Operating and Maintenance Costs

Table 9.3 summarizes the estimates operational costs for the current biosolids management system and for a system utilizing anaerobic digestion. Maintenance (labor) costs are summarized in Table 9.4. In Table 9.5, the cost savings from generating electricity in the cogeneration system versus the annual maintenance costs of the system are summarized. The value of power offset by the combined heat and power system is estimated to be \$282,000 annually. If the digestion facility is utilized

to its capacity (additional 15%) the value of the power savings would increase by \$45,000 per year.

**Table 9.3, Annual Estimated Operating Costs**

<i>Annual Estimated Operating Costs</i>	<i>Current Biosolids Management</i>	<i>Biosolids Management With Anaerobic Digestion</i>	<i>Difference</i>
<b>WAS Thickening and Dewatering</b>			
Polymer Usage <sup>1</sup>	\$34,000	\$20,400	\$13,600
WAS Thickening Operation (Power Costs) <sup>2</sup>	\$12,000	\$3,100	\$8,900
BFP Operation (Power Costs) <sup>3</sup>	\$3,840	\$2,300	\$1,540
<b>Lime Stabilization</b>			
Lime Cost <sup>4</sup>	\$90,000	\$0	\$90,000
Fertilizer Costs due to pH and calcium Saturation <sup>5</sup>	\$30,000	\$0	\$30,000
<b>Composting Facility</b>			
Amendment Cost <sup>6</sup>	\$295,000	\$177,000	\$118,000
Vehicles (fuels, maintenance) <sup>7</sup>	\$18,600	\$11,000	\$7,600
Electric Power Costs <sup>8</sup>	\$90,000	\$63,000	\$27,000
Fuel Cost <sup>8</sup>	\$113,000	\$79,000	\$34,000
Compost Revenue <sup>9</sup>	(\$55,000)	(\$33,000)	(\$22,000)
<b>Treatment Facility</b>			
Vehicles (fuel, maintenance) <sup>10</sup>	\$54,000	\$32,400	\$21,600
Electric Power Costs <sup>11</sup>	\$445,000	\$423,000	\$22,000
Fuel Cost <sup>12</sup>	\$84,000	\$34,000	\$50,000
<b>Residual Disposal</b>			
Biosolids Land Application Cost <sup>13</sup>	\$291,000	\$175,000	\$116,000
Biosolids Landfilling Cost <sup>14</sup>	\$157,000	\$0	\$157,000
<b>Digester Equipment</b>			
Digester Equipment Maintenance Cost <sup>15</sup>	\$0	\$33,000	(\$33,000)
<b>Total Estimated Annual Biosolids Management Costs</b>	<b>\$1,660,000</b>	<b>\$1,020,000</b>	<b>\$640,000</b>

- 1) Polymer Usage is expected to decrease by 40%
- 2) HP of existing DAF equipment is approximately 47 hp; GBT equipment approximately 20 hp
- 3) BFP typically operates 5.5 days per week for 10 hours a day; With GBT WAS thickening and digestion, it is estimated that BFP will operate 5.5 days per week for 6 hours a day
- 4) Lime stabilization will not be used when anaerobic digester is operational
- 5) Regulatory fees for land applying lime stabilized biosolids
- 6) Assume a 40% reduction due to lower biosolids quantities
- 7) Assumes 40% reduction
- 8) Assumes 30% reduction in energy use

- 9) Compost revenue will decrease due to less biosolids available for composting
- 10) Assumes 40% reduction
- 11) Assumed that energy usage at the LAWPCA will be reduced by 5% with DAF replacement
- 12) Assumes 75% reduction in fuel oil or natural gas due to use of biogas for heating
- 13) Assumes 40% reduction
- 14) Assumes all biosolids will be beneficially reused
- 15) Assumes equipment O&M is 2% of equipment capital cost

Based on the evaluation, an annual cost savings of approximately \$640,000 would be realized by utilizing anaerobic digestion to stabilize sludge at the treatment facility. This does not include any labor cost reduction. As shown in Table 9.4 below, total labor costs with anaerobic digestion are projected to be similar to existing labor costs and no difference is included in this financial analysis.

**Table 9.4, Annual Estimated Labor Costs**

<i>Parameter</i>	<i>Current Biosolids Management</i>	<i>Biosolids Management With Anaerobic Digestion</i>
WAS Thickening and Dewatering	\$201,000	\$140,000
Lime Stabilization	\$1,000	\$0
Compost Facility	\$182,000	\$182,000
Anaerobic Digester System		\$38,000
<b>Total</b>	<b>\$384,000</b>	<b>\$360,000</b>

**Table 9.5, Annual Value of Electricity Produced**

<i>Parameter</i>	<i>Current Biosolids Management</i>	<i>Biosolids Management With Anaerobic Digestion</i>
Estimated Value of Power Production (\$/year) <sup>1</sup>	N/A	\$305,000
Estimated Annual Operating Cost <sup>2</sup>		
Power Costs	N/A	\$1,000
Labor	N/A	\$2,000
Media Costs	N/A	\$20,000
Net Estimated Value of Power Produced	N/A	\$282,000

1) LAWPCA currently purchases power at approximately \$0.12 per kWh

2) Power cost based on running a 1 kW chiller operating continuously. Estimated that siloxane and hydrogen sulfide media will be replaced 1 time year, costing \$20,000. Annual labor O&M costs approximated by assuming that each time the media is changed, 40 hours of a maintenance staff person's time is required, at \$50/hour.

### 9.2.3 Comparison of Capital Costs with Project Cost Savings

In order to determine the financial feasibility of the digestion/energy recovery project, a simple comparison of costs and savings over a 20 year period was conducted. Two scenarios were evaluated: 1) without any grants or low interest loans, and 2) with the equivalent of a 50 percent grant. The equivalent 50 percent

grant could include a Department of Energy (DOE) grant or a low interest loans such as the DEP SRF program loans.

Table 9-6 shows the financial analysis. Capital costs were taken from Table 9-1. Annual bond costs were based on a 20-year revenue bond of 5 percent with equal annual payments. The annual operating cost savings were based on the average savings over a 20-year period and are approximate. Total savings are approximately \$922,000 in the first year of operation of the anaerobic digester facility and escalate to approximately \$1.6 million by the 20<sup>th</sup> year for an annual average savings of \$1,250,000 for the 20 year period.

To include the effects of inflation, all operating costs were escalated at 3 percent per year. A standard 20-year planning discount rate of 4.7 percent as recommended by the U.S. Office of Management and Budget was used. The operating cost savings includes both reduced operating costs due to lower quantities of biosolids as well as the savings from avoided electricity costs. An escalation rate for electricity of 3 percent was used, although many economists expect that energy costs will escalate faster than other costs. Another factor in the financial analysis is the current LAWPCA debt service payments. The Authority has three loans issued 1990, 1991 and 1992 that will be completed by 2012. In 2009, the Authority incurred \$790,000 in costs associated with these loans which will decrease to zero in 2012.

For the scenario with no grants, the net average annual cost savings to the Authority are approximately \$50,000 and are within the cost estimating accuracy of this feasibility study. With a 50 percent grant equivalent, the average savings is significant at approximately \$650,000.

**Table 9-6**  
**Financial Analysis of Anaerobic Digester/Energy Recovery Project**

<i>Item</i>	<i>Project With No Grants</i>	<i>Project With 50 Percent Grant Equivalent</i>
Estimated Capital Costs	\$15,000,000	\$7,500,000
Annual Bond Cost	\$1,200,000	\$600,000
Annual Operating Cost Savings	\$1,250,000	\$1,250,000
Net Annual Savings	\$50,000	\$650,000

### 9.3 Greenhouse Gas Emission Analysis

There has been increased interest in the U.S. in analyzing wastewater treatment and biosolids management program's greenhouse gas emissions. The gases of most concern are carbon dioxide, methane and nitrous oxide. Greenhouse gases differ in their influence on trapping heat in the atmosphere. Therefore, a relative scale of global warming potential (GWP) has been developed, based on atmospheric research.

The global warming potential of CO<sub>2</sub> is 1 (the standard to which all others are referenced). Methane has a GWP of 21; nitrous oxide has a GWP of 310. Therefore, controlling releases of these two gases is of even greater importance to biosolids

management than controlling CO<sub>2</sub> emissions. For ease of comparison, protocols require reporting of GHG emissions in CO<sub>2</sub> equivalents (CO<sub>2</sub> eq), i.e. the sum of all GHG emissions, with the quantities of non-CO<sub>2</sub> emissions multiplied by their respective GWP. Thus, one metric ton (Mg) of methane is reported at 21 Mg CO<sub>2</sub> eq.

Protocols for estimating emissions take into account direct emissions from biosolids processes or transport of biosolids emissions from purchased power and heat, and indirect emissions from supply chain uses such as lime and product utilization. Under the protocol, it is possible to have negative emission estimate because of carbon sequestration in soil when biosolids are land applied.

The GHG emissions from LAWPCA's current biosolids management program, based on 2008 data (and some 2009 estimates) are estimated to be approximately 3,360 Mg CO<sub>2</sub> equivalents (CO<sub>2</sub> eq). See Appendix B.

Composting is the largest single source of emissions, but that is because it manages the largest quantity of LAWPCA biosolids. Part of the land application process is the separate unit process of alkaline stabilization. This has a significant GHG emissions impact due to the use of some manufactured lime (30% of the mix). Lime manufacture and the emissions of the carbon from the lime applied to the soil has significant associated GHG emissions.

Landfilling produces by far the largest emissions, because of the methane generated and emitted. Even though only a small proportion of the LAWPCA biosolids are landfilled, this action has a disproportionately high impact on total emissions.

If LAWPCA were to install anaerobic digestion (AD) and combined heat and power (CHP) systems, the net emissions from the biosolids management program is estimated to be 560 Mg CO<sub>2</sub> eq.

The significant reduction in GHG emissions in the future would be due to several factors:

- Digester gas produced will be used for heat and power that replace the use of fossil fuels.
- Anaerobic digestion reduces the volume of wastewater solids to be managed, which reduces the energy requirements for composting and land application.
- The future projection assumes no solids will be landfilled, which is a significant contributor to greenhouse gas emissions in the current operations. Even if some solids were landfilled in the future, their methane emissions would be lower, because of digestion.
- Without any lime stabilization, purchased lime used for alkaline stabilization would not be needed; it is currently a significant source of Scope 3 emissions.

Table 9-7 compares estimated greenhouse gas emissions for existing and proposed future practices anaerobic digestion with energy recovery will significantly reduce the emission of those gases which have the most impact on global warming potential.

**Table 9-7**  
**Estimated Greenhouse Gas Emissions**  
**(Mg CO2 equivalents per year)**

<b>Source</b>	<b>Existing Practices</b>	<b>With Anaerobic Digestion and Energy Recovery</b>
Direct Emissions	2,240	725
Purchased Heat and Power	302	(-185)
Indirect Supply Chain and Product Use	814	23
<b>Total</b>	<b>3,356</b>	<b>563</b>

## 9.4 Project Conclusions and Recommendations

Based on the amount of biosolids currently produced and accounting for future flow and loading increases to the wastewater treatment plant, it is recommended that two, single stage high rate anaerobic digesters be constructed. The digesters, each approximately 65 feet in diameter with a side water depth of approximately 30 feet, will generate biogas to be used in a cogeneration system, creating electricity and heat for use at the treatment facility. The biogas cogeneration system will consist of two, 270 kW reciprocating engines. Depending on the quality of the biogas, the biogas cleaning system will most likely consist of hydrogen sulfide, moisture and siloxane removal.

To produce sludge that is best amenable to anaerobic digestion, it is recommended that the existing dissolved air floatation (DAF) units that currently thicken waste activated sludge (WAS) be replaced with gravity belt thickeners (GBTs).

The equipment selection and layouts for this feasibility study are based on proven anaerobic digestion and energy recovery technologies. The costs presented in this feasibility study are consistent with standard digestion practices. During the preliminary design phase of the project, it may be possible to reduce project costs and/or optimize facility efficiency by further evaluating several facility components, as described below.

1. Location of anaerobic digesters: Determine whether the digesters should be located near the chlorine contact tanks or near the process building. The

advantage of locating the digester system near the process building may be the reduction in total project costs by reusing the existing space within the building. However, modification will need to be made to the existing influent screening facility with new screens, screen conveying and transport loading facilities.

2. Anaerobic digester vessel configuration: The feasibility study configuration called for “standard” digesters with a diameter to height ratio of approximately two and fixed digester covers. Egg shaped digesters, tall digesters (with a diameter to height ratio of approximately 1) and other vessel configuration are available as well as different cover configurations (floating, fixed). It is not likely that any cost savings would be gained by this examination.
3. Combined heat and power equipment: The feasibility study calls for biogas cleaning followed by cogeneration using two, 270 kW reciprocating engine generators. Selection of the optimal number and size of the gas cleaning equipment and engines requires confirmation of average, maximum and minimum biogas production and prediction of seasonal digester heating needs by month. This type of refinement should be accomplished as part of the preliminary design.