APPENDIX L

Technical Memorandum No. 9
Digester Gas Utilization

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MADISON METROPOLITAN SEWERAGE DISTRICT
SOLIDS HANDLING FACILITIES PLAN

TECHNICAL MEMORANDUM NO. 9
DIGESTER GAS UTILIZATION

Date: December 21, 2009 **Project #:** 4364

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1.0 Purpose

The purpose of this technical memorandum (TM) is to evaluate the existing digester gas utilization facilities at the Nine Springs Wastewater Treatment Plant (NSWWTP).

2.0 Summary of Findings and Recommendations

The key findings and recommendations of this TM are summarized below:

- The existing gas treatment and gas storage facilities have adequate capacity to handle the projected 2030 digester gas production.
- The existing hot water boilers and the proposed low-pressure steam boilers will provide adequate capacity for the 2030 projected digester and building heating requirements of 23.1 MMBTU/hr.
- The existing cogeneration units have adequate capacity to handle the 2030 projected digester gas available for cogeneration. The installation of additional cogeneration capacity is not recommended.
- The use of digester gas for electrical power generation or heating will depend on the cost of natural gas and electricity at the moment of use. Based on a preliminary estimate using the planning level costs of electricity and natural gas, digester gas utilization to offset natural gas purchases may be more economically favorable than cogeneration.

3.0 Background

The Madison Metropolitan Sewerage District (MMSD) is seeking to implement a sludge stabilization technology that meets Class A biosolids requirements while maintaining the current biosolids land application programs. TM-03A Sludge Stabilization Alternatives Evaluation identified acid-phase digestion and conventional digestion with Cambi Thermal Hydrolysis Process (THP) as viable alternatives for sludge stabilization at the NSWWTP. The implementation of these alternatives will result in increased digester gas production. In order to maximize the potential energy cost offsets, the capacity of the existing gas utilization facilities must be evaluated.

Digester gas generated at the NSWWTP is used for hot water heating and simultaneous production of electricity and heat in the cogeneration facilities. The NSWWTP uses the heat generated from the cogeneration equipment to maintain the digester target temperatures and use the electrical energy to run other plant processes. The 10th Addition Preliminary Design Report (PDR) evaluated the installation of an additional reciprocating engine at the NSWWTP and concluded that the anticipated gas production for 2020 would be insufficient to justify the installation of an additional reciprocating engine. Due to increased electricity and natural gas costs, the availability of funding, and more recent digester performance data including acid-phase digestion (mesophilic-thermophilic-mesophilic), the installation of additional cogeneration capacity at the NSWWTP is evaluated in this TM.

4.0 Digester Gas Production

Table 9.1 presents the gas production estimates for current and future flow conditions.

Table 9.1
Nine Springs WWTP
Digester Gas Production

	Current [1]	2030 Projection
Digester Solids Annual Average Loading, ppd	106,300	154,500 [2]
Volatile Solids Reduction, ppd	52,500	76,300 [3]
Digester Gas Production, cfd	763,800	1,106,700 [4]
Gas Production to VSR Ratio, cf/lbs	14.5	14.5
Energy Production, MMBTU/hr [5]	16.7	24.1

Note:
(1) Based on NSWWTP process and operations data for the period of 05/2007 to 05/2008.
(2) Based on 2030 projected values presented in TM No. 1.
(3) Based on 2007-2008 average volatile solids concentration of 76 percent in the digester feed and volatile solids reduction of 65 percent.
(4) Based on 2007-2008 gas production to VSR ratio
(5) Based on 524 BTU per cubic foot of digester gas.

5.0 Digester Gas Characteristics

Table 9.2 presents the digester gas characteristics based on the results from samples collected from 07/2008 to 12/2008. The levels of hydrogen sulfide (H_2S) and siloxanes in both sets of samples are within the typical range for anaerobic digesters.

Table 9.2
Nine Springs WWTP
Digester Gas Characteristics

Parameter	2008 Sampling (1)
Methane, % by volume	60.5
Carbon dioxide, % by volume	39.6
Hydrogen Sulfide, ppmv	1,200
Siloxanes, ppmv	1,750
Heating Value, BTU/cf	556

Note:
(1) Based on results from gas samples collected on 8/11/08 and 12/11/08.

6.0 Electricity and Gas Usage

Table 9.3 presents a summary of the gas and electricity usage at the NSWWTP. As part of the 10th Addition Improvements, the digestion facility was converted to temperature-phased digestion (TPAD) and Digesters No. 4 - 6 were retrofitted to operate in thermophilic mode. For this reason, only data from 2006 to 2008 was used to estimate the historic gas usage at the NSWWTP.

Table 9.3 Nine Springs WWTP *Current Energy Consumption*			
	Average	**Max**	**Min**
Gas Usage [(1)]			
Hot Water Boiler Digester Gas Usage, MMBTU/month	4,400	7,000	1,700
Cogeneration Digester Gas Usage, MMBTU/month	4,900	8,200	2,600
Total Digester Gas Requirements, MMBTU/month	9,300	12,300	7,100
Purchased Natural Gas, MMBTU/month	1,700	4,400	0
Electricity Demand			
Daily Purchased Electricity Demand, kWh [(2)]	61,000	89,500	38,500
Daily Cogeneration Output, kWh [(1)]	32,100	34,500	8,000
Total Daily Demand, kWh [(1)]	93,100	124,000	46,500
Purchased Electricity On-Peak Demand, kW [(2)]	3,300	4,300	2,600
Purchased Electricity Off-Peak Demand, kW [(2)]	3,400	4,100	2,800

Notes:
(1) Based on NSWWTP historic data during 2006-2007.
(2) Based on 50-Year Master Plan purchased electrical consumption during 2001-2007.

7.0 Existing Facilities

7.1 Digester Gas Treatment

Digester gas is treated in a packaged plant system to remove moisture, siloxanes, and H_2S to prevent fouling of the cogeneration equipment. The gas treatment system was designed by Applied Filter Technologies and includes iron sponge filters for H_2S removal, a gas chiller for moisture removal, and SAG system (patented media filters) for siloxanes removal. The packaged plant has a capacity of 800 cfm (1,152,000 cubic feet per day), which is adequate to treat the projected 2030 maximum month digester gas production.

7.2 Digester Gas Storage

Low-pressure gas storage provides a constant gas supply to the cogeneration facilities and maximizes energy production during peak utilization periods. Digester gas is stored during periods when production exceeds utilization, minimizing the amount of gas sent to the flares. During periods where digester gas production does not meet the minimum requirements of the cogeneration facility, stored gas can be used to continue operating at maximum levels. Gas storage at NSWWTP is provided inside two 70-ft diameter sludge storage tanks with gasholder covers and a combined

storage capacity of 64,400 cubic feet (at 9.2 inches water column). The existing digester gas storage has adequate capacity for the projected 2030 gas production with approximately 84 minutes of storage, which is above the minimum recommended for cogeneration facilities (30 min).

7.3 Cogeneration Facilities

Digester gas produced at the NSWWTP is currently used to fuel two (2) reciprocating engines, one (1) engine-driven blower, and six hot water boilers. The heat generated in the reciprocating engines and the engine-driven blower is recovered and used to maintain the digester temperatures. Surplus digester gas is burned in a candlestick flare. Table 9.4 presents a summary of the existing digester gas utilization facilities.

Table 9.4
Nine Springs WWTP
Existing Digester Gas Utilization Facilities

	Reciprocating Engines	Engine-Driven Blower	Hot Water Boilers
No. Units	2	1	6
Electrical Capacity per Unit, kW	475	550	-
Heating Capacity per Unit, MMBTU/hr	1.85	2.00	4.3 - 5.9 (1)
Power Generation Efficiency, %	28	30	-
Maximum Gas Utilization (Combined), cfd (2,3)	527,600	247,300	1,402,000
Average Gas Utilization (Combined), cfd (2,4)	370,400	168,900	177,600

Notes:
(1) Three 4.3 MMBTU/hr units (Central Loop) and three 6.8 MMBTU/hr units (East Loop).
(2) Assumes 524 BTU per cubic foot of digester gas.
(3) Based on nominal electrical capacity.
(4) Based on NSWWTP 1992-2008 data.

8.0 Capacity Evaluation

A summary of the evaluation for the existing cogeneration capacity is presented in Table 9.5.

Table 9.5
Nine Springs WWTP
Digester Gas Production

	Current Conditions		2030 Conditions	
	Winter	Summer	Winter	Summer
Digester Gas Production, MMBTU/hr	16.7 (1)	16.7 (1)	24.1 (1,2)	24.1 (1,2)
Heating Requirements, MMBTU/hr				
Digester Heating Requirements (3)	8.5 (4)	6.1 (4)	14.0 (2,4)	10.3 (2,4)
Building Heating Requirements (5)	7.1	2.3	9.1 (6)	2.3
Total Heating Requirements	15.6	8.4	23.1	12.6
Engine-Driven Blower				
Digester Gas Usage, MMBTU/hr	3.5	3.5	4.4	4.4
Recovered Heat, MMBTU/hr (7)	1.2	1.2	1.5	1.5
Engine Generators (8)				
Available Gas, MMBTU/hr (9)	(1.2)	9.0	(1.9)	12.5
Recovered Heat, MMBTU/hr (7)	0	3.0	0	3.9

Note:
(1) Includes existing Digesters No. 1-6.
(2) Includes proposed Digester No. 8.
(3) Based on annual average solids loading.
(4) Includes existing Digesters No. 1-7.
(5) Based on 10th Addition Predesign Report
(6) Based on a heating demand of 2.0 MMBTU/hr for the proposed digester control and thickening buildings.
(7) Assumes 34 percent of the fuel energy is recovered as heat.
(8) Existing engine generators No. 1 and No. 2 with a total capacity of 11.5 MMBTU/hr
(9) Available gas for cogeneration = Gas produced - Heating requirements - Blower usage + Recovered heat

For the purposes of this capacity evaluation, the digester gas usage to offset natural gas purchase was considered a priority over cogeneration. The use of digester gas for electrical power generation or heating will depend on the cost of natural gas and electricity at the moment of use. Based on a preliminary estimate using the planning level costs for electricity ($0.08 per kWh) and a natural gas ($0.69 per therm), the cost per MMBTU is approximately $23 for electricity and $69 for natural gas. Therefore, digester gas utilization to offset natural gas purchases appears to be more economically favorable than cogeneration. In this scenario, the digester gas is first utilized to fuel the hot water boilers and the engine-driven blower and residual gas utilized to fuel the cogeneration units. A more

detailed analysis for the development of strategies for digester gas usage may be conducted during design.

9.0 Recommendation

Based on the projected 2030 digester gas production, the digester and building heating requirements, and the capacity of the existing cogeneration units, the installation of additional cogeneration capacity is not recommended.