Validation of Plant Solids Loadings Parameters and Plant Capacity

PREPARED FOR:	City of St. Petersburg
COPY TO:	Alliance for Bayway Communities, Eckerd College
PREPARED BY:	CH2M
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CH2M has been tasked by the City of St. Petersburg to perform a peer review of the Biosolids to Energy Project that will centralize biosolids treatment at the Southwest Water Reclamation Facility (SWWRF). At the completion of these projects, all waste sludge from the Northeast Water Reclamation Facility (NEWRF) and the Northwest Water Reclamation Facility (NWWRF) will be pumped to the SWWRF where it will be treated along with SWWRF sludge to Class A standards in a new treatment process that includes thickening, anaerobic digestion, dewatering and energy recovery. Flows, including waste sludge, from the Albert Whitted WRF (AWWRF) collection basin have already been diverted to SWWRF for treatment, and these additional flows influent flows to SWWRF have been permitted by the Florida Department of Environmental Protection (FDEP).

Objective

The objective of this Technical Memorandum ™ will be to validate the solids loadings parameters used in the selection of the centralized solids treatment processes and any impacts to overall capacity at the Southwest WRF.

Documents

The following documents were reviewed as part of the evaluation:

- TM No. 1: Basis of Conceptual Design of Evaluation for Sludge and Yard Waste Production Rates, August 26th, 2010 (TM1)
- TM No. 3: Evaluation of WRF Sludge Consolidation/Conveyance Options to SWWRF and NW/NEWRF Conversion to Class-A Biosolids/Beneficial Reuse to Land Disposal, January 20th, 2011 (TM3)
- TM No. 4: Recommended Plan for Biosolids Waste to Energy, July 18th, 2011 (TM4)
- Preliminary Design Report, Biosolids to Energy Project, June 19th, 2015, (PDR)
- Southwest Water Reclamation Facility Biosolids to Energy Project, Volume 4 – Drawings Biosolids Improvements. Guaranteed Maximum Price. (GMP Biosolids Drawings)

Findings

Design Flows and Loads

The Biosolids to Energy Project will centralize solids treatment at the SWWRF; therefore, the solids handling and treatment facilities at SWWRF must be designed for the projected solids at all three WRFs. The NEWRF and NWWRF will pump waste activated sludge (WAS) into the SWWRF collection system where it will be treated initially as part of the liquid stream. Due to this higher solids loading into the SWWRF, the Biosolids to Energy Project includes modifications to the liquid treatment stream at SWWRF with the addition of primary clarification. The development of the design flows and loads for this project included both an evaluation of historical data and projections from a calibrated process model. The evolution of this process is described below.

Evaluation of Historical WRF Data

NEWRF and NWWRF

The key design parameter for the Biosolids to Energy Project of the NEWRF and NWWRF is WAS generation. Initially WAS generation rates were determined for each facility from 2007-2009 operating data and included in TM1. This included four conditions: annual average day (AAD), maximum month average day (MMAD), maximum week average day (MWAD), and maximum day (MD). The values were used to develop peaking factors for each of these loading conditions.

The AAD WAS values were also compared with the influent (5-day carbonaceous biological oxygen demand) $CBOD_5$ to determine the net sludge yield for each WRF. The data analyzed for the NEWRF provided a net sludge yield of 0.9 lb-VS (volatile solids)/lb-BOD_5, which is consistent with typical values seen for plants operating at similar conditions. Similar data for the NWWRF resulted in a net sludge yield of 1.17 lb-VS/lb-BOD_5, which is considered high but was used further in the analysis.

The procedures used in determining the WAS rates and sludge yield are reasonable and typical of those used in this type of evaluation. However, standard engineering practices typically utilize five or more years of data when available, and therefore additional years of data would provide a higher level of confidence.

SWWRF

Initially the development of the design loadings for SWWRF in TM1 included WAS generation rates determined via the same manner as described above for NEWRF and NWWRF. As the project developed however, these WAS generation rates were not relevant due to the addition of primary clarification at SWWRF and the addition of the flow from the AWWRF that is no longer in service. Primary clarification at SWWRF was first described in TM3 as part of the evaluation on the consolidation/conveyance options of the Biosolids to Energy Project. The results of this evaluation led to the selection of an alternative that included conveyance of WAS from NEWRF and NWWRF to the SWWRF collection system. In order to mitigate impacts to the secondary treatment processes at SWWRF due to the higher influent loadings—and increase gas production in the digestion process due to a higher percentage of volatile solids—primary clarification was included. The addition of primary clarification will significantly impact the existing secondary treatment process, and therefore historical data on WAS production at SWWRF is not relevant to the Biosolids to Energy Project moving forward. Due to the lack of relevant historical data, design loadings for the project were determined by process modeling which is described below.

In order to develop the process model, influent flows and loads at the SWWRF are required. In an earlier version of the PDR (September 6, 2013), Brown and Caldwell (BC) analyzed influent flow and load projections based on historic City service area information, multiple population projections, and historic flow and load information at each WRF. The influent flow projections during dry and wet weather conditions and subsequent peaking factors will be reviewed and analyzed in another report as part of another ongoing project (City Project No. 15073-121).

The City service area information utilized the US Census Bureau to obtain year 2010 population information. The City of St. Petersburg Planning Commission's and the City Council's *2007 Evaluation and Appraisal Report* was used to determine that "because the City is nearly fully developed (less than 6% vacant), the land use within the City is not anticipated to change significantly within the planning period for this project which is through the year 2035." This assumption, which seems reasonable, provides for constant peaking factors to be used throughout the future influent flows and loads projections as the population and land uses are not expected to change significantly over time.

The multiple population projections used in BC's earlier version of the PDR were used to determine annual average wastewater flow percentage increases. The language of the multiple population projections was not included in BC's Final PDR, but the annual average wastewater flow percentage increases noted in each report were the same (0.026% for NEWRF and NWWRF Services Areas, and 0.400% for AWWRF and SWWRF Service Areas). The Final PDR noted that these values were recommended by the City.

The following assumptions were used to develop pollutant loadings in Table 2-7 in the PDR for Temperature, $CBOD_5$, total suspended solids (TSS), total Kjeldahl nitrogen (TKN), and total phosphorus (TP):

- The permitted AADF of 20-mgd (millions gallons per day) will be used despite a projected flow of 17.91-mgd in 2035
- There will be no new significant industrial loads
- The influent wastewater into SWWRF will be primarily domestic
- Influent pollutant concentrations would not change in the future due to infiltration and inflow rehabilitation in the collection system or reduced water consumption
- Influent concentration and loadings for SWWRF and AWWRF from January 2007 through December 2011.
- Utilization of SWWRF Design Loading Rates (chemical oxygen demand (COD) to $CBOD_5$, $CBOD_5$ to TSS, volatile suspended solids (VSS) to TSS, COD to TKN, ammonia (NH_3-N) to TKN, COD to TP, phosphate (PO_4-P) to TP) from a wastewater characterization study conducted by BC and report submitted by BC on March 18, 2013 entitled *City of St. Petersburg's Southwest Water Reclamation Facility Treatment Process and Hydraulic Evaluation*.

Significant upgrades to the collection system that reduce infiltration and inflow could reduce influent flow and thus increase the influent pollutant concentrations. However, this types of upgrades do not impact the population served or the influent loadings to the WRF. The loadings for the SWWRF provided in Table 2-7 were developed using a reasonable approach and appear to be conservative based on the historical data and industry standards.

Design Loading to the Biosolids to Energy Facilities

As indicated above, the addition of primary clarification at the SWWRF made the historical sludge production data less relevant and required process modeling to determine the design loadings to the new solids processes which was described in the PDR. The BioWin model included the secondary treatment processes at the NEWRF and NWWRF along with the proposed primary/secondary processes at SWWRF. A schematic of the model is included in the PDR as Figure 2-7. The PDR indicates that the historical WAS data from the NEWRF and the NWWRF was used to calibrate these components of the model. Design influent AADFs in 2035 of 11.57-mgd and 10.11-mgd for the NEWRF and the NWWRF respectively were presented in Table 2-1 in the PDR. These flowrates assumed a 0.026% per year increase in the AADF. The influent loading conditions to the NEWRF and the NWWRF were not presented in the PDR however. The influent loading and the subsequent WAS production for the NEWRF and NWWRF will be confirmed as part of the ongoing review of the calibrated BioWin model.

The influent flows and loads to the SWWRF were included in the PDR as described above. The PDR indicated that a range of primary clarifier performance was modeled and the sludge production rates at 65%, 70% and 80% performance (per TSS removal) were presented in Table 2-11. The WAS production rates were determined using the BioWin model with an approximate net sludge yield of 0.5 lb-VS/lb-BOD_5, which is consistent with WRFs using similar processes. The final design loadings to the new consolidated solids treatment facilities included in the Biosolids to Energy Project were presented in Table 2-12, which matched the values listed in the Mass Balance included in the GMP Biosolids Drawings. The PDR indicated a primary clarifier performance of 80% was assumed along with the addition of ferric chloride to enhance settling. This level of performance provides a conservative approach for sizing primary sludge handling facilities, but may impact other parameters such as gas production in digestion and secondary treatment performance.

Centralized Solids Processing and Handling Facilities

Primary Clarification

The initial concept for adding primary clarification to SWWRF was described in TM3 and utilized repurposed tanks and high surface overflow rates. However, as the project progressed it was determined that new primary clarifiers would be constructed and sized to provide surface overflow rates more typical to industry standards. The primary clarification facilities included in the Biosolids to Energy Project design are described in the PDR and key parameters are summarized in the following table.

Table 1. Primary Clarification
Biosolids to Energy Project Peer Review

Parameter	Value	Note
Primary Clarifiers		
Maximum Design Flow	40-mgd (combined)	
Number of Units	2	
Diameter	100-ft	
Surface Area	7,584-ft^2 (each)	
Surface Overflow Rate	Average: 1,295-gpd/ft^2 Peak: 2,585-gpd/ft^2	Installed capacity
Maximum Fe Addition	5 mg/L	As Ferric Chloride
Target TSS Removal	AADF: 85% MMADF: 80%	MMADF value per Mass Balance in GMP Biosolids Documents

Notes: gpd – gallons per day; mg/L – milligrams per liter

Primary clarification was designed to treat flows up to 40-mgd or two times the design AADF. It was indicated that flows above 40-mgd are due to wet weather events and are not expected to increase the loading to the WRF and thus not impact downstream liquid processes. In addition, WAS storage is provided at NEWRF and NWWRF and operations can limit or cease pumping WAS during peak wet weather flow events, which eliminates any impacts the Biosolids to Energy Project has on the hydraulic capacity at SWWRF. These assumptions seem reasonable for this application.

The surface loading rates listed are for the installed capacity and therefore significantly higher rates would be seen with one unit out of service. The expected performance with one unit of service was not included in the PDR. Any impacts to secondary treatment with a reduction in performance in this condition will be determined as part of the ongoing review of the calibrated BioWin model used in the design of the Biosolids to Energy Project and a thorough evaluation on the process selection will be included in TM 3 Validation of Solids Process Selection and Supporting Analysis as part of this Wastewater Project Peer Review.

WAS Pumping and Holding

The existing WAS pumping and WAS Holding Tank will continue to be utilized in the new process but the WAS grinders and some WAS and secondary scum pumping will be relocated. The modifications to the liquid processes will not impact the capacity of the WAS system.

Thickening

All primary and secondary sludge produced at the SWWRF will be pumped to the existing WAS Storage Tank before thickening. The modification to the thickening process at SWWRF includes the addition of a second 2-meter gravity belt thickener (GBT), enclosing the existing Thickening Building and connecting the facility to the new odor control system. The thickening modifications were detailed in Appendix B of the PDR.

Table 2. Thickening
Biosolids to Energy Project Peer Review

Parameter	Value	Note
Gravity Belt Thickeners		
Number of Units	Two	
Size	2-meter (each)	
Loading	200-gpm 300-gpm	AADF (PS + WAS) PHF (PS + WAS)
Thickened Sludge Performance	6%	

Notes: gpm – gallons per minute

The modifications to the thickening process also include additional auxiliary equipment for the new GBT including a thickened sludge transfer pump, a wash water pump and an emulsion polymer system. The modifications to the thickening process utilize existing facilities and equipment where possible and provide a reasonable level of service and redundancy.

Anaerobic Digestion and Gas Handling

Anaerobic Digestion
The proposed anaerobic digestion process utilizes a thermophilic digester, followed by batch tanks and finally a mesophilic digester which will produce a Class A biosolid and provide gas for energy recovery. Some key design criteria and process parameters for the digesters are summarized in the table below.

Table 3. Anaerobic Digestion
Biosolids to Energy Project Peer Review

Parameter	Value	Note
Design Criteria		
Thermophilic Volatile Solids Loading Rate	Less than 0.35-lb VS/ft^3 day	At Peak week per PDR
Thermophilic Hydraulic Retention Time	Greater than 7 days	At AADF conditions
Mesophilic Volatile Solids Loading Rate[1]	Less than 0.20 lb VS/ft3 day	At MWAD
Mesophilic Hydraulic Retention Time	Greater than 10 days	At AADF conditions
Digester 1 Thermophilic		
Diameter	100-ft	
Operating Volume	1.76-MG	
Hydraulic Retention Time	10.4 days	AAD
	8.9 days	MMAD
	7.4 days	MD
Volatile Solids Loading Rate[2]	0.33 lb-VS/ft^3 day	MMAD
	0.40 lb-VS/ft^3 day	MD
Batch Tanks		
Length / Width	Six 21-ft x 21-ft cells	
Operating Volume	0.247-MG	Combined
Hydraulic Retention Time	34.9 hours	AAD
	29.8 hours	MMAD
	24.6 hours	MD
Digester 2 Mesophilic		
Diameter	105-ft	
Operating Volume	2.3-MG	
Hydraulic Retention Time	13.5 days	AAD
	11.5 days	MMAD
	9.5 days	MD
Volatile Solids Loading Rate[3]	0.13 lb-VS/ft^3 day	MMAD
	0.15 lb-VS/ft^3 day	MD

Note: 1. Recommended by CH2M. 2. Approximated based on 78.5% VSS/TSS in combined sludge. 3. Approximated assuming 50% VSS reduction in thermophilic digester

The volatile solids loading criteria defined in the PDR is based on a maximum week condition. However, neither the mass balance in the PDR or in the GMP Biosolids Drawings included maximum week loading conditions so this design criteria could not be validated. The digesters do meet the hydraulic retention time criteria specified in the PDR, but since the retention times are within 7-13 days the maximum week retention time would also be relevant to this analysis. A thorough evaluation on the process selection will be included in TM 3 Validation of Solids Process Selection and Supporting Analysis as part of this Wastewater Project Peer Review.

Digester Gas Production and Handling

A key component of the Biosolids to Energy project is the ability to recover energy both as gas from the digestion process and the potential biosolids as a future fuel source. A combined waste to energy facility utilizing yard waste and biosolids as feedstocks is not included in the current project, but was included as a potential second phase in the future. The current project does include new facilities to collect, upgrade and use gas produced in the digesters.

An evaluation of predicted digester performance, gas production and the overall worth will be included in TM 3 Validation of Solids Process Selection and Supporting Analysis as part of this Wastewater Project Peer Review.

Dewatering

In the final process of the Biosolids to Energy Project the digested sludge will be dewatered prior to hauling to land application sites. The initial technology selected for this application was centrifuge dewatering. However after a technology review the decision was made to not use centrifuges primarily due to the potential for pathogen reactivation and regrowth following the Temperature-Phased Anaerobic Digestion (TPAD) process. Potential dewatering technologies were reviewed again and screw presses were selected for this project. Due to this change the PDR does not contain the same level of detail for the dewatering processes as compared to the other process. The information included in the table below was compiled from the PDR and the GMP Biosolids Drawings.

Table 4. Dewatering
Biosolids to Energy Project Peer Review

Parameter	Value	Note
Design Criteria	159-gpm 2,821-lbs/hr 3.6% solids	Maximum day conditions per PDR Appendix C
Operating Time	24 hours/day 7 days/week	
Screw Presses		
Number of Units	Three	
Dewatered Sludge Performance	15%	Per GMP Biosolids Drawings

Notes: lbs/hr – pounds per hour

The selection of screw presses for dewatering is reasonable based on the technology review provided in the PDR and based on CH2M project experience. Additional information on the process selection will be included as needed in TM 3 Validation of Solids Process Selection and Supporting Analysis as part of this Wastewater Project Peer Review.

Overall Southwest WRF Capacity

The secondary treatment process at SWWRF will be impacted by the Biosolids to Energy Project due to the additional loads from the WAS conveyed from NEWRF and NWWRF, the addition of primary clarification and the increased recycle flows due to larger solids treatment and handling facilities. The potential impacts will be evaluated as part of the ongoing review of the calibrated BioWin model.

Summary

The original solids loading data developed for this project included WAS and digested sludge production rates of the then four operating WRFs. Based on the selected alternative which included a centralized solids treatment facility at SWWRF, conveyance of WAS from NEWRF and NWWRF to the SWWRF collection system and the addition of primary treatment at SWWRF much of this initial data was no longer relevant. The WAS production rates from NEWRF and NWWRF were still used to calibrate WAS flows added to the influent flow at SWWRF. The remaining solids loading parameters were developed using BioWin model calibrated to existing data for some processes and to industry standards for new processes. Influent information for the SWWRF included in the PDR appeared to be reasonable and appropriate. An evaluation of the BioWin model is ongoing, and a peer review of any information relevant to this model will be included in TM 3 – Validation of Solids Process Selection and Supporting Analysis.

A preliminary analysis was also made of the projected loadings to the new or modified facilities included in the Biosolids to Energy project: primary clarification, combined sludge thickening, anaerobic digestion and dewatering. No unreasonable loading conditions were observed in this analysis, however a more thorough evaluation of the selected process will be included in TM 3 as part of this Wastewater Project Peer Review.