Clean Water Services
East Basin 2019 Master Plan Project

Technical Memorandum 12
SOLIDS CAPACITY EVALUATION

FINAL | June 2021

Contents

Technical Memorandum 12 - Solids Capacity Evaluation

Table

Figures

Technical Memorandum 12

SOLIDS CAPACITY EVALUATION

12.1 Summary

Facilities planning for the Durham Advanced Wastewater Treatment Facility (AWWTF) requires a comprehensive understanding of the capacity (treatment and hydraulic) of the various liquids and solids processes throughout the facility. This memo documents the analyses that were done to determine the actual process capacities of the solids treatment processes. The process and hydraulic capacities of the liquid treatment processes are summarized in technical memorandum (TM) 11.

The Durham AWWTF solids processing facilities are schematically illustrated in Figure 12.1. The primary sludge (PS) generated from the primary clarification (PC) step are fermented and thickened in two gravity thickeners (GTs) in series GT-1 and GT-3 producing volatile fatty acids (VFAs) that are fed back to the aeration basin (ABs). The waste activated sludge (WAS) generated from the secondary process along with the chemical sludge (CHS) settled in the chemical clarifiers (CCs) are pre-thickened in another GT to produce thickened WAS (TWAS) that is sent to the phosphorus release tank (PRT) process to release phosphorus. WAS thickening and PRT improvements are currently underway to replace the current GT process with rotary drum thickeners and replace the current PRT tank with a new tank. The effluent from the PRT or thickening centrifuge feed (TCF) is then post-thickened using thickening centrifuges (TCs). The twice thickened WAS (TTWAS) is combined with the thickened primary sludge (TPS) in digester feed tanks prior to anaerobic digestion, and primary scum (PSC) is added to the blended feed to produce digester feed (DF). External fats oils and grease (FOG) is fed the digesters in addition to the DF. The digested sludge (DS) is stored in a digested sludge holding tank (DSHT) and fed from there to dewatering centrifuges. The dewatered biosolids is then hauled off-site for Class B land application. The post-thickening centrate (WAS'ate) and the dewatering (DW) centrate are both stored prior to being fed to the struvite recovery facility (SRF) to produce struvite as Crystal Green.

The AWWTF also captures, conditions, and beneficially uses digester gas in an engine-based cogeneration system that produces power and heat, and also in boilers that provide supplemental heat. Excess biogas is flared.

A solids processing capacity summary is presented in Table 12.1. Capacity for each of the solids unit processes is presented in terms of unit process hydraulic and mass loads.

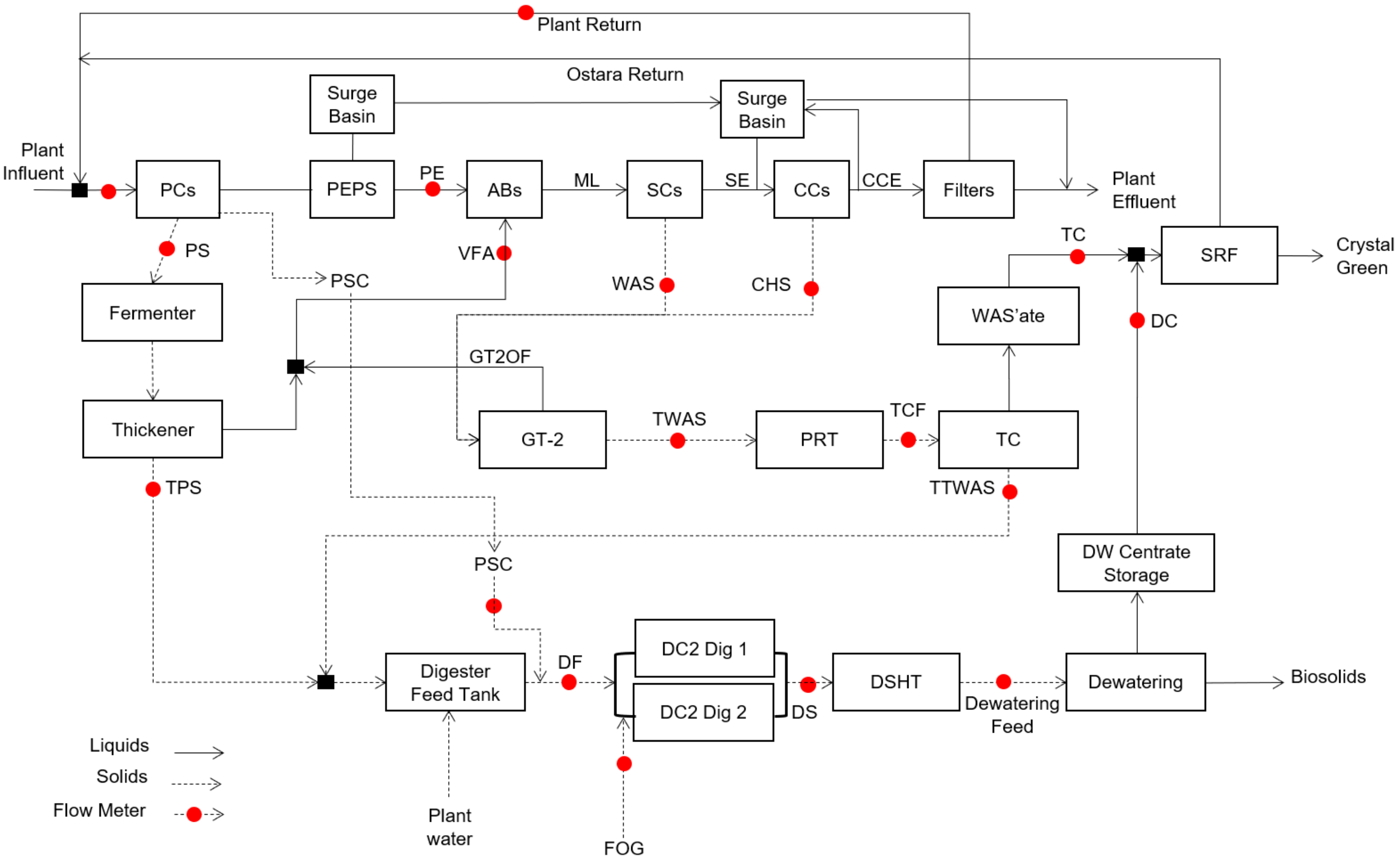


Figure 12.1 Existing Durham Solids Processing Overview

Abbreviations: CCE = chemical clarifier effluent; DC = dewatering centrate; GT2OF = gravity thickener 2 overflow; ML = mixed liquor; PE = primary effluent; PEPS = primary effluent pump station; SC = secondary clarifier; .

Table 12.1 Existing Durham Solids Processing Capacity Analysis Summary

Solids Unit Process	Process Condition Basis for Capacity	Units in Service / Installed at hrs per day / days per week	Design Criteria	Durham Plant Loadings		Year of Capacity Exceedance
				Current (2020)	Future (2040)	
PS gravity thickening / fermentation	MW PS Load	2/2 at 24/7	25 ppd/sf	27.8 ppd/sf	37.7 ppd/sf	2020
WAS/CHS pre-thickening GT-2	MWDW WAS Load MMDW WAS Load	1/1 at 24/7	15 ppd/sf 12 ppd/sf	17.4 ppd/sf 14.5 ppd/sf	23.9 ppd/sf 19.9 ppd/sf	2020 2020
WAS/CHS pre-thickening RDTs(1)	MW WAS Flow MM WAS Flow	2/2 at 24/7 1.5(8)/2 at 24/7	800 gpm 600 gpm	345 gpm 251 gpm	474 gpm 349 gpm	Beyond Buildout
PRT(2,3)	MWDW TWAS Flow	1/1	HRT = 24 hrs	52 hrs	38 hrs	Beyond Buildout
WAS TC(2)	MWDW TWAS Flow	2/3 at 22/7	300 gpm	197 gpm	270 gpm	2050
WAS'ate storage(2)	MWDW TWAS Flow	1/1	-	HRT = 2.4 hrs	HRT = 1.8 hrs	-
Anaerobic digestion; DC1 digesters out of service(4,5)	MM Flow_{IS+FOG} MM VSLR_{IS} MM VSLR_{IS+FOG}	2/2 (DC2) at 24/7	SRT = 15 days 0.17 lb VS/cf-d 0.23 lb VS/cf-d	SRT = 17.1 days 0.15 lb VS/cf-d 0.18 lb VS/cf-d	SRT = 12.5 days 0.20 lb VS/cf-d 0.24 lb VS/cf-d	2027(5)
DSHT(6)	MM DS Flow	3/3	7 days of storage	12.4 days of storage	9.3 days of storage	2078
Centrifuge dewatering(6)	MM DS Load MM DS Flow	1/2 at 22/6	3,000 lb/hr 240 gpm	1,720 lb/hr 150 gpm	2,350 lb/hr 200 gpm	2056
DW centrifuge centrate storage	MM DS Flow	1/1	3 days of storage	3.8 days of storage	2.9 days of storage	2036
BS storage	MM Cake Volume	2/2	1 day of storage	2.0 days of storage	1.5 days of storage	2077
Gas conditioning / cogeneration	AA Biogas Flow	2/2 at 24/7	460 scfm	459 scfm	460 scfm(7)	2020(7)

Notes:

Abbreviations: AA = average annual; BS = dewatered biosolids; DC1 = Digester Complex 1; DWMM = dry weather MM; DWMW = dry weather MW; gpm = gallons per minute; hrs = hours; IS = indigenous sludge; lb/hr = pounds per hour; lb VS/cf-d = pounds volatile solids per cubic foot per day; MM = max month; MW = maximum week; ppd/sf = pounds per day per square foot; RDT = rotary drum thickener; scfm = standard cubic feet per minute; SRT = solids retention time; VSLR_{IS} = indigenous sludge volatile solids loading rate; VSLR_{IS+FOG} = combined sludge (indigenous sludge plus FOG) volatile solids loading rate.

(1) Assumes that 37 percent of the WAS flow bypasses the RDTs. This bypass flow rate was determined to keep the WASSTRIP TS at 1.5 percent (Jacobs, 2019).

(2) Capacity based on existing PRT-release tank.

(3) Based on a combined WAS + TWAS concentration of 1.5 percent.

(4) DC1 includes four tanks. One tank is used solely for digested sludge storage and two tanks could be used to replace the capacity of one DC2 digester if that digester needs to be taken out of service or, more frequently, for additional digested sludge storage. The fourth tank is being repurposed as a new PRT-release tank.

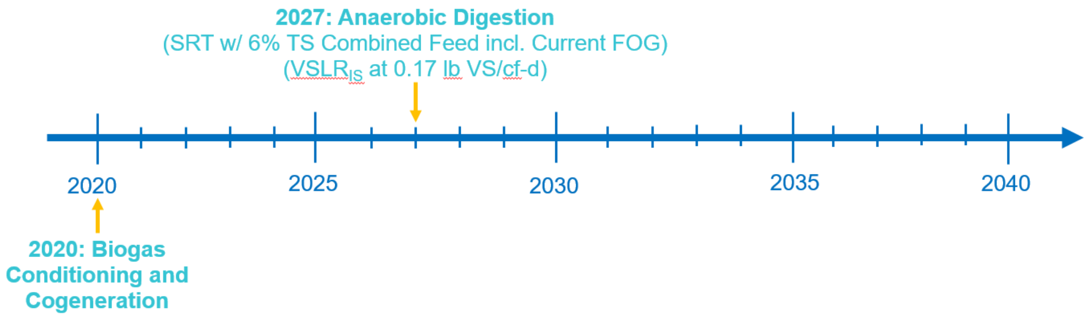
(5) TPS thickened to 5 percent and TTWAS thickened to between 5.5 percent and 7 percent. Capacity exceedance is projected to occur in 2021 if TTWAS is thickened to 5.5 percent, but could be extended to 2027 if TTWAS were thickened to 7 percent. TTWAS thickened to 7 percent is assumed for this table. Additionally, the corresponding VSLR to match a 2027 capacity limit is also shown in this table. If a VSLR_{IS} of only 0.16 lb VS/cf-d can be achieved, capacity would be exceeded in 2024.

(6) TPS thickened to 5 percent and TTWAS thickened to 5.5 percent. Assumes 3 DC1 Digesters are available.

(7) This reflects that the existing cogeneration engines are fully utilized.

(8) Each RDT will have two drums. Assumes that one drum will be out of service.

Figure 12.2 summarizes the processes found to be capacity-limited within the planning horizon and indicates the timeframe for when capacity will be exceeded based on each process's design criteria. Figure 12.2 does not include the primary sludge gravity thickening/fermentation system because a project for expanding the capacity of that system is already planned. Additionally, the biogas conditioning and cogeneration (cogen) systems are operating at the current capacity of the existing cogeneration system. While another engine and associated conditioning units could be added to that system to gain capacity, Clean Water Services (the District) seeks to evaluate different biogas utilization alternatives and may decide to not expand cogeneration beyond its existing capacity. While DW centrifuge centrate storage is noted as reaching capacity in 2036, it is likely that the District would slightly ease its design criterion for centrate storage rather than expand capacity for this process. Hence, the priority process that will require a capacity increase within the planning horizon is anaerobic digestion.



NOTES:

(1) Based on SRT, digestion capacity could be required between 2021 and 2027 if feed is thinner than noted or if FOG feed is increased. Based on a VSLR$_{IS}$ range of 0.16 - 0.18 lb VS/cf-d, digestion capacity could be required between 2024 and 2031.

(2) The current 3-day design criterion for dewatering centrifuge centrate storage triggers additional storage in 2036. However, that criterion may be relaxed in the future, so additional storage needs are not shown within the planning horizon.

(3) The existing gravity thickening/UFAT system is currently out of capacity. However, this is not included in the timeline because there is already a project underway for capacity expansion of this system.

Figure 12.2 Capacity-Limited Solids Processes and Year Capacity Reached

The timeframe for when additional anaerobic digestion capacity will be required is a range relative to both the SRT criterion and the volatile solids loading rate (VSLR) criterion. These ranges also depend both on stable digester operations as well as what percent solids can be fed and processed in the digesters. Operating data shows that the thickening centrifuges can reliably attain 5.5 percent solids concentrations, the existing TTWAS pumps have pressure capacity to pump this stream, and the digester feed pumps can reliably pump a 5.5 percent solids feed to the digester. Furthermore, operating data shows that TPS can consistently and reliably achieve a concentration of 5 percent solids. With these historical percent solids, the existing digestion capacity would be insufficient by 2021 based on the SRT criterion. Thus, to extend the capacity of the existing digesters from and SRT standpoint, a thicker digester feed is needed.

Per discussions with plant staff, the recirculation pumps in the digesters start to have operational issues when the digested solids concentration is 3.5 percent or greater. This digested solids concentration depends on both the volatile solids reduction (VSR) in the digesters as well as the combined digester feed concentration. Figure 12.3 shows the expected digested sludge concentration relative to the combined digester feed concentration for various VSRs. As shown in the figure, to keep the expected digester sludge concentration below 3.5 percent 94 percent of the time, the combined digester feed concentration should not exceed 6 percent solids. To achieve a digester feed concentration of 6 percent solids, the TTWAS concentration would have to consistently be 7 percent solids. This is higher than the concentration TTWAS is currently operated at (5.5 percent solids). This also assumes the TPS solids concentration remains at 5 percent solids. At a combined digester feed concentration of 6 percent solids, the hydraulic load to the digesters would be reduced and the existing digesters would provide sufficient capacity until approximately 2027.

AWWTF staff have indicated that operating at a TTWAS concentration of 7 percent is feasible, as long as the pipelines that transport TTWAS remain clear. Additionally, the existing TTWAS pumps and the digester feed pumps have pressure capacity to pump this stream.

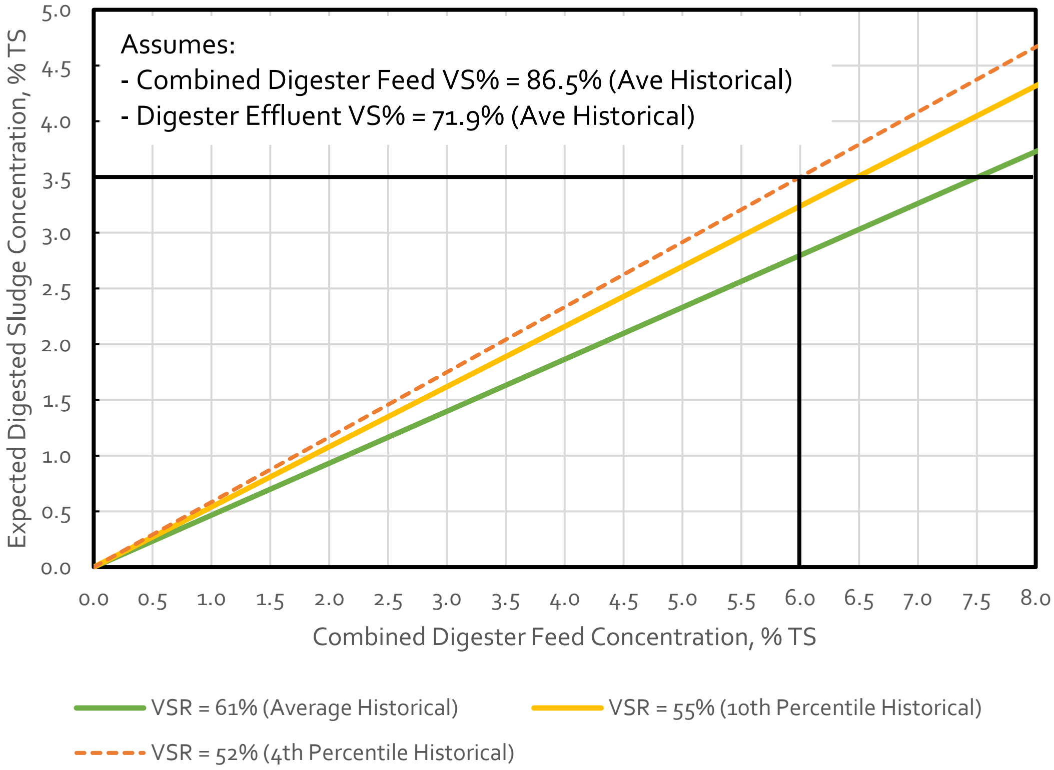


Figure 12.3 Projected Digested Sludge % TS with Varying Digester Feed % TS and Historical VSR

In addition to assessing digester capacity on an SRT basis, digester capacity must also be assessed based on the VSLR, which is more strongly governed by the indigenous sludge (IS) load than the plant's external FOG feed, as long as the FOG load is kept to a maximum of 30 percent of the total volatile solids (VS) load to maintain overall digestion process stability. Further discussion of why the 30 percent ratio of FOG to IS VS load was chosen can be found in section 12.4.2.2 below. In general it aligns with testing done on the AWWTF's digesters, operational input from other facilities practicing FOG co-digestion, and digester stability research conducted by Cook et al, in 2017. The capacity evaluation conducted in this report shows that an IS-based VSLR ($VSLR_{IS}$) range of 0.16 to 0.18 lb VS/cf-d under maximum month conditions would necessitate additional digester capacity in 2024 or 2031, respectively. The plant has not historically operated at a $VSLR_{IS}$ much higher than 0.16 lb VS/cf-d for sustained periods, and high loading rates can cause instability in the digestion process. However, for the Durham AWWTF's specific digester operations and feed characteristics, it is not known how high a sludge-based

$VSLR_{IS}$ could be accommodated over a sustained period while retaining process stability. While a $VSLR_{IS}$ of 0.18 lb VS/cf-d could provide sufficient digester capacity through 2031 if sustained stably, the SRT criterion is more stringent, and both the SRT (with 7 percent TTWAS solids concentration) and $VSLR_{IS}$ criteria indicate that new digestion capacity will be needed by 2027, at which point the projected $VSLR_{IS}$ would be approximately 0.17 lb VS/cf-d.

Based on this analysis and the discussion above, the main solids process capacity–based need at the plant is anaerobic digestion. Additional digestion capacity will be needed by 2027 if a $VSLR_{IS}$ of 0.17 lb VS/cf-d can be accommodated stably, TTWAS can be thickened and pumped consistently and reliably at 7 percent solids concentration, the digester feed pumps can consistently and reliably pump a digester feed concentration of 6 percent solids, and the digester heating and mixing system can operate at digested sludge concentrations up to 3.5 percent solids. If these conditions cannot be met, an SRT-based capacity shortfall could occur as soon as 2021. Furthermore, indigenous sludge-based VSLR and digester stability will need to be monitored, and if instability starts to occur when $VSLR_{IS}$ exceeds 0.16 lb VS/cf-d, additional digestion capacity may be necessary prior to 2027.

12.2 Primary Sludge Thickening

The PS thickening and fermentation process (also referred to as the unified thickening and fermentation [UFAT] process) produces VFAs for the liquids treatment process via the fermentation step. The District has three GTs; one is currently used for thickening WAS and two are used for thickening and fermenting PS. The two PS GTs are operated in series as one fermenter/thickener train to produce VFAs to optimize the biological nutrient removal process.

PS is discharged into GT-1 for fermentation. The overflow flows by gravity to the VFA wet well and is pumped back into GT-3 with the VFA discharge pumps for thickening. In addition, the underflow from GT-1 is also periodically withdrawn and conveyed to GT-3. Underflow from GT-3 is conveyed as TPS to digester feed, and the high VFA overflow from GT-3 is metered and returned to the anaerobic zones of the ABs.

The GT design criteria for PS solids loading is 25 ppd/sf with one GT used to thicken PS downstream of fermentation. Each GT has a diameter of 50 ft, so the capacity of the PS GT is approximately 49,000 pounds per day (ppd) total solids (TS).

Figure 12.4 indicates that the PS solids loading capacity to this fermenter/thickener train was exceeded in 2017 and 2018, and PS loads are projected to increase. Thus, the primary sludge thickening capacity is insufficient for both current and future PS loads when the thickeners operate in series for fermentation and thickening. If the thickener is taken out of service, the fermenter would revert to operation as a thickener with the same capacity limitation, but without production of VFAs through fermentation. Under these overloaded conditions the PS will not be thickened as much in the thickener, resulting in thinner TPS sent to the digesters, decreasing digester capacity. Furthermore, overloading the fermenter decreases the carbon available for the secondary treatment process. The District is already aware of capacity limitations in the system and a project to increase capacity is planned. Design of this project has been started and it is expected that the upgraded facility will be complete in the fall or winter of 2022.

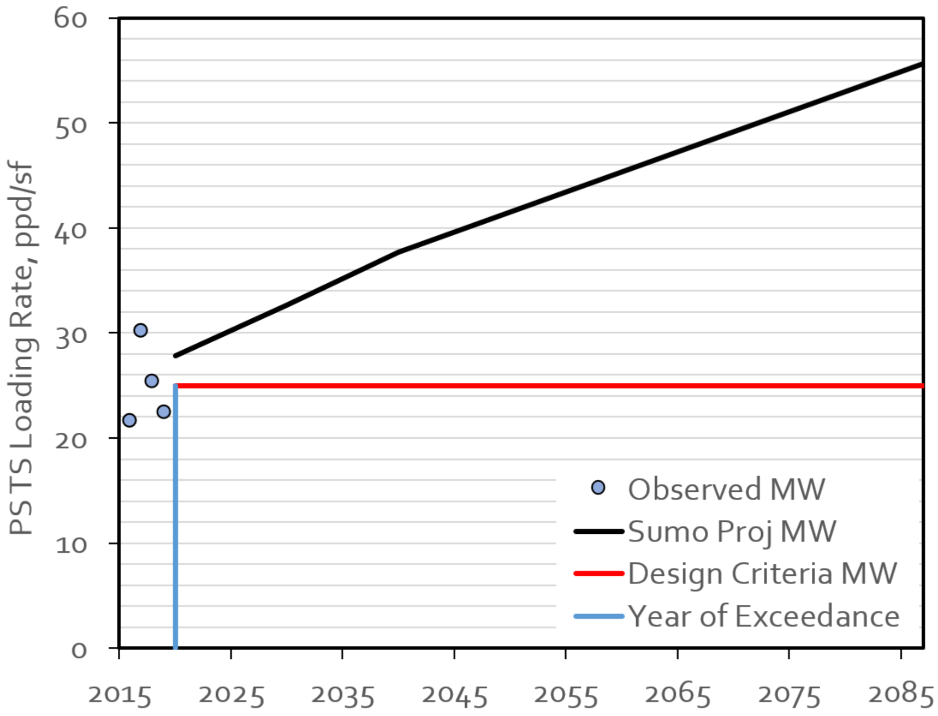


Figure 12.4 Primary Sludge Thickening Capacity - Gravity Thickener

12.3 WAS and Chemical Sludge Thickening

WAS and CHS are currently combined and thickened together prior to the PRT, and thickened again prior to digestion. WAS/CHS thickening upstream of the PRT is referred to as "Pre-Thickening" to produce TWAS. WAS thickening prior to anaerobic digestion is referred to as "Post-Thickening" to produce TTWAS.

12.3.1 WAS/CHS Pre-Thickening

Currently WAS and CHS are thickened with a GT. Due to capacity constraints in the WAS thickening process, the District is in preliminary design of a project to replace the WAS gravity thickening process with a RDT-based mechanical thickening. Once the RDT-based system is online, the CHS will be removed from the PRT and sent to the plant drain via the backwash basins as a recycle stream. Additionally, this project will move PRT out of the existing footprint to make room for expanding the PS thickening/fermenting process. Because the GT will remain in this service until the RDT system is operational, this section evaluates the capacity of both WAS pre-thickening processes: (1) the current GT, and (2) the future RDT-based system.

12.3.1.1 Gravity Thickener

WAS is pumped continuously from the secondary clarifiers to GT-2. CHS is pumped from the bottom of the CCs with pumps cycling in response to a timer control system. The CHS solids concentrations are not monitored, but based on conversations with the District, the CHS is often quite dilute and an insignificant load compared to the WAS. CHS is combined with WAS and pumped to GT-2. The maximum solids loading rates for operating GT-2 with WAS/CHS are 15 ppd/sf under max week dry weather (MWDW) conditions, and 12 ppd/sf under max month dry weather (MMDW) conditions. Both of these criteria were exceeded in 2017 and 2018, as seen in Figures 12.5 and 12.6, respectively. Based on the projected increase in solids loading, the capacity of GT-2 for thickening dilute WAS/CHS is insufficient for both current and future sludge loads. This capacity deficit will be addressed via installation of RDTs for WAS thickening in the near future.

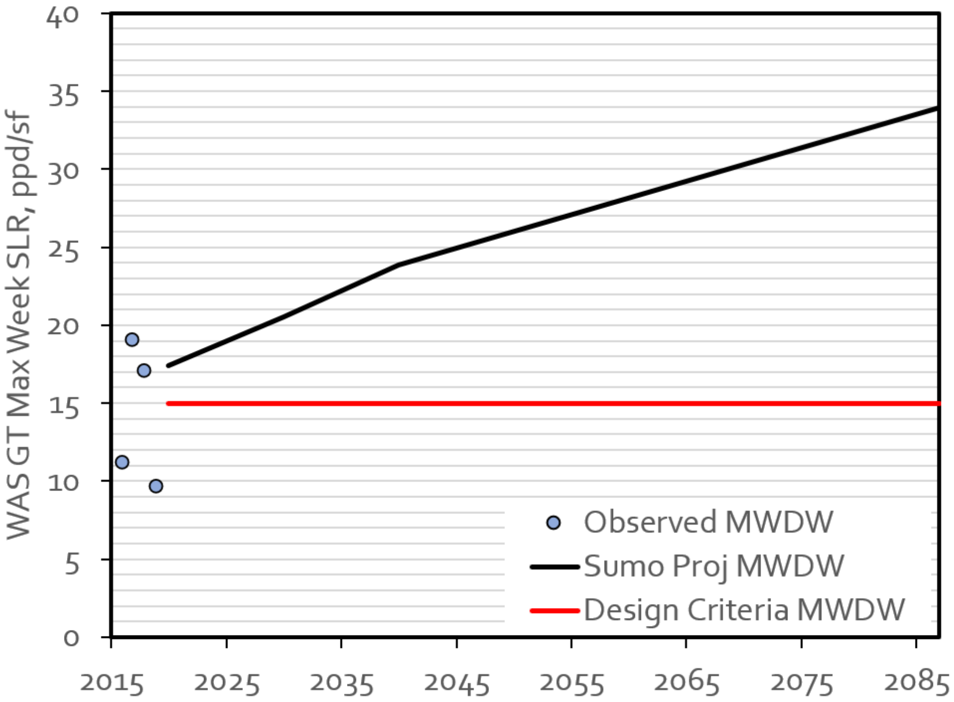


Figure 12.5 WAS/CHS Pre-Thickening Capacity – Gravity Thickener; Dry Weather Max Week

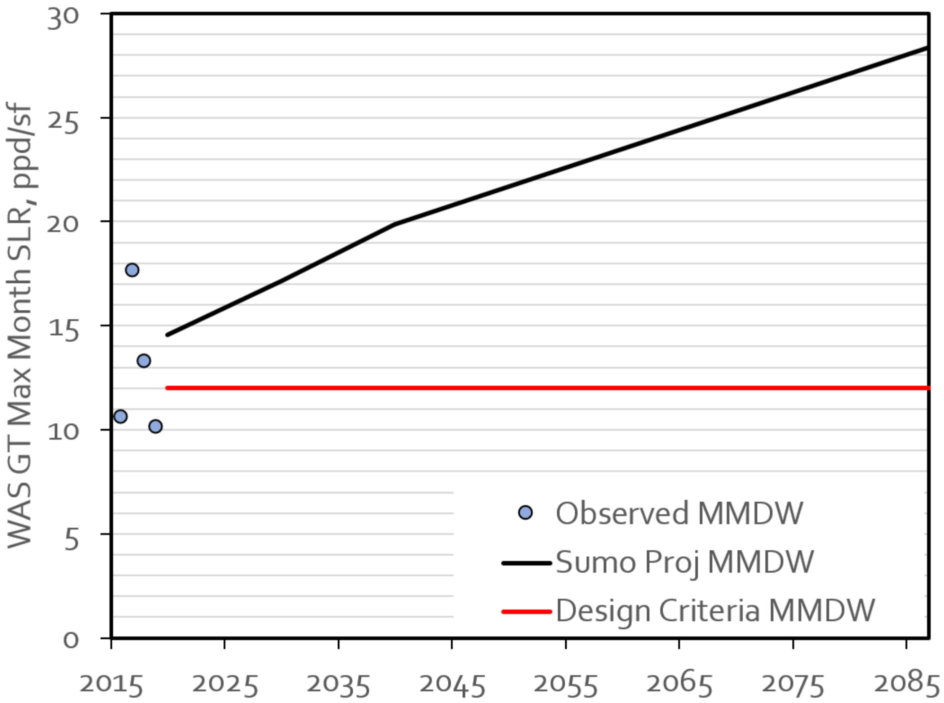


Figure 12.6 WAS/CHS Pre-Thickening Capacity – Gravity Thickener; Dry Weather Max Month

12.3.1.2 Rotary Drum Thickeners

Two RDTs will replace GT-2. The design criteria and proposed operating strategy for the RDT system were described in the WASSTRIP Improvements Predesign Report (Jacobs, 2019). The RDTs will continuously pre-thicken WAS to produce the stream fed to the PRT to release phosphorous. This stream will then be fed to the existing TCs for post-thickening. Since the typical TS concentration of thickened sludge from an RDT (5 percent) exceeds the ideal PRT TS thickness (1.5 percent), the plan is to thicken a portion of the WAS and blend the TWAS with WAS to achieve the ideal concentration for feed to the thickening centrifuges (1.5 percent). This capacity analysis of the RDT-based WAS thickening process assumes bypassing 37 percent of the WAS around the RDT based on the following assumptions:

- The WAS TS concentration equals 0.7 percent which is the average concentration over the last three years.
- The RDT TWAS TS concentration equals 5 percent and the RDT capture equals 95 percent (Jacobs, 2019).
- Ideal PRT TS concentration equals 1.5 percent (Jacobs, 2019).

The limiting criterion for the RDT capacity is the hydraulic loading rate, which is 400 gpm per RDT (or 200 gpm per RDT drum). With both of the new RDTs in service, this corresponds to a total hydraulic loading rate of 800 gpm, which is well above both current and projected 2040 max week WAS flows requiring thickening (so that the blended TWAS total solids concentration is equal to 1.5 percent), as shown in Figure 12.7. With one drum out of service, the remaining three drums (combined 600 gpm) will be capable of providing sufficient capacity to effectively thicken max month WAS flows through buildout, as shown in Figure 12.8. Additionally, with one drum out of service, the remaining three drums will be capable of providing sufficient capacity to effectively thicken the max week WAS flows through approximately the year 2065. Note that in both Figures 12.7 and 12.8, the WAS flows depicted reflect only the portion that is thickened on the RDT, not the total WAS flow.

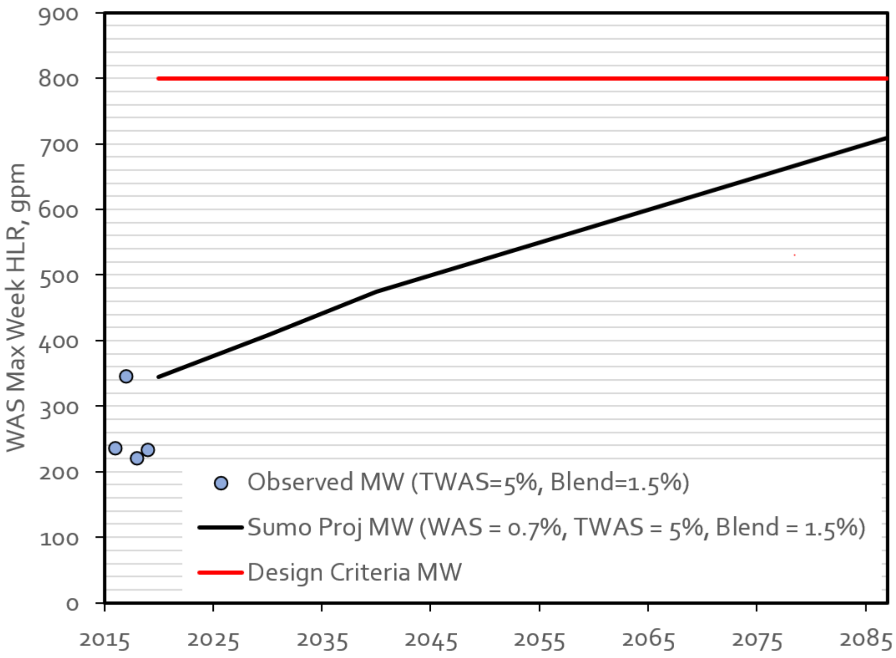


Figure 12.7 WAS/CHS Pre-Thickening Capacity – All Rotary Drum Thickeners in Service; Max Week

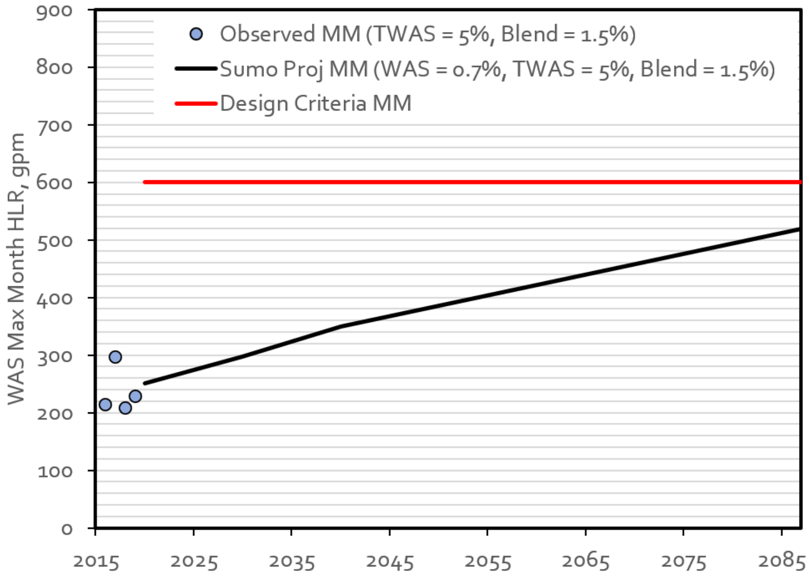


Figure 12.8 WAS/CHS Pre-Thickening Capacity – Three RDT Drums in Service; Max Month

12.3.2 WAS Release Tank

The TWAS (bypassed WAS and thickened WAS) is sent to the PRT tank, where it is allowed to react for 24 to 30 hours to allow phosphorus release for recovery via Ostara. The existing PRT has an area of 3,064 square feet and a side water depth of approximately 25 feet for a total volume of approximately 570,000 gallons. The District sets the operating depth of the tank to maintain the hydraulic retention time (HRT) at approximately 24-hours. At a design TWAS concentration of 1.5 percent TS, the projected PRT feed flow will remain below the value that would reduce HRT below the 24-hour HRT criterion through buildout (assuming the full tank volume), as shown in Figure 12.9. Note that with the PRT project, this tank will be replaced with a new tank in one of the existing DC1 digesters. The volume of a DC1 digester is approximately 707,000 gallons which is greater than the current PRT volume, thus providing sufficient capacity through buildout.

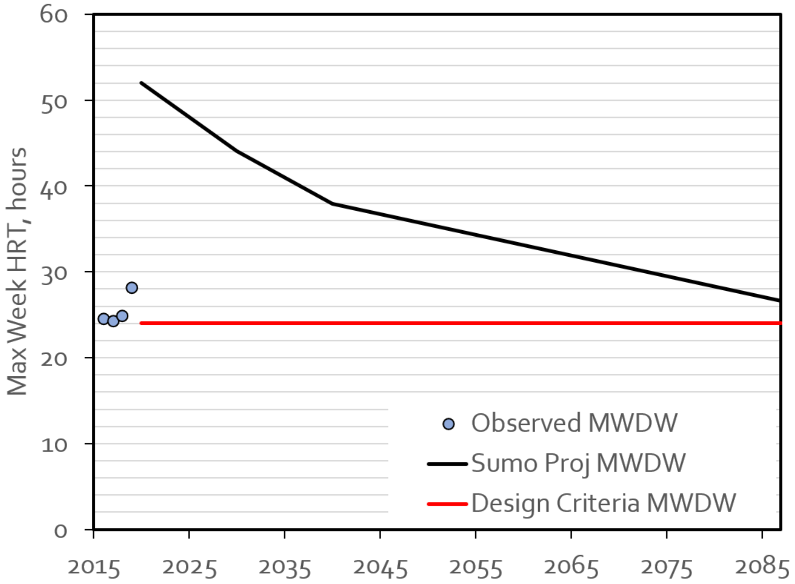


Figure 12.9 PRT Capacity

12.3.3 WAS Post-Thickening

After the PRT and prior to anaerobic digestion, TWAS is thickened again in the TCs. The WAS Post-Thickening processes include the TCs and the WAS'ate storage.

12.3.3.1 Thickening Centrifuges

The TCs are rated at 150 gpm each, operated for 22 hours per day, 7 days per week. At a typical TWAS concentration of 1.5 percent TS, and with two of three available machines in operation, the result is a thickening feed capacity of 300 gpm. This capacity is sufficient for thickening current and projected 2040 TWAS MWDW flows, as seen in Figure 12.10. Under max week wet weather (MWWW) conditions, when optimized operation of the PRT is not as critical, the District could choose to operate the PRT process at concentrations thicker than 1.5 percent (in 2017, the MWWW flow to the thickening centrifuges was 2.2 percent). Alternatively, the projected 2040 MWWW TWAS flow can be thickened with the assumed PRT TS concentration of 1.5 percent with two of the three centrifuges through 2026 after which point, all three centrifuges would be required for MWWW loads. Only two centrifuges are required through 2040 to thicken the MMWW load.

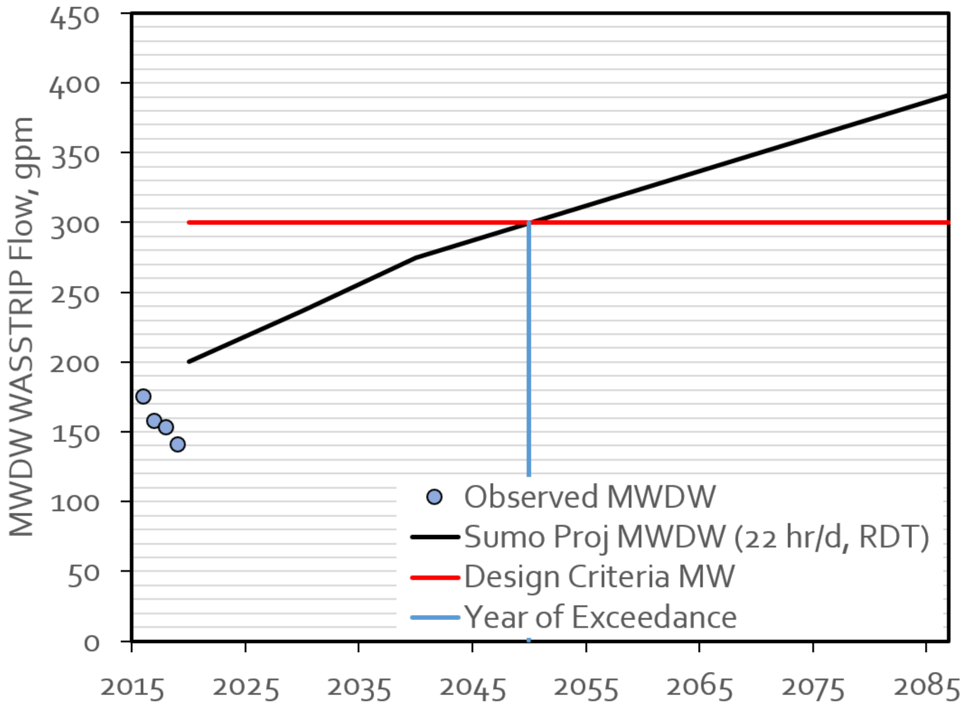


Figure 12.10 WAS Post-Thickening - Centrifuge

12.3.3.2 WAS'ate Storage

Centrate from the thickening centrifuges (WAS'ate) flows to a 20,000-gallon centrate storage tank where the WAS'ate is then fed continuously to the SRF for phosphorous recovery. Thus this tank operates as a wide spot in the line to help equalize centrate flows between centrifuge thickening and the SRF which have different feed rates and runtimes. While the tank is not typically emptied and then refilled in full during normal operations, this analysis assesses the capacity of the tank in terms of how long it would take to fill the tank, if empty, under current and future centrifuge feed flows, assuming TWAS is thickened from 1.5 percent TS to TTWAS at

5.5 percent TS. This analysis thus provides a way to understand the magnitude of the change in available storage over time, with the understanding that actual operations are more complex. Under current MWDW TWAS flows, the tank takes approximately 2.4 hours to fill. The fill time decreases to approximately 1.8 hours to fill in 2040, as seen in Figure 12.11. Under MWWW conditions, WAS and TWAS flows can be greater than during the dry weather season. During the wet weather season, when optimum performance of the PRT is not as crucial, the District could operate the PRT at a higher TS concentration to decrease WAS'ate flows and maintain fill times similar to the dry weather season. Otherwise, if maintaining the target PRT TS concentration of 1.5 percent, the WAS'ate fill time is projected to drop to 1.3 hours during the MWWWFs. The District does not have a specific design criterion for fill time of this tank. Hence, this fill time represents the operational buffer that might be available should the tank be emptied. This analysis also provides information to help the plant understand when changes to how thickening and the SRF are run need to be made (e.g. run the thickening centrifuges at a lower rate for a longer period of time to avoid overflowing the tank).

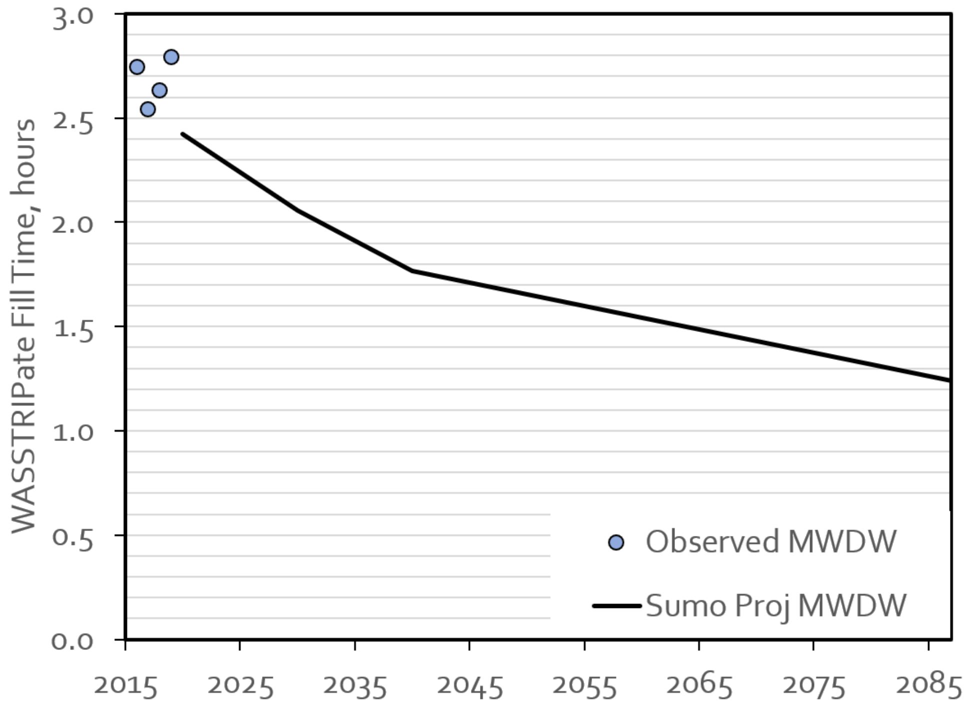


Figure 12.11 WAS Thickening Centrifuge Centrate Storage Capacity

12.4 Anaerobic Digestion and Digested Sludge Storage

TPS and TTWAS are combined and anaerobically digested. This section discusses capacity of the digester feed tanks, anaerobic digestion and digested sludge storage processes.

12.4.1 Digester Feed Tanks

TTWAS is pumped from the TCs to the digester feed tanks. Just upstream of the feed tanks, TTWAS is combined with TPS from GT underflow. Both streams are combined in the pipe and then mixed in the digester feed tanks.

Mixers in the tanks operate to maintain a relatively uniform sludge blend. Each tank has a volume of 14,150 gallons. The max month combined sludge flow into the tanks under wet weather conditions is currently about 153,000 gpd, with the flow expected to be 210,000 gpd in 2040. One tank in service provides 2.2 hours of mixing time, whereas both tanks in service provide approximately 4.4 hours of mixing time in 2020. At projected 2040 hydraulic loads, the max month wet weather mixing times are expected to be reduced to 1.6 hours for a single tank in service and 3.2 hours with both tanks in service. The District does not have a specific design criterion for mixing time in these tanks, but the available mixing time should be sufficient for uniform mixing. While there is no industry standard mixing time, generally one to four hours is long enough to provide a wide spot in the line and to ensure sufficient mixing. Any longer, and it is possible that the sludge will start to digest in the feed tank.

12.4.2 Anaerobic Digesters

Due to the complicated nature of the anaerobic digestion process with the co-digestion of FOG, this section describes in more detail the background, design criteria and capacity assessment of the anaerobic digestion process.

12.4.2.1 Background

The anaerobic digestion process consists of five tanks housed in two digestion complexes. DC1 has four tanks, each with 63-foot diameter and 30-foot sidewall depths. Each digester has an effective digestion volume of 707,000 gallons. Of the four tanks, one is used as the DSHT, another is slated for use as a PRT, leaving two digesters that act as redundant capacity to one large digester in Digester Complex 2 (DC2). The DC1 digesters are not typically in service due to age and operating issues with system components, including the digester mixers.

When used, the DC1 digesters are fed sequentially by the digester feed pumps. Digested sludge from these digesters overflows into the DSHT, where it can be held for feed directly to the dewatering centrifuges. Alternatively, the DC1 sludge can overflow from DSHT1 into the digester feed tanks for transfer to DC2 and additional retention time. One disadvantage of this flow path is that the sludge discharges into the digester feed tanks, releasing CO_2 and changing the pH such that struvite can form on the tank mixer impeller and the digester feed pumps.

DC2 has two 80-foot-diameter digesters with 35-foot sidewall depths. Each digester has an effective digestion volume of 1,300,000 gallons. While these two digesters typically operate in parallel, they can be operated in series, with the second digester acting as a holding tank. Digested sludge from DC2 is pumped to the DSHT 1 by the associated digested sludge pumps. The District typically operates with only the two digesters in DC2. The digesters in DC1 are maintained as redundant capacity to allow a digester in DC2 to be taken out of service for maintenance. These two DC1 digesters maintained as redundant capacity also provide additional digested sludge storage capacity. For this capacity analysis, the plant's normal operation scenario was assumed: both DC2 digesters in service for digestion with two digesters in DC1 remaining as backup.

12.4.2.2 Design Criteria

Design criteria for the anaerobic digesters based on SRT and VSLR were used to assess digestion capacity. At the maximum month condition, with all digesters in service, the SRT should be a minimum of 15 days as is required by the 503 regulations for Class B biosolids. The VSLR criterion is less discrete, especially when accounting for co-digestion of external feedstocks with municipal solids. However, $VSLR_{IS}$ ranges include 0.1 to 0.16 lb VS/cf-d (WEF Manual of Practice No. 8, 5th Edition) and 0.1 to 0.15 lb VS/cf-d (WEF Solids Process Design and Management,

2012) for mesophilic high-rate anaerobic digestion. These values provide guidance, but it is possible that slightly higher $VSLR_{IS}$ values could be sustained given the appropriate conditions, sludge characteristics, and ancillary processes. For the capacity assessment, a maximum $VSLR_{IS}$ of 0.16 lb VS/cf-d was used, but capacity implications of values up to 0.18 lb VS/cf-d were also examined.

The plant has been accepting external feedstock, primarily FOG, for co-digestion with IS for several years. When co-digesting easily digested feedstock like FOG, higher overall VSLR values can be sustained but a balance of IS and FOG is necessary to maintain process stability. Operational input from other facilities practicing FOG co-digestion indicates that keeping FOG-based VS load at 30-35 percent, maximum, of the total VS load maintains process health and avoids operational upsets like foaming. From 2016-2019, the plant has historically fed FOG at rates that range from 10-29 percent of total VS load under maximum month conditions. The digestion process has remained healthy under these conditions, so the plant's operating history does not provide a maximum limit for FOG loading. Theoretical limits based on chemical oxygen demand (COD) have also been proposed, but these have remained difficult to track regularly due to the difficulty in obtaining representative samples from the highly variable FOG source. From plant experience, VS-based tracking remains the most practical option. Hence, a VS -based maximum loading rate of 0.23 lb VS/cf-d for indigenous sludge and FOG co-digestion that balanced operational experience and theory was determined and used for the capacity assessment.

This value was determined through the incorporation of the following:

- $VSLR_{IS}$ of 0.16 lb VS/cf-d.
- Digester stability research conducted by Cook et al. in 2017 (Cook, Skerlos, Raskin, and Love. "A stability assessment tool for anaerobic codigestion". Water Research, 112, pp. 19-28, 2017). This study considered digester stability relative to the composition of organic loads; namely, the contributions to loading from lipids, carbohydrates, and proteins. The results were plotted in a ternary diagram (Figure 12.12) where green regions represent the most stable operations. A key conclusion of this research was that stability strongly correlates to COD-based protein loads and that stability drops off if protein contributions are less than approximately 16 percent or higher than 39 percent.
- Theoretical COD-to-VS ratios for lipids, carbohydrates, and proteins:
  - Lipids – 2.91 lb COD:lb VS.
  - Protein – 1.53 lb COD:lb VS.
  - Carbohydrate – 1.07 lb COD:lb VS.
- Theoretical fractionation of IS by lipids, carbohydrates, and proteins:
  - Lipids – 26 percent by mass on COD basis; 13 percent by mass on VS basis.
  - Protein – 39 percent by mass on COD basis; 38 percent by mass on VS basis.
  - Carbohydrate – 35 percent by mass on COD basis; 48 percent by mass on VS basis.
- Assumption that FOG is 100 percent lipids.
- Comparison of theory-based VS load from sludge vs FOG to operational experience.

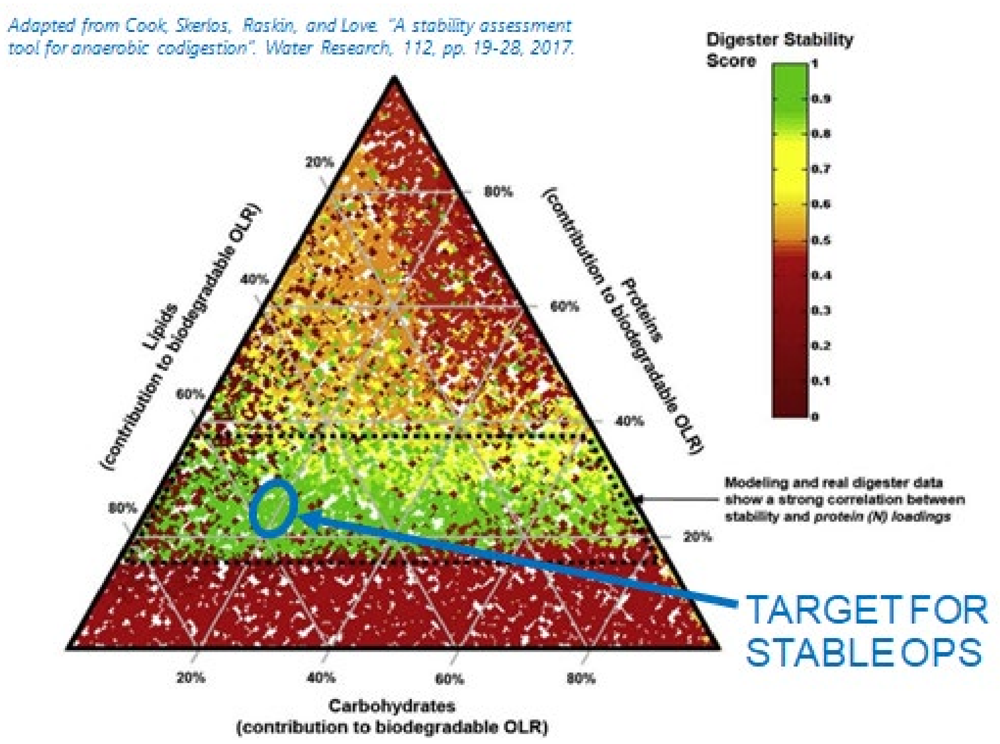

Adapted from Cook, Skerlos, Raskin, and Love. "A stability assessment tool for anaerobic codigestion". Water Research, 112, pp. 19-28, 2017.

Figure 12.12 Ternary Diagram for Digester Stability (Adapted from Cook et al. 2017)

As shown in Figure 12.12, the highest concentration of green, stable operations is where COD-based organic loads are comprised of approximately 20 percent protein, 20 percent carbohydrates, and 60 percent lipids. With this as the target for COD-based organic loads in a co-digestion application and through the use of the COD-to-VS ratios and IS fractionation noted above, the maximum contribution to the IS+FOG organic load from FOG was determined. The result from this analysis showed that stable operations should be maintained if VSLR_{IS} = 0.16 lb VS/cf-d, VSLR_{FOG} = 0.07 lb VS/cf-d, and $\text{VSLR}_{\text{IS+FOG}}$ = 0.23 lb VS/cf-d. At these values, the COD-based mass fractions of the total organic load from protein, carbohydrates, and lipids would be 21 percent, 19 percent, and 60 percent, respectively.

This organic loading split results in 30 percent of the total VS load contributed by FOG, which supports the operational experience indicating stable operations when FOG is limited to 30-35 percent of total VS load. Furthermore, the District conducted a dewaterability study of increased FOG loading that included determination of organic loads on the ternary diagram (Figure 12.13). In this study, Digester 2 was loaded more heavily for FOG than Digester 1 (roughly 100 percent more FOG on a 20-day average flow basis), and operational stability parameters such as volatile acid-to-alkalinity ratios were monitored. Digester 2 remained stable during the study at the FOG loads introduced, including the high FOG contributions which resulted in values on the ternary diagram within the target zone described above. Relative to its primary goal, the study did not find a decrease in dewaterability from the FOG loads investigated.

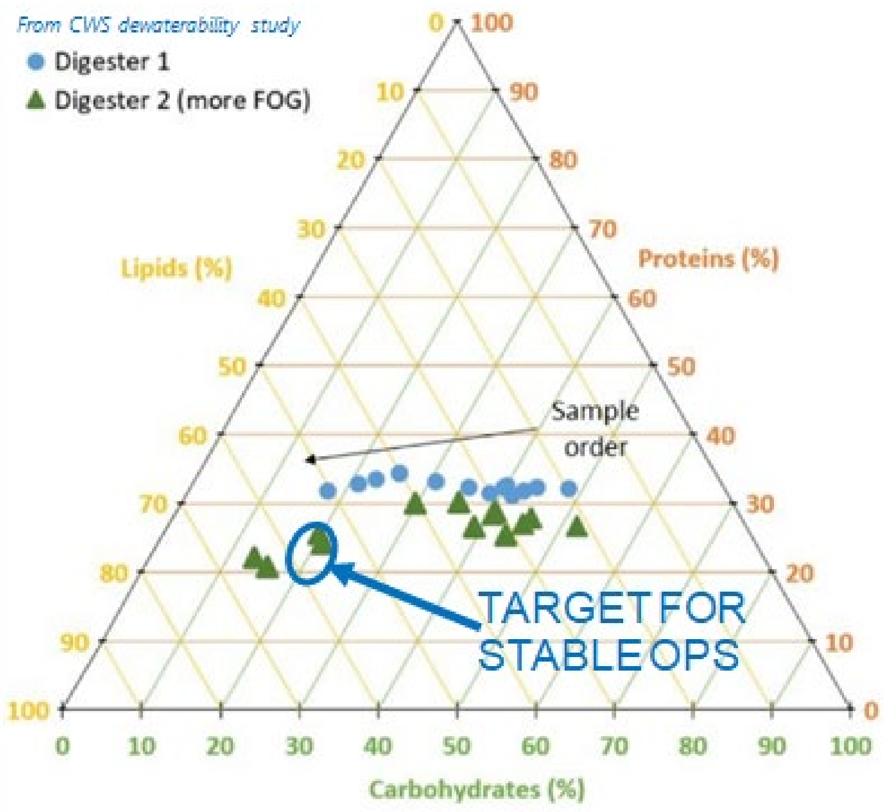


Figure 12.13 Organic Load Contributions from District FOG Dewaterability Study Plotted on Ternary Diagram

12.4.2.3 Capacity Assessment

For the SRT-based assessment, capacity was projected for IS digester feed that included TPS thickened to a concentration of 5 percent TS, and TTWAS thickened to a concentration of 5.5 percent. Operating data showed that the PS thickeners and thickening centrifuges can reliably and consistently attain these solids concentrations, and the existing TPS and TTWAS pumps have pressure capacity to pump these streams to the digesters. Digester loading projections also included FOG, assuming that the average FOG flow from 2016 to 2019 remains constant in the future and continues to be fed to the digesters along with increasing IS flows. The retention times for IS only and for FOG+IS were then assessed to project the timeframe for when the SRT-based design criterion of 15-days would be exceeded.

At these constant volumetric FOG loading rates and the TPS and TTWAS solids concentrations noted above for projected increases in the associated flows, the projected SRT for the FOG+IS case exceeds the minimum 15-day max month SRT by 2021, as seen in Figure 12.14. This indicates a need to either increase digester IS feed solids concentration to increase SRT, or to reduce FOG flows to the digesters as IS flows increase over time. If FOG co-digestion were stopped completely, leaving only IS feed to the digesters, the digesters would have sufficient capacity to meet the 15-day max month SRT requirement through 2028, as seen in Figure 12.14. The District receives significant tipping fee revenue from the FOG acceptance program and produces renewable energy with the biogas generated in digestion. Hence, the District intends to continue its FOG acceptance program, and other means of increasing SRT are required.

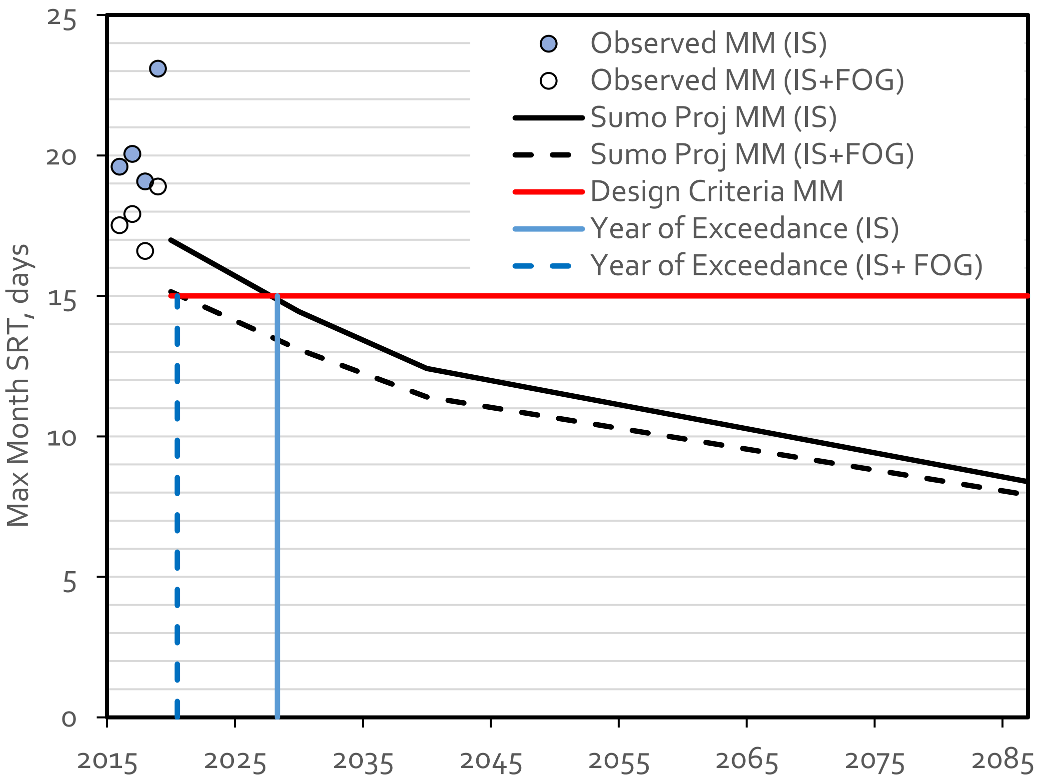


Figure 12.14 Anaerobic Digestion Capacity with 5% TPS and 5.5% TTWAS; Max Month SRT

SRT-based capacity was projected for digester feed with TTWAS at 7 percent solids concentration, which when combined with 5 percent TPS, would result in an overall digester feed solids concentration of 6 percent. If the thickening centrifuges could consistently and reliably achieve 7 percent solids concentration, the TTWAS pumps would require replacement to pump this material to the digesters due to increased pressures. However, the thicker solids concentration would reduce hydraulic load on the digesters and the existing digesters would provide sufficient capacity until approximately 2027, as shown in Figure 12.15.

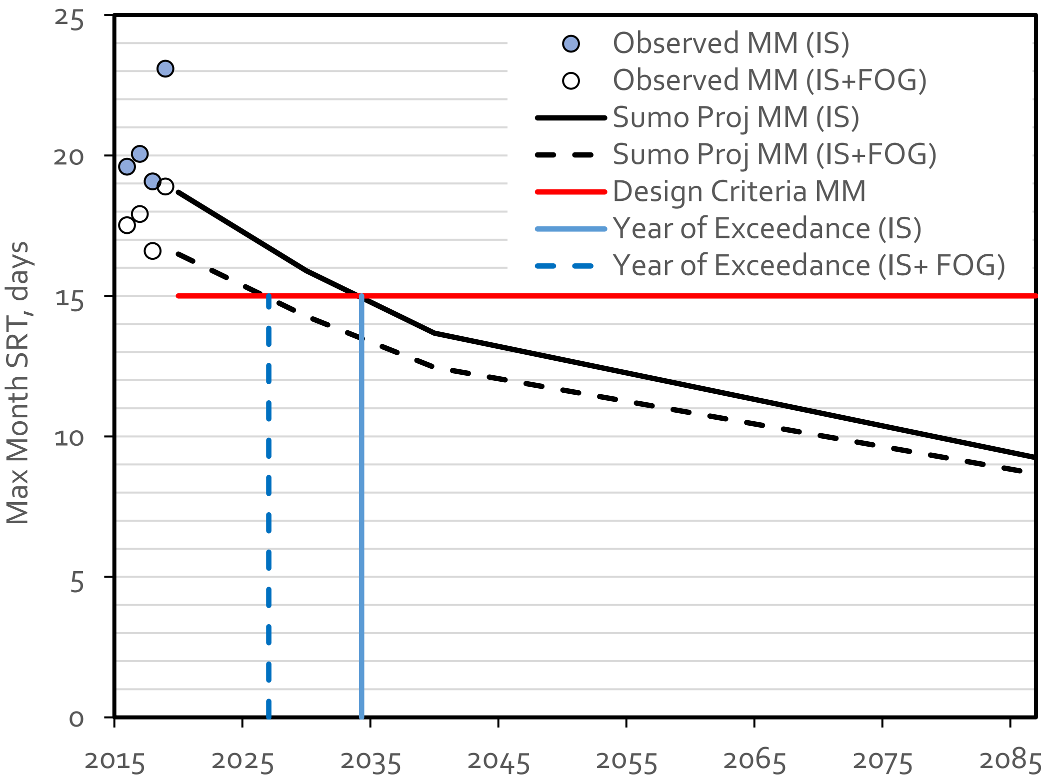


Figure 12.15 Anaerobic Digestion Capacity with 5% TPS and 7% TTWAS; Max Month SRT

Figure 12.16 shows that the $VSLR_{IS}$ is expected to exceed the 0.16 lb VS/cf-d max month criterion by 2024. When FOG is added to the digester, the max month VSLR is increased proportionally up to a maximum FOG contribution of 30 percent.

The plant has not historically operated at a $VSLR_{IS}$ much higher than 0.16 lb VS/cf-d for sustained periods as is shown in Figure 12.17, and high loading rates can cause instability in the digestion process. However, it is not known for the plant's specific digester operations and feed characteristics how high a sludge-based $VSLR_{IS}$ could be accommodated over a sustained period while retaining process stability. While a $VSLR_{IS}$ of 0.18 lb VS/cf-d could provide sufficient digester capacity through 2031 if it were able to be sustained stably, the SRT criterion actually governs before that, and both the SRT (with 7 percent TTWAS solids concentration) and $VSLR_{IS}$ criteria indicate that new digestion capacity will be needed by 2027, at which point the projected $VSLR_{IS}$ would be approximately 0.17 lb VS/cf-d.

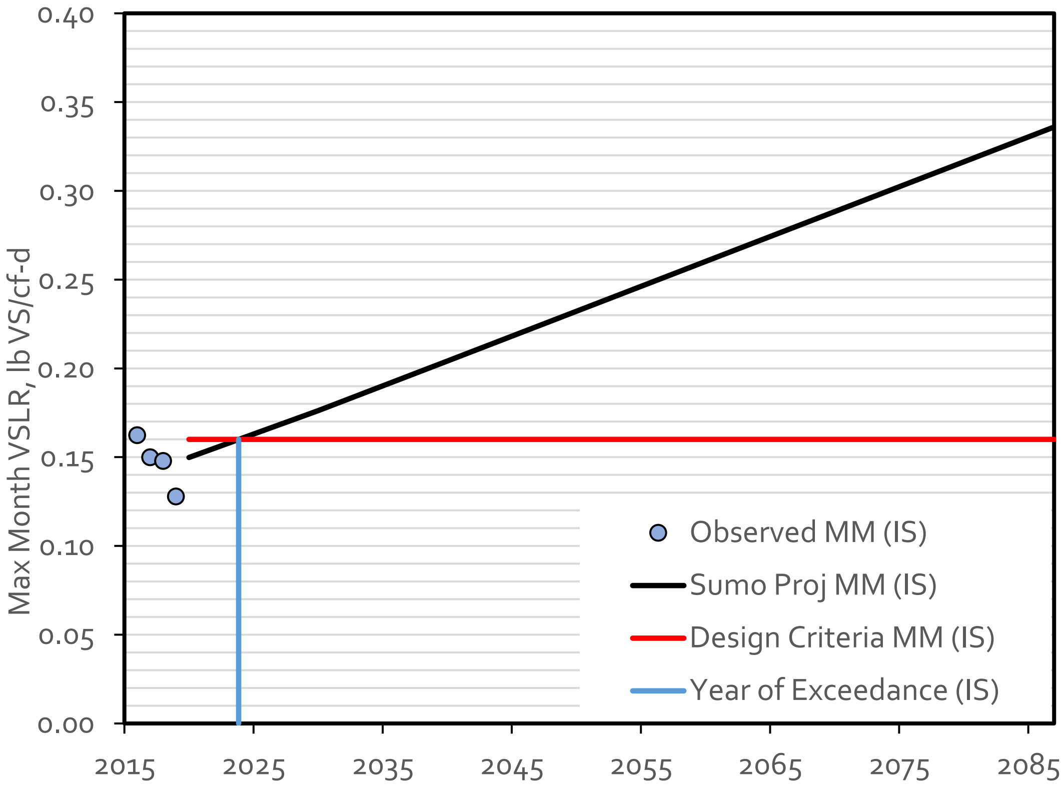


Figure 12.16 Anaerobic Digestion Capacity; Volatile Solids Loading Rate

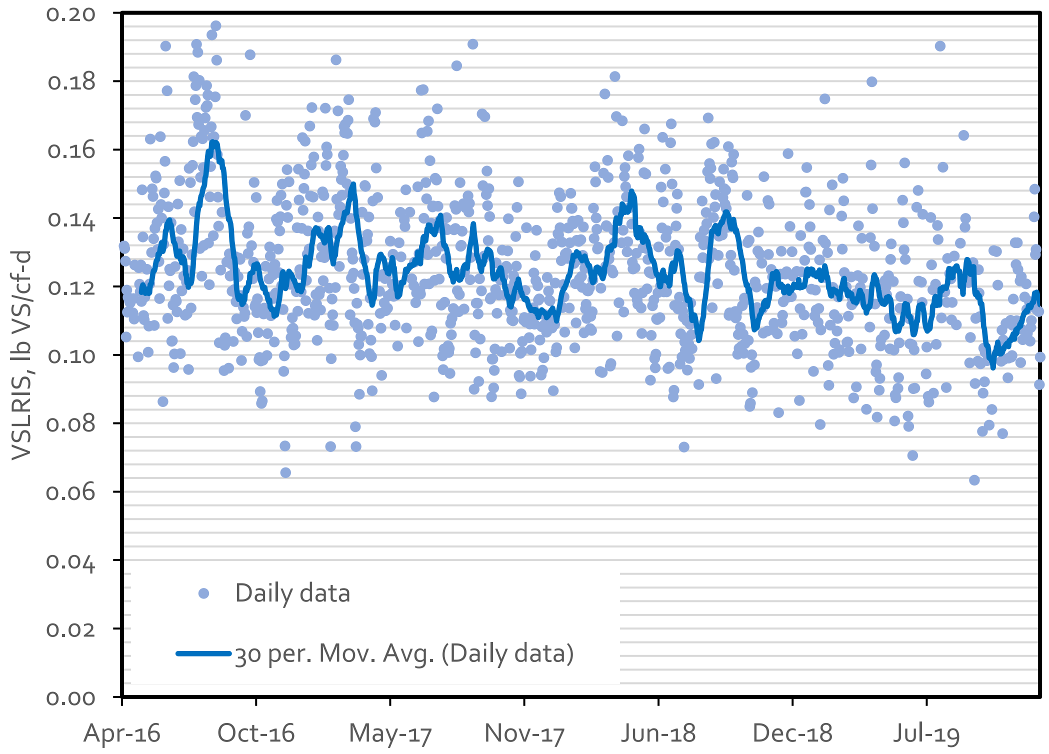


Figure 12.17 Anaerobic Digestion Historic VSLR

Based on the analysis conducted, additional digestion capacity will be needed by 2027 if a $VSLR_{IS}$ of 0.17 lb VS/cf-d can be accommodated stably and the combined digester feed can be thickened and pumped consistently at a solid concentration of 6 percent solids. This combined digester feed solids concentration can be achieved if TPS is consistently produced and pumped with a minimum solids concentration of 5 percent and if TTWAS can be thickened and pumped consistently at 7 percent solids concentration. To achieve this TTWAS solids concentration, the existing TTWAS pumps will need to be tested as soon as possible to ensure that they can pump a 7 percent solids to avoid the SRT-based capacity shortfall that could occur as soon as 2021 if TTWAS cannot be thickened and pumped consistently at solids concentrations higher than 5.5 percent. If testing indicates that the TTWAS pumps are unable to perform consistently and reliably at this solid concentration, they will require replacement as soon as possible. Indigenous sludge-based VSLR and digester stability will need to be monitored and if instability starts to occur when $VSLR_{IS}$ exceeds 0.16 lb VS/cf-d, additional digestion capacity may be necessary prior to 2027.

To reflect current equipment and limitations, analyses for the solids processes downstream of the digesters assume that the TTWAS concentration is maintained at 5.5 percent. The impacted downstream processes include digested sludge storage, centrifuge dewatering, and cake storage.

12.4.3 Digested Sludge Storage

Digested sludge storage is provided within DC1. Currently, two of the four tanks in DC1 are required to reliably back up a digester in DC2 should it need to be taken out of service for maintenance or if there is a digester upset. One additional DC1 tank will be repurposed as a PRT. This leaves one tank within DC1 solely for the purpose of digested sludge storage, as was assumed in the 2017 Biosolids Master Plan. However, the two DC1 digesters used for digester redundancy can also be used as additional digested sludge storage capacity and are in fact more frequently used this way, particularly in the winter months if the gorge freezes over and biosolids cannot be hauled to their end use. Less frequently, these two DC1 digesters are also used as additional sludge storage capacity if the dewatering centrifuges are not operational. Thus during these two scenarios – in the winter when the gorge freezes or if all the dewatering centrifuges are not operational – the plant would not be able to take a DC2 digester offline. While this poses a small risk, it is how the plant currently operates and plans to continue operating in the future. To mitigate this risk, the plant does have the ability to store biosolids offsite. According to the 2017 Biosolids Master Plan, the plant also retains the option of storing biosolids on District facility properties by mixing the biosolids with sawdust and stockpiling. These biosolids would then be land applied once field and/or transportation conditions allow.

With the volume of three tanks in DC1 allocated to the DSHT, there is sufficient capacity to meet the 7-day criteria for digested sludge storage through 2078, as seen in Figure 12.18. As noted above, operating with three DC1 digesters as digested sludge storage would not allow the plant to take a DC2 digester out of service, adding risk to plant operations. If instead only one DC1 digester is available for digested sludge storage, the plant currently has around 4 days of storage. In 2040 and at buildout the plant would have 3 days and 2 days of storage, respectively.

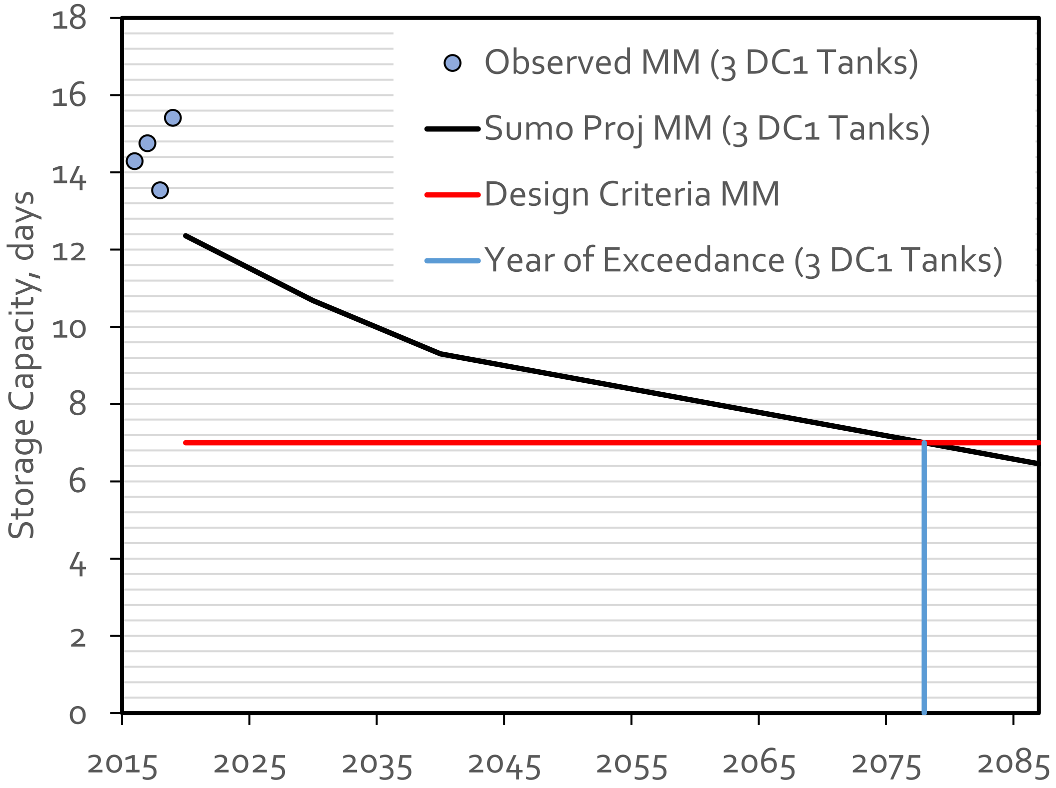


Figure 12.18 Digested Sludge Storage Capacity with Three DC1 Tanks

12.5 Dewatering

Anaerobically digested sludge is dewatered prior to hauling for land application. The centrate from the dewatering centrifuge is equalized in a holding tank prior to being fed to the Ostara process. The dewatered cake is held in a silo prior to being hauled off-site. This section discusses the dewatering centrifuges, centrate holding tank and BS storage.

12.5.1 Dewatering Centrifuges

The centrifuge dewatering design criteria are based upon the equipment's specifications and maximum month loading conditions. The mass loading criterion is 3,000 pounds (lbs) TS per hour per machine at max month conditions. The maximum hydraulic load to each machine is 240 gpm at max month conditions, assuming the corresponding feed solids concentration is 2.5 percent TS. If the solids concentration decreases below 2 percent TS, the unit's hydraulic loading rate of 300 gpm may govern. It is also assumed in this analysis that the centrifuges are operated 22 hours per day, 6 days per week. Current loads actually allow less dewatering run time with higher instantaneous loading rates, but this criterion was used to normalize current operations to projected conditions.

Based on this operating schedule, the dewatering centrifuges are capable of meeting both criteria under current and projected 2040 hydraulic and solids loads with full redundancy, as seen in Figures 12.19 and 12.20, respectively.

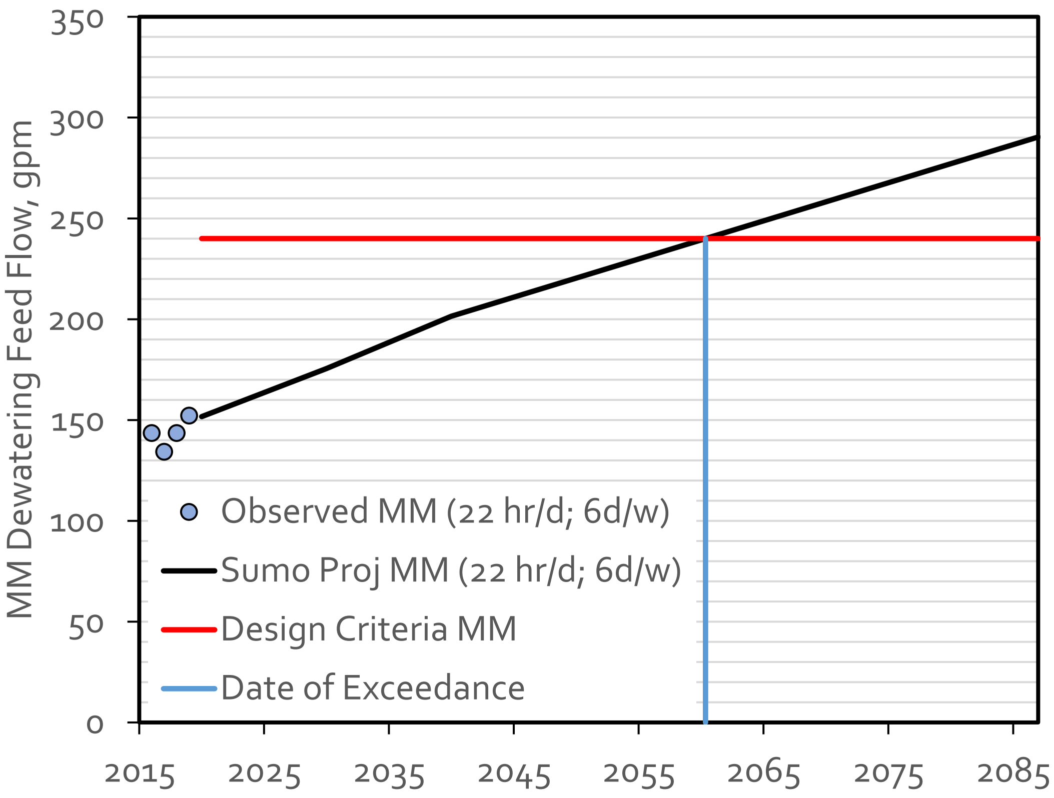


Figure 12.19 Dewatering Centrifuge Capacity; Max Month Hydraulic Loading

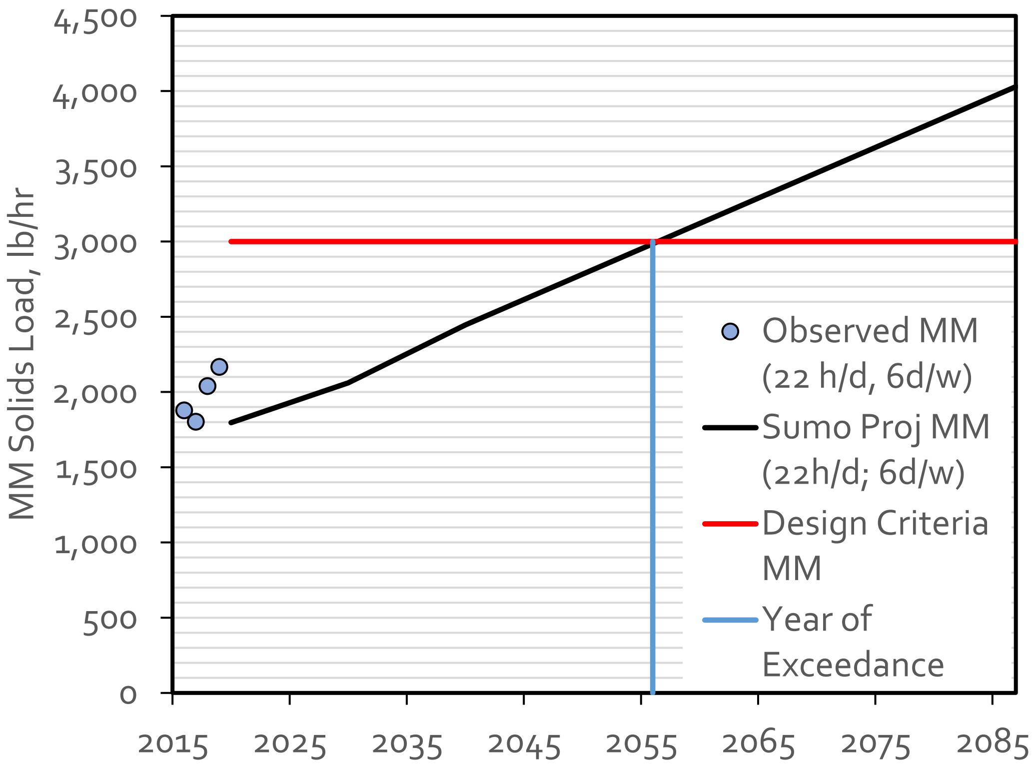


Figure 12.20 Dewatering Centrifuge Capacity; Max Month Solids Loading

12.5.2 Dewatering Centrifuge Centrate Storage

Centrate from the dewatering centrifuges is stored in two 290,000-gallon tanks. Due to District's operational practices, it was assumed that the tanks had only 270,000 gallons of usable volume. It is assumed for the purposes of this analysis that projected dewatered cake is 21.5 percent TS based on what was demonstrated during performance testing of the new centrifuges at the centrifuge design capacity of 3,000 lb/hr. It is also assumed that the dewatering centrifuge captures 96 percent of solids in its cake. These projected dewatering performance values were used rather than historical data to reflect the impact of these new centrifuges. Based on the projected hydraulic loading to the dewatering centrifuges, it is expected that the time needed to completely fill the dewatering centrate storage tanks remains above the design capacity of three days until 2036, as seen in Figure 12.21. Because the District may reduce its centrate storage design criterion in the future, it does not currently plan on expanding the dewatering centrate storage capacity.

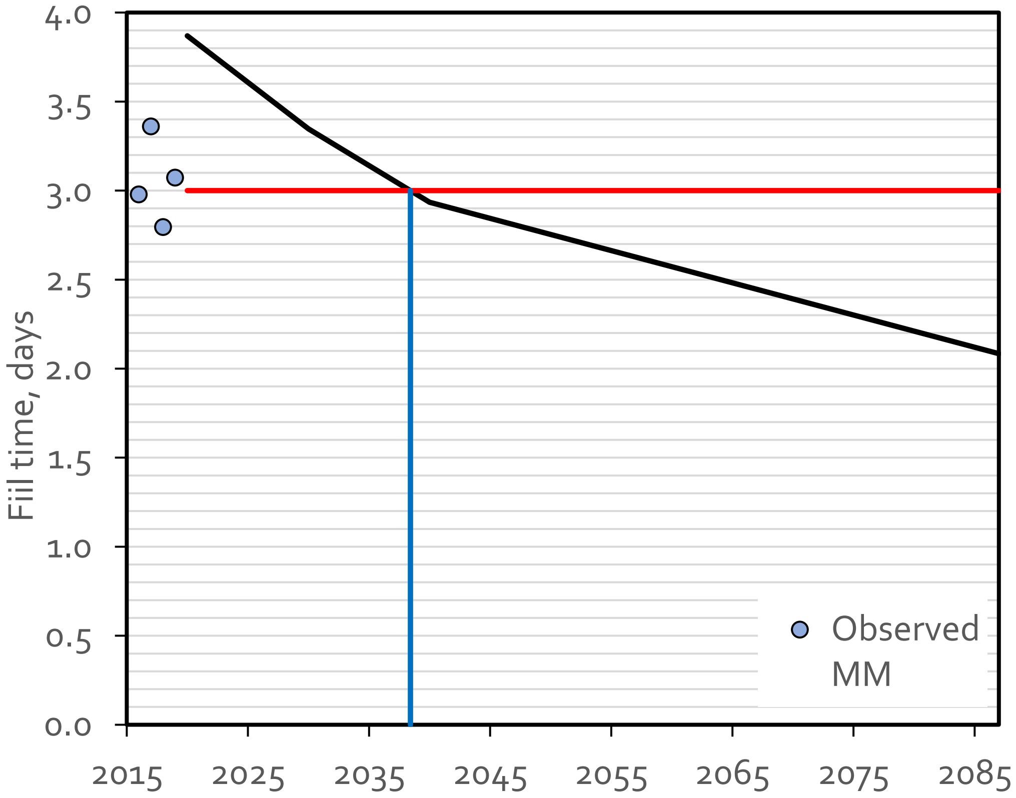


Figure 12.21 Dewatering Centrifuge Centrate Storage Capacity

12.5.3 Biosolids and Truck Loadout

There is a single dewatered biosolids silo with two hoppers, each with a volume of 2,740 cubic feet (cf). Based on operational data, a total of 130 wet tons of biosolids can be stored in the hoppers which is slightly more than the 120 wet tons given in the 2017 Biosolids Management Plan. The design criterion for biosolids storage is both hoppers combined can provide at least a full 24-hour day of sludge storage under max month conditions. This is less than the two-day design criteria assumed in the 2017 Biosolids Master Plan.

Based on these assumptions and the projected dewatered cake solids, the combined volume of both hoppers meets the 1-day storage time criterion for both current and projected 2040 max month conditions, as seen in Figure 12.22. Notably, the observed data falls below the projection line. This is due to lower cake solids concentrations in the observed data (16.75 percent - 18.23 percent) than what is used for the projections (21.5 percent).

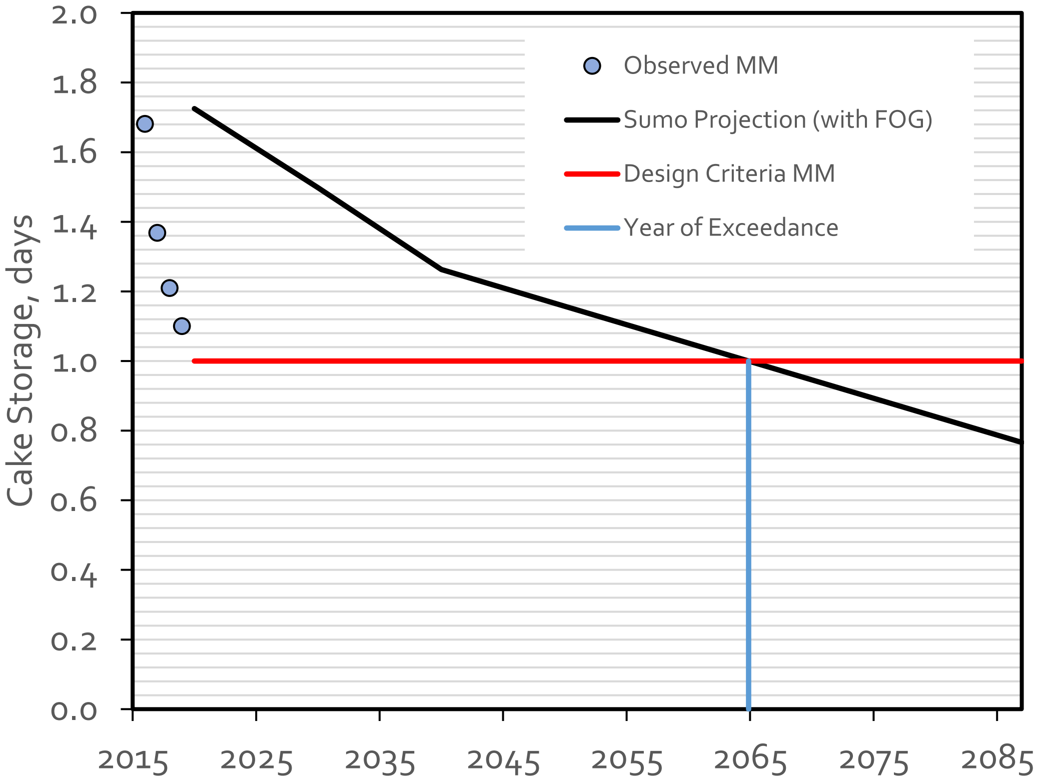


Figure 12.22 Cake Storage Capacity

12.6 Gas Conditioning and Cogeneration

Design criteria for the gas conditioning system and cogeneration engines are based on average annual biogas production rates. Excess biogas beyond the capacity of the gas conditioning / cogeneration systems can be used to fuel the plant boilers, or it can be flared. There are currently two cogeneration engines, each rated for 848 kilowatts (kW) and a heat recovery capacity of 3.3 million British thermal unit per hour (MMBTU/hr). The gas conditioning system includes one 460 cubic feet per minute (cfm) chiller, two 460 cfm gas booster blowers, and 690 cfm gas heat exchanger, hydrogen sulfide removal, and siloxane removal systems.

The biogas conditioning system chiller is sized to match the capacity of the cogeneration engines. Based on the plant's biogas characteristics, and the engine's efficiency, this translates to a biogas consumption capacity of approximately 230 cfm per engine, or 460 cfm total.

Figure 12.23 shows the total gas consumed as well as the gas consumed by each engine, both of which are operating close to capacity. Maximizing cogeneration capacity is the District's goal, so current operations show that the plant is close to achieving this goal. As biogas production increases with additional IS and constant FOG feed, the engines will be fully utilized and additional cogeneration and chiller capacity will be required to increase gas utilization through cogeneration. However, the District is interested in other biogas utilization options after full engine utilization is realized.

The biogas production projection in Figure 12.23 was estimated by separately determining contributions from IS and FOG digestion. The biogas from IS digestion was estimated by assuming 60 percent volatile solids destruction of IS and a specific gas production of 15 cubic feet per pound (cf/lb) VS destroyed at average digester loading rates. These values were then backed out of the historical gas production data to estimate the contribution associated with FOG digestion. The specific biogas yield for FOG feed based on this estimation method was approximately 15 cubic feet per gallon (cf/gal) FOG fed and the associated specific methane yield was approximately 10 cf/gal FOG fed. It should be noted that these values for FOG-based biogas and methane yield differ from values found by the District during early FOG bench scale testing. The specific biogas yield for IS was very close to the associated values found during that same testing. Figure 12.23 assumes IS flows increase over time while FOG flows remain at a constant feed rate, consistent with current FOG flows.

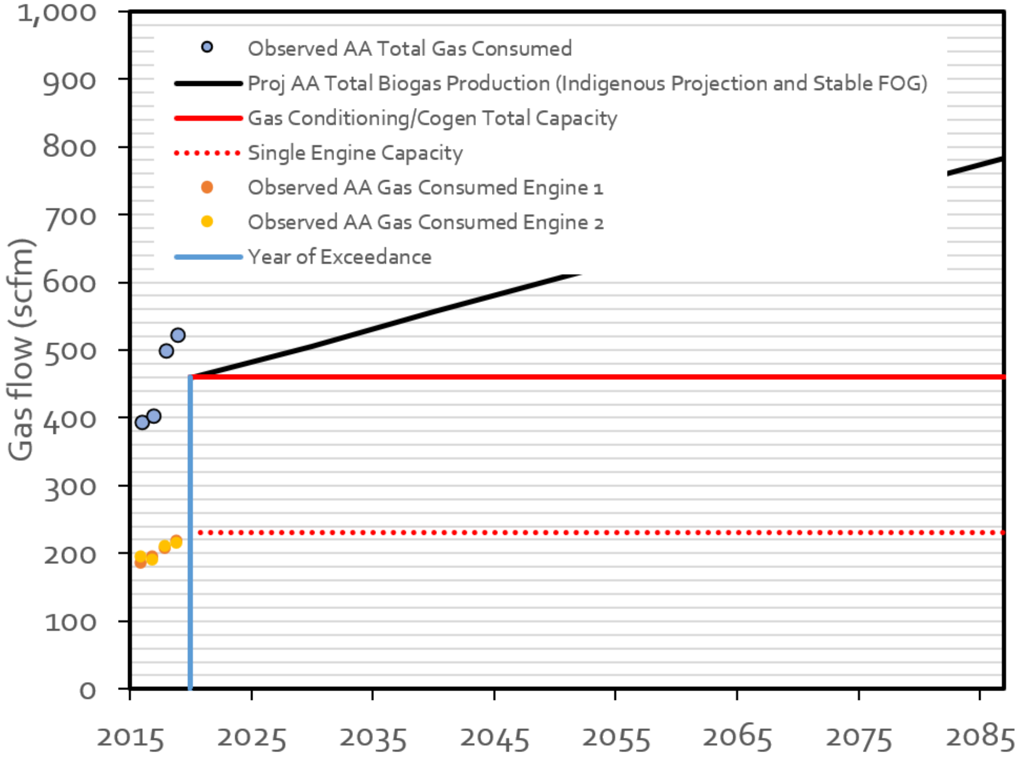


Figure 12.23 Gas Conditioning and Cogeneration System Capacity (Average Annual Biogas Production)