City of FRESNO
DEPARTMENT OF PUBLIC UTILITIES

BIOSOLIDS MASTER PLAN
at the Fresno/Clovis Regional Wastewater Reclamation Facility

Final // December 2019

MATERIAL MATTERS, Inc.

carollo

City of Fresno

BIOSOLIDS MASTER PLAN

FINAL | December 2019

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Abbreviations

ºC	degrees Celsius
ºF	degree(s) Fahrenheit
~	approximately
µg/L	micrograms per liter
µg/m3	micrograms per cubic meter
AACE International	Association for the Advancement of Cost Engineering International
AB	Assembly Bill
AC	acre
ADC	alternative daily cover
ADD	average day demand
ADM	anaerobically digestible material
ADMMF	average-daily maximum month
AFY	acre-feet per year
Air District	San Joaquin Valley Air Pollutions Control District
ASP	aerated static pile
ATCM	Airborne Toxic Control Measure
BACT	Best Available Control Technology
BFPs	belt filter presses
BFT	BioForce Tech
BMP	Biosolids Master Plan
BOD	biochemical oxygen demand
BTU	British Thermal Unit
Btu/lb	British thermal unit per pound
Ca	calcium
CAA	Clean Air Act
CalRecycle	California Department of Resources Recycling and Recovery
CAPCOA	California Air Pollution Control Officers Association
CAPs	criteria air pollutants
CARB	California Air Resources Board
Carollo	Carollo Engineers, Inc.
CASA	California Association of Sanitary Agencies
CCR	California Code of Regulations
CDFA	California Department of Food and Agriculture
CEPT	Chemically enhanced primary treatment
CEQA	California Environment Quality Act
CFR	Code of Federal Regulations

CH_4	methane
CI	Compression-Ignition
City	City of Fresno
CO	carbon monoxide
CO_2e	CO_2 equivalent
Coalition	Bay Area Biosolids Coalition
COD	chemical oxygen demand
CPI	Consumer Price Index
CVC	Central Valley Compost
CWEA	California Water Environment Association
CY	cubic yards
DAFTs	dissolved air flotation thickeners
DEP	Department of Environmental Protection
DT	dry tons
DWQ	Division of Water Quality
EI&C	Electrical Instrumentation and Controls
EQ	Class A Exceptional Quality
ERCs	Emission Reduction Credits
FBIs	Fluidized bed incinerators
Fe	iron
FOG	fats, oils, and grease
FRP	fiberglass reinforced plastic
FSSD	Fairfield-Suisun Sewer District
FTE	full time employee
g/bhp-hr	gram per brake horsepower-hour
GHG	greenhouse gas
Global GAP	Global Good Agricultural Practices
gpcd	gallons per capita day
gpd/ac	gallons per day per acre
gph	gallons per hour
gpm	gallons per minute
H_2S	hydrogen sulfide
HA	health advisory
HC	hydrocarbon
hp	horsepower
HPA	high pressure Air
hr	hour
HRT	hydraulic retention time
K	potassium

KOH	potash
lb	pound
lb/cu ft	pounds per cubic feet
MAD	mesophilic anaerobic digestion
MBR	membrane bioreactor
MCL	maximum contaminants levels
MCRT	mean cell residence time
MDD	maximum day demand
MDRR	Mt. Diablo Resource Recovery
MG	million gallons
mg/L	milligrams per liter
mgd	million gallons per day
MHFs	multiple hearth furnaces
MinDD	minimum day demand
MinMD	minimum month demand
MLSS	mixed liquor suspended solids
Mm	millimeter(s)
MMBtu/hr	million British thermal units per hour
MMD	maximum month demand
MOP	Manual of Practice
MRM	multiple reaction monitoring
msl	mean sea level
N	nitrogen
N_2O	nitrous oxide
NAAQS	National Ambient Air Quality Standards
NaOH	caustic soda
NMHC+NOx	non-methane hydrocarbon plus nitrogen oxides
NPDES	National Pollutant Discharge Eliminations System
NSPS	Standards of Performance for Stationary Compression-Ignition Internal Combustion Engines
NSR	Federal New Source Review
O&M	operation and maintenance
OIG	Office of Inspector General
OMRC	Organic Material Recovery Center
OMRI	Organic Materials Review Institute
OSHA	Occupational Safety and Health Administration
P	phosphorus
PFAS	perfluoroalkyl substances
PFOA	Perfluorooctanoic Acid

PFOS	Perfluorooctane Sulfonate
PFRP	process to further reduce pathogens
PGF	Power Generation Facility
PHD	peak hour demand
PLC	programmable logic controller
PM	particulate matter
ppmv	parts per million as volume
ppt	parts per trillion
PR	pathogen reduction
PR	pathogen reduction
PS	primary sludge
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PSRP	process that significantly reduce pathogens
PTO	Permit-to-Operate
RAS	return activated sludge
RDRS	Recycling and Disposal Reporting System
RFQ	Request for Qualifications
RNG	Renewable Natural Gas
RO	reverse osmosis
rpm	rotations per minute
RWQCBs	Regional Water Boards
RWRF	Fresno-Clovis Regional Wastewater Reclamation Facility
SB	Senate Bill
SCADA	supervisory control and data acquisition
SCAP	Southern California Alliance of Publicly Owned Treatment Works
SCAQMD	South Coast Air Quality Management District
SGN	size guide number
SIP	California State Implementation Plan
SJVAPCD	San Joaquin Valley Air Pollution Control District
SKFCSD	Selma-Kingsburg-Fowler County Sanitation District's
SO_2	sulfur dioxide
SRT	solids retention times
SSI	sewage sludge incinerator
SWRCB	State Water Resources control Board
TACs	toxic air contaminants
THP	thermal hydrolysis pretreatment
TPY	tons per year
TS	total solids

TSS	total suspended solids
TVS	total volatile solids
TWAS	thickened waste activated sludge
UC	University of California
US EPA	United States Environmental Protection Agency
UV	Ultraviolet
VA:Alk	volatile acids to alkalinity ratio
VAR	vector attraction reduction
VOC	volatile organic compound
VS	volatile solids
VSin	volatile solids concentration of the solids that enter the digestion process
VSLR	volatile solids loading rate
VSR	volatile solids reduction
VSS	volatile suspended solids
WAS	waste activated sludge
WDRs	Waste Discharge Requirements
WEFs	Water Environment Federation's
WRF	water reclamation facility
WT	wet ton
WTP	water treatment plant
WWTP	wastewater treatment plant
yd^3	cubic yards

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EXECUTIVE SUMMARY

The Fresno-Clovis Regional Wastewater Reclamation Facility (RWRF) produces over 250 wet tons of Class B biosolids each day resulting from its existing solids treatment processes. For decades, the City of Fresno has relied on mesophilic anaerobic digestion to produce Class B biosolids that a third-party hauls away for further processing and beneficial use. The City sought to complete a forward-looking biosolids master plan (BMP) to assess whether, and how, the current biosolids management operations should be modified or changed in support of the City's desire to diversify its biosolids management, promote biosolids beneficial use, address risk mitigation, and reduce operating costs.

The project team used a step-wise approach to develop the City's BMP, starting with an assessment of the existing solids system to determine performance and remaining capacity of each process (Chapter 1). Population growth and solids loads were projected through 2040 and used to identify potential process constraints and/or capacity shortfalls. The team identified current operational deficiencies/challenges and developed recommendations for addressing each.

The project team concurrently assessed existing and potential future biosolids related regulations (Chapter 2) to identify drivers for various solids management approaches, particularly the effect on end-use or disposal options for biosolids. Such changes could impact operating costs, and the team identified options for how the City could address those potential changes.

Additionally, the team identified emerging technologies, including gasification, pyrolysis, (pre-digestion) thermal hydrolysis, and (post-digestion) thermo-chemical hydrolysis to compare against the current mesophilic anaerobic digestion practices and more conventional drying and composting Class A options. To assess whether the final products of these processes could be beneficially used, a regional market assessment was performed (Chapter 3). The team contacted local industries including farmers, agricultural goods suppliers, and those involved with land reclamation to gauge level of interest, acceptable price points, concerns, and aesthetic preferences for each industry and each type of product (Class B cake, Class A cake, liquid Class A soil amendment, dried pellets, biochar, etc.).

The processing technology alternatives were then evaluated in a two-step process (Chapter 4). The team first performed an initial (pass/fail) screening with a shortlist of criteria to eliminate alternatives deemed infeasible or impractical relative to the City's goals. The remaining viable alternatives then underwent a detailed financial and non-financial criteria evaluation. The financial evaluation considered capital and O&M costs in a life cycle cost analysis. Non-financial evaluation criteria included specific topics related to technical, social, and environmental considerations, such as ease of O&M, biosolids product marketability, and impacts on greenhouse gas emissions. The team conducted a pairwise comparison process with City staff to determine the relative importance of each evaluation criterion and develop weighted scores to rank each alternative for every evaluation parameter. The team based its short- and long-term recommendations for biosolids management on the overall evaluation results.

This BMP allowed the City to holistically assess the solids handling processes and identify areas for improvement, potentially gaining efficiencies now and lower capital and O&M costs in the future. Furthermore, the City now has a plan with options to minimize cost, mitigate future risks, and recover resources in a manner that matches its vision and goals.

The following sections summarize each step of the BMP discussed in the above introduction.

ES.1 Capacity and Performance of Existing Solids Processes

Chapter 1 presents the solids processes capacity and performance assessment, which was conducted to determine whether the existing solids system has sufficient capacity to handle projected loads, and to identify current operational deficiencies/challenges. It also presents the current and future solids flows and loads used as a basis for the capacity assessment, and the current solids handling operating costs.

This section summarizes the key findings from the capacity and performance assessment. For more details of the assessment and on operating costs, see Chapter 1. Table ES.1 summarizes the findings from the capacity and performance assessment, by process area.

Table ES.1 Capacity and Performance Assessment Findings Summary

Process	Sufficient Capacity - Current	Sufficient Capacity – Future	Modifications to Address Capacity Constraints	Modifications to Improve Performance
PS and WAS Pumps	Yes	Yes, except under peak future conditions	Under peak future conditions, one of the two standby B-side WAS pumps may need to operate as a duty pump.	N/A
DAFTs	Yes	Yes, except under peak future conditions	Under peak future conditions, both DAFT units may need to operate in parallel, and backup polymer pumps need to operate as duty.	• Optimize polymer selection to improve solids capture in DAFT. • Replace TWAS float pumps to handle higher solids concentrations.
ADM Receiving Station	Yes	Yes	N/A	• Change tank indicator light programming to promote more even use of the three stations. • Charge a higher tipping fee or reject loads that are too dilute.
Anaerobic Digestion	Yes	No	Additional large digesters will be needed in 2024, 2032, and 2038, under the current digester feed configuration. To delay capital improvements, the feed configuration could be changed to feed ADM to all the digesters, in which case additional digesters would be needed in 2026, 2033, and 2039, or the digester feed solids concentration could be increased.	• Change feed configuration to allow all digesters to receive ADM. • Resolve struvite issues by inspecting the digester 3 to 8 booster pump suction lines and replacing with glass-lined ductile iron if needed, or by implementing a phosphorus recovery system, which would address struvite issues plant-wide
Biogas Utilization	No	No	An additional flare and an additional boiler are needed. Projects are currently undergoing to add additional capacity for each.	• The City is undergoing negotiations with PG&E for a pipeline injection project.
Dewatering	Yes	Yes	N/A	• Optimize polymer selection for the centrifuges to improve solids capture and reduce polymer usage • Optimize polymer selection for the BFPs to improve cake solids concentration • Monitor run times for each of the dewatering units • Monitor solids capture efficiency of the BFPs
Biosolids Conveyance and Storage	Yes	Yes	N/A	• To resolve issues with the centrifuge cake pumps, the City is testing the impact of lubrication rings in different locations. Polymer should be used rather than water for maximum pressure reduction.

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ES.1.1 Current and Future Solids Loads

Data from 2013 to 2017 were analyzed to determine the current solids quantities and characteristics for both the influent wastewater and delivered ADM. Solids loads were projected through year 2040 using population projections. Table ES.2 summarizes the current and future solids production.

Table ES.2 Current and Projected Future Solids Production

Parameter	Units	Current Conditions	2040 Projections
Primary Sludge	lb/day	129,000	198,000
Thickened Waste Activated Sludge	lb/day	76,500	124,000
ADM	lb/day	20,500	49,000

ES.1.2 Primary and Waste Activated Sludge Handling

Two primary sludge (PS) pump stations pump from the primary clarifiers to the anaerobic digesters. Four WAS pump stations pump from the three sides of the secondary treatment processes and the MBR units to the DAFTs. The PS pumps and WAS pumps have sufficient capacity under current and future conditions, with plenty of standby pumps to provide adequate backup during maintenance. The only limitation identified was that under peak future conditions, one of the two standby (B-side) WAS pumps may need to operate as a duty pump.

ES.1.3 Sludge Thickening

Primary sludge is thickened in primary clarifiers. The WAS is thickened in DAFTs. There are currently four DAFTs, but the City plans to demolish the two older, smaller units because their equipment is not functional and their capacity is not needed. The DAFT units operate for roughly one month at a time before switching between duty and standby. Neat emulsion polymer is combined with non-potable water in polymer blending units, and injected into the WAS pipe just upstream of the DAFT units. Floating sludge is skimmed from the top of the DAFT and heavier bottom sludge is pumped from the bottom. The combined floating and bottom sludge are referred to as Thickened Waste Activated Sludge (TWAS).

The DAFTs have sufficient capacity based on both solids and hydraulic loading under current and most projected conditions. The maximum daily solids to the DAFTs is projected to be slightly above the design criteria in 2040. Under those conditions, the City may continue operating a single DAFT unit and the solids capture efficiency may decrease, or the City could opt to operate both DAFT units concurrently. The projected maximum polymer usage exceeds the capacity of the existing duty polymer pump. Additional polymer pumps may also need to operate during future peak flows. The TWAS pumps have sufficient capacity under current and future conditions.

The performance assessment identified that the solids capture is lower than the design criteria, and that the TWAS float pumps experience issues when the TWAS concentration is greater than five percent. To address these issues, two modifications were identified. Rather than using the same polymer for both thickening and dewatering, the City could optimize polymer selection for thickening to improve solids capture. The City could replace the TWAS float pumps to handle higher solids concentrations.

ES.1.4 ADM Receiving Station

The RWRF receives Anaerobically Digestible Material (ADM) including fats, oils, and grease (FOG) and a variety of food wastes from food processing plants, commercial kitchens, and industrial plants for co-digestion. The ADM receiving station includes three 15,000-gallon fiberglass reinforced plastic (FRP) tanks, rock trap grinders, chopper pumps, ADM transfer pumps, and automatic fill, mixing, and drain valves.

The system components have sufficient capacity for current and future operating conditions, assuming the contribution of volatile solids from ADM compared to PS and TWAS (10 percent plant-wide) would remain constant. However, there may be operational constraints with regards to hauling schedules and tank availability. If ADM load frequencies continue to increase, it is recommended to pursue fixed hauler schedules to minimize wait times and allow for more consistent operation.

Two potential performance improvements were identified. Because of its location, ADM Tank No. 1 and its associated equipment have experienced higher use than the other loading stations. The City could alter the tank indicator lights programming to show tank availability sequentially to promote more even use and wear of the three stations. Some haulers bring very dilute loads with low potential biogas production. The City is considering options to address this issue by either implementing a sliding scale tipping fee for each hauler based on the approximate projected biogas production, or rejecting haulers that do not meet a minimum VSS and/or COD concentration.

ES.1.5 Anaerobic Digestion

PS, TWAS, and ADM are sent to anaerobic digesters for stabilization. The RWRF has 13 anaerobic digesters, with slightly varying configurations. The PS and TWAS are fed to all operating digesters, whereas the ADM is fed only to Digesters 9 through 13. The digesters are mixed and operated at mesophilic temperatures for stabilization. Digested sludge (biosolids) is conveyed to one of two of the smaller digesters (Digesters 1 or 2) that operate as biosolids storage tanks upstream of the dewatering system. Biogas is stored in the Digester 7 Dystor flexible membrane digester cover.

The capacity assessment identified that the digesters are limited by SRT rather than VSLR. Under the existing feed configuration where only Digesters 9 through 13 receive ADM, new large digesters are needed in 2024, 2032 and 2038 to meet the day 15 day SRT pathogen reduction requirement. As a way to delay capital improvements, the feed configuration could be changed to feed ADM to all the digesters. This would delay the need for additional digesters to 2026, 2033, and 2039. Another way to delay capital improvements is to increase digester feed solids concentration by optimizing operation of the primary clarifiers and DAFT.

The performance assessment identified that the digesters are operating well, with appropriate SRT, VSLR, and volatile acids to alkalinity ratio. Two modifications to improve performance and resolve operational issues were identified. In addition to delaying capital improvements, changing the ADM feed configuration to allow ADM feed to all digesters would also improve performance. Struvite issues were identified in the booster pump suction lines for Digester Nos. 3 through 8, but not for Digester Nos. 9 through 13, which are glass lined. The City could inspect the lining of the pipes at issue and replace with glass lined ductile iron pipe if necessary, to prevent struvite buildup. Alternatively, the City could implement a phosphorus recovery system that would reduce struvite issues in both digestion and dewatering process areas.

ES.1.6 Biogas Utilization and Management

At this time, the majority of biogas produced at the plant is flared to prevent digester gas from venting to the atmosphere. A portion of biogas is consumed to operate a boiler, which is used for digester heating. Biogas used to be used in gas turbines, but these were decommissioned in 2016. The RWRF installed a biogas conditioning system in 2012 to produce biomethane for pipeline injection. The City is in the process of negotiating with PG&E on a pipeline injection project.

The permanent flare does not have sufficient capacity to handle all the biogas produced in the event that all other equipment is not operational. The RWRF installed a temporary flare to ensure sufficient capacity, and is beginning a project to address the need for additional flare capacity. The City has experienced drops in digester temperature, indicating boiler capacity limitations. The City is currently developing a Request for Qualifications (RFQ) to install new boilers.

ES.1.7 Dewatering

Biosolids are routed from the holding tanks, either Digester 1 or 2, to the dewatering facility by two variable speed vertical centrifugal transfer pumps. The biosolids dewatering facility contains five older belt filter presses and three newer centrifuges each fed by a separate progressive cavity feed pump and dedicated polymer feed pumps. The polymer system consists of two bulk polymer tanks, two polymer mix tanks, and two polymer feed tanks, each with dedicated mixers and pumps. Each stage is equipped with duty and standby equipment. The current polymer type is optimized for the BFPs. Roughly 30 percent of all dewatering feed flow is sent to the BFPs while 70 percent is sent to the centrifuges.

The BFPs, centrifuges, and associated feed pumps, and polymer system have sufficient capacity for current and future conditions.

The performance assessment identified that centrifuge cake has a higher percent solids than the design range, while BFP cake solids is below the design range. To address this issue, new polymer types could be tested for the BFPs to confirm suitable dose and cake performance. BFP solids capture is not monitored. The centrifuge solids capture is often below the design range of 95 percent and polymer consumption for the centrifuges is above the design criteria. The new polymer contract optimized for centrifuge operation should help decrease centrifuge polymer consumption and increase percent solids capture.

It is recommended that the City monitor equipment run times for each of the dewatering units to make future analyses more accurate. We also suggest that the City monitor the solids capture efficiency of the belt filter presses to determine actual performance and provide a basis for optimization.

ES.1.8 Biosolids Conveyance and Storage

Dewatered biosolids (cake) is transported to one of two storage silos where it is then transferred to trucks for beneficial use through compost or land application. Cake from the centrifuges is transported by screw conveyors into cake pumps, and pumped to the storage siloes. Cake from the BFPs is transported by belt conveyors. Cake from the BFPs can only be sent to Silo 2, whereas centrifuge cake can be sent to either silo.

The conveying equipment and storage silos have sufficient capacity to handle the current and future cake loads.

Plant staff has had and continues to have repeated issues with the centrifuge cake pumps. The City is testing the impacts of lubrication rings in different locations on the cake pump discharge piping. Polymer should be injected into the lubrication rings rather than water for maximum pressure reduction.

ES.2 Current and Future Regulations

Chapter 2 presents a comprehensive review of current and anticipated future regulations regarding solids treatment and end use, as well as air emissions, and analyzed how these regulations could potentially impact the RWRF. This summary gives a brief overview of the air and greenhouse gas (GHG) regulations, but mostly focuses on the biosolids and organic waste management regulations which are most pertinent to the BMP.

ES.2.1 Summary of Potential Regulatory Issues

Through the planning horizon of 2040, the RWRF will consider strategies to comply with current and developing (future) regulations. In general, the future regulations that have the greatest impact on the RWRF biosolids management planning are those requiring major process changes or additions. Table ES.3 summarizes solutions that can be implemented at the RWRF to comply with current and future potential regulatory issues.

Table ES.3 Summary of Potential Regulatory Issues and Solutions

Topic	Issue	Potential Solution
Biosolids	Landfilling of biosolids is becoming increasingly restricted and land application of Class B biosolids may become less restrictive (i.e., the County Ordinance banning land application may be lifted if the regulations under SB 1383 require it).	Diversify biosolids management to decrease risk and increase reliability of RWRF's biosolids management.
Air Emissions	New emissions monitoring and more restrictive emissions limits for CAPs and TACs may limit onsite biogas management options, which is closely linked to the anaerobic digestion process.	Plan for increasingly stringent emissions requirements and need for emissions control equipment for the digesters and stationary combustion units.
Greenhouse Gases (GHG)	While the RWRF is not seeking to expand its organic feedstocks it receives, WRFs are being looked at as part of the solution to managing organic waste diverted from landfills statewide (to reduce methane emissions at landfills). This may result in pressure being applied to the RWRF to accept diverted food waste, which could lead to additional GHG emissions reporting and management.	Monitor GHG emissions regulations and continue to track and weigh the costs and benefits related to accepting diverted food waste and/or contributing to other GHG related state mandates and goals.

ES.2.2 Wastewater Solids Regulations

ES.2.2.1 Current Regulations

Federal, state and local regulations determine whether biosolids can be beneficially used or must be disposed. Governing treatment of biosolids products is primarily the role of EPA (via 40 CFR Part 503) and the SWRCB (via the General Order). However, in California, local regulations (generally at the county level) have significantly limited beneficial use of biosolids.

At the federal level, 40 CFR Part 503, *Standards for the Use or Disposal of Sewage Sludg*e, governs biosolids management. The rule establishes biosolids quality standards based on three parameters: pathogen reduction (PR), vector attraction reduction (VAR), and pollutant (metals) concentrations. Depending on the pathogen reduction process, biosolids are categorized as Class A and Class B. For example, the RWRF currently produces Class B biosolids by meeting the PR requirement of 15 day SRT in mesophilic anaerobic digestion, and the VAR requirement of 38 percent reduction in volatile solids content. Pollutant concentrations are complied with through the industrial pretreatment program.

In addition to the requirements above, 40 CFR 503 provides guidance on best practices for land application of biosolids, provides site restrictions for each type of biosolids, and sets the requirements for monitoring, recordkeeping, and reporting.

At the state level, biosolids management is primarily regulated by California's State Water Resources Control Board (SWRCB), the Division of Water Quality (DWQ), and the nine Regional Water Boards. The RWRF is regulated under the Central Valley Regional Water Board. SWRCB's General Order goes beyond the requirements of 40 CFR 503 by requiring additional biosolids testing, soil testing, and groundwater sampling. The Central Valley Regional Water Board adopted the State's General Order.

The SWRCB and the RWQCBs generally recognize that Class A, Exceptional Quality biosolids products such as heat dried pellets, properly prepared composts, and liquid product from thermo-chemical hydrolysis are commercial products and their use is not regulated by the SWRCB. This is also the case for biochar, which is excluded by 40 CFR Part 503. In these cases, the California Department of Food and Agriculture (CDFA) is in charge of licensing these products as fertilizers.

Counties across California have developed local ordinances that have squandered beneficial use of biosolids, ranging from requiring conditional use permits or high minimum insurance to banning land application of all biosolids, regardless of quality. Fresno County, as well as the adjacent Kings County and Tulare County, have banned Class B biosolids land application.

ES.2.2.2 Future Regulatory Considerations

At the federal level, biosolids regulations are well established, with few changes anticipated in the planning horizon. In contrast, at the state level, anticipated changes to California's biosolids and organic waste regulations will influence biosolids management options, making the development and execution of a flexible management program essential. The following key trends are observed, and Table ES.4 summarizes specific bills relating to these trends and their potential impact on the RWRF.

- Concerns about microconstituent in biosolids may require additional monitoring of certain pollutants. PFAS related regulations may limit land application of biosolids.

- Recent litigation and legislation are overturning local ordinances banning or limiting land application of biosolids. This could open up more land application sites and beneficial use opportunities, closer to the RWRF.
- SB 1383 and other state assembly and senate bills are promoting landfill diversion of organics including food waste and biosolids. This could result in development of more anaerobic digestion and composting facilities, both in the public and private sector, increased codigestion of organics at WRFs with excess anaerobic digestion capacity, and an increase in compost and biosolids products in the market.
- CalRecycle, the State Water Board, and the California Air Resources Board (CARB) see co-digestion of food waste and fats, oils, and grease with sewage sludge at municipal WRFs as a key strategy for achieving reductions in methane emissions across the state more cost-effectively.
- Using biosolids and green waste as alternative daily cover (ADC) in landfills will no longer qualify as beneficial use and will instead be deemed disposal.
- The state is encouraging an increase in tracking and reporting of organic waste recycling and disposal (including sludge, biosolids, and digestate).

Table ES.4 Summary of Future and Potential Biosolids and Organic Waste Regulations

Regulation	Summary	Impact to RWRF	Status
Microconstituents			
Biannual review of 40 CFR Part 503	As part of the 2009 Targeted National Sewage Sludge Survey, the EPA found nine pollutants of potential concern: barium, beryllium, manganese, silver, 4- chloroaniline, fluoranthene, pyrene, nitrate, and nitrite. Limits for these compounds could be included in 40 CFR Part 503 in the future.	RWRF may be required to measure these nine compounds in their biosolids.	Potential future regulation
2019 EPA OIG Review of Biosolids Program	The main concern from the Office of Inspector General (OIG) is that chemical risk assessments have not been conducted for 352 pollutants found in biosolids and more research is needed to determine their safety. The EPA plans to conduct a risk assessment by 2022, and promulgate regulations as needed.	RWRF may be required to measure additional micro-pollutants in their biosolids.	Potential future regulation
Perfluoroalkyl substances (PFAS)	Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are substances used in a variety of industrial applications and household products that have been found to have negative impacts on human health at very low concentrations. The exposure pathway of greatest concern for biosolids is leaching of PFAS from biosolids land application sites to ground and surface waters used as drinking water sources. It is expected that California's SWRCB will require testing of groundwater at sites amended with biosolids in the near future.	Land application of biosolids may be limited or banned if PFAS concentrations in groundwater are found to be higher than the limits for safe drinking water.	Potential future regulation
Organic Waste Diversion and Land Application			
AB 845 (2012)	States that counties cannot pass ordinances banning importation of biosolids or any other solid waste based on its origin.	Elimination of local ordinances will open up additional land application sites.	Established
Overturn of Measure E and Measure X	Measure E in Kern County, banning importation and land application of Class B biosolids, was overturned in 2017. Measure X in Imperial County, banning importation of biosolids from other counties, was overturned in 2018.	Elimination of local ordinances will open up additional land application sites.	Established
SB 1383 (2016)	Requires the reduction of short-lived climate pollutants (including methane) to achieve *statewide* GHG reduction targets by 2030. Requires a regulation be developed and adopted by end of 2018, to accomplish 50 percent diversion of organics (including food waste and WRF solids and biosolids) from landfills by 2020 relative to 2014 levels and 75 percent diversion by 2025. Currently only anaerobic digestion and composting are considered landfill diversion. CalRecycle is making efforts to ensure markets for products (digestate and biogas). These include language in SB 1383 to overturn local ordinances limiting land application of biosolids, and a procurement requirement for compost and biogas.	May see increased competition for land application and composting sites. Elimination of local ordinances will open up additional land application sites. Entities that produce organic waste may seek to send their organic waste to the RWRF.	Final regulation: January 2020 Effective: 2022 Enforceable: 2024
AB 341 (2011)	Sets a goal that 75 percent of solid waste generated (including organics) be source reduced, recycled, or composted by the year 2020. Provides a platform for state agencies to consider WRFs as part of the solution to achieve this goal.	May see increased competition for land application and composting sites.	Deadline: 2020
SB 970 (2016)	Requires CalRecycle, when awarding a grant for organics composting or anaerobic digestion, to consider the amount of GHG emissions reductions that may result from the project and the amount of organic material that is diverted from landfills as a result of the project. This bill allows for larger grant awards to be given to large-scale regional integrated projects that provide cost-effective organic waste diversion and maximize environmental benefits.	More funding may be available for regional projects that provide cost-effective organic waste diversion that maximize environmental benefits.	Determined Per Project
AB 1826 (2014)	As of April 1, 2016, requires a business (commercial or public entity) or residential dwelling of five (5) or more units, generating a certain amount (starts at eight [8] CY and over time decreases to two [2] CY) of organic waste per week to arrange for recycling services. This bill requires phased implementation for the reduction of organic waste production and creates market certainty for the diversion of organic waste from businesses and multifamily dwellings to a recycling service (e.g., anaerobic digesters at WRFs).	Entities that produce organic waste may seek to send their organic waste to the RWRF.	Phased Implementation 2016 - 2020
Healthy Soils Initiative (2015)	Collaboration of state agencies and departments, led by CDFA, to promote the development of healthy soils on California's farm and ranchlands (e.g., through land application of biosolids) building adequate soil organic matter that can increase carbon sequestration and reduce overall GHG emissions.	The RWRF may see additional incentive for land application of biosolids.	Developing Key Actions

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Table ES.4 Summary of Future and Potential Biosolids and Organic Waste Regulations (continued)

Regulation	Summary	Impact to RWRF	Status
Landfill Alternative Daily Cover (ADC)			
AB 1594 (2014)	States green waste will no longer qualify for diversion credit when used as ADC at a landfill. Green waste that is mixed with biosolids for use as ADC currently receives diversion credit under AB 939, but will no longer be able to do so for the green waste portion beginning in 2020. As a result, it is expected that landfills will not accept biosolids (if not mixed with green waste) for ADC since they need the combination to achieve a workable moisture content.	With green waste no longer receiving diversion credit for use as ADC, may limit the amount of biosolids used as ADC.	Effective: 2020
SB 1383 (2016)	ADC of biosolids will no longer qualify as diversion and will be considered disposal.	May see increased competition for land application and composting sites, as other agencies' biosolids are no longer used as ADC.	See above.
AB 876 (2015)	Requires entity to track and annually report the amount of organic waste in cubic yards it will generate over the next 15 years, the additional organic waste recycling facility capacity that will be needed to process that waste, and identify new or expanded organic waste recycling facilities (such as WRF anaerobic digesters) capable of reliably meeting that additional need.	RWRF may be identified as a recycling facility for accepting additional organic waste.	First report was due: August 2017
AB 901 (2015)	Changes disposal and recycling reporting to CalRecycle. Waste, recycling (including WRFs), and compost facilities, as well as exporters, brokers, and transporters of recyclables or compost will be required to submit information directly to CalRecycle on the types, quantities, and destinations of materials that are disposed of, sold, or transferred inside or outside of the state. CalRecycle is given enforcement authority to collect this information.	The RWRF will be required to report the types, quantities, and destinations of their biosolids to CalRecycle starting in Q3 of 2019.	Regulation Adoption: Spring 2019 First Reports: Q3 2019

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ES.3 Biosolids Market Assessment

Chapter 3 presents the findings from the biosolids quality and market assessment performed by Material Matters. The market assessment consisted of the following three major tasks, each of which is summarized in the following sections. For more details on the market assessment methodology and results, please refer to Chapter 3.

1. An evaluation of the RWRF's baseline biosolids quality and quantity data,
2. A preliminary market assessment to understand current biosolids management practices by Fresno and other California utilities, and
3. A final market assessment to final market assessment to define preferences of local businesses, including product qualities, quantities, seasonal demand, and potential outside-the-gate expenses and revenues.

ES.3.1 Biosolids Quality and Quantity Assessment

Material Matters reviewed the anaerobic digestion performance and biosolids quality data relevant to meeting the pathogen reduction, vector attraction reduction, and pollutant (metal) limits required to produce a Class B biosolids product. Additional biosolids quality data pertinent to biosolids' agricultural value were also reviewed including volatile solids content, and nutrient concentrations for nitrogen, phosphorus, potassium, and micro-nutrients.

Material Matters also characterized the other products considered in the BMP, and developed information sheets with information about each product to aid in the biosolids market interviews. Products under consideration include: Class B anaerobically digested biosolids (baseline), Class A/EQ Cake produced via thermal hydrolysis, Class A/EQ liquid produced via post-digestion thermo-chemical hydrolysis, biochar produced via pyrolysis or gasification, Class A/EQ dried granule produced via thermal drying, and Class A/EQ compost produced via composting.

ES.3.2 Biosolids Management Practices

ES.3.2.1 City of Fresno

100 percent of the RWRF's biosolids are beneficially used, with about half going to land application and the other half to composting. In 2016 and 2017, 48 and 44 percent respectively, of the RWRF's biosolids were directly land applied. The land application sites are approximately 60 miles away (all in Merced County), and biosolids are typically applied as a fertilizer for corn silage and wheat, primarily in the spring and fall prior to crop planting. Composting accounted for 52 and 56 percent of biosolids management for the City's biosolids in 2016 and 2017 respectively. While the contract defines the processing facility as Liberty Composting, Inc., which is located 82 miles away, the majority of Fresno's biosolids that were composted were sent to a closer facility - the Central Valley Compost (CVC) composting facility, which is located 60 miles away.

The market assessment findings reveal Fresno's biosolids management program is cost-effective relative to biosolids management programs across California. The City's had a contract with Synagro at a price of $26 to $28 per wet ton from 2013 through 2018, which is approximately two-thirds to half the price of most other biosolids management programs in California. Two (2) new contracts began in November 2018, with Synagro and Holloway at $31.86 and $33.85 per wet ton, respectively. The City's biosolids management program continues to be less costly than the majority of other biosolids management programs in California.

ES.3.2.2 Other California Biosolids Programs

Material Matters contacted 32 of the 48 largest wastewater treatment plants in California to understand how other utilities are managing their biosolids.

In 2017, the majority (79 percent) of biosolids produced by the largest WRFs in California met Class B standards. The quantity of biosolids produced in each biosolids classification, reported in both percentage and dry tons (DT), is depicted in Figure ES.1.

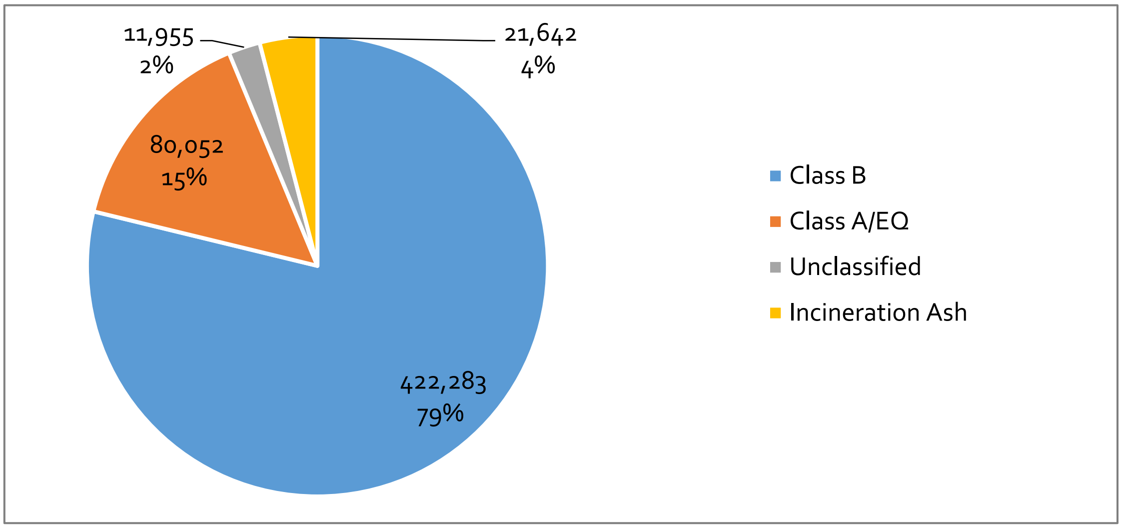


Figure ES.1 Quantity and Classification of Biosolids Produced by California's 48 Largest WRFs (excluding Fresno)

The majority (77 percent) of biosolids produced by the largest wastewater treatment plants in California in 2017 were processed through mesophilic anaerobic digestion. The quantity of biosolids produced by each process (in dry metric tons) is summarized in Figure ES.2.

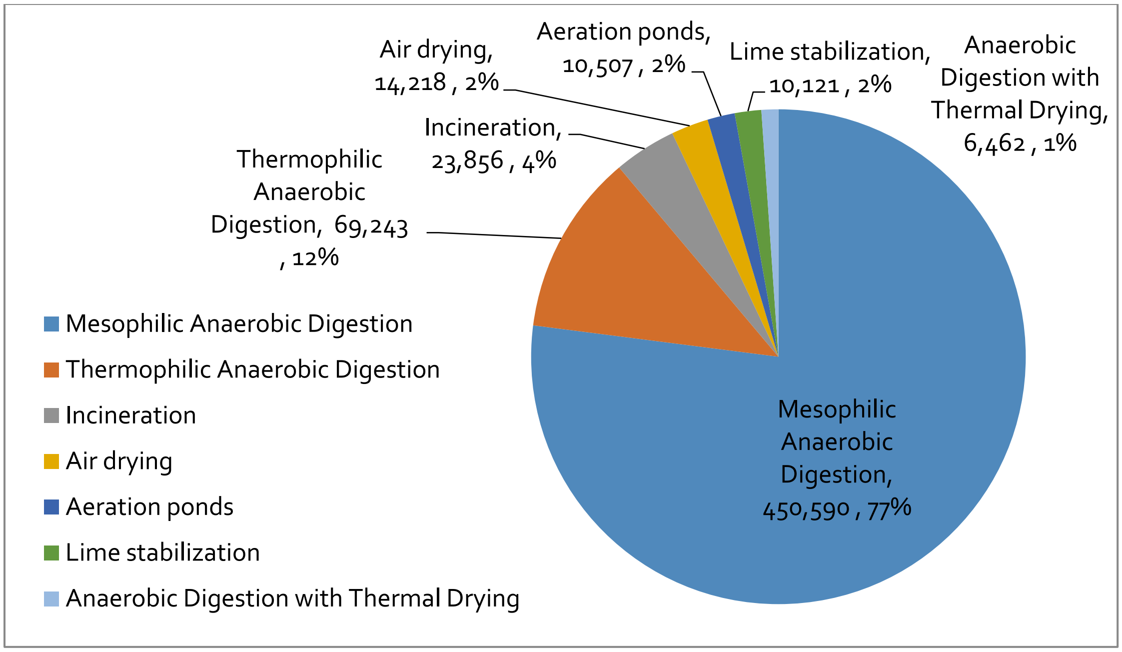


Figure ES.2 Solids Stabilization Methods Used for Biosolids Produced by California's 48 Largest WRFs (excluding Fresno)

In 2017, eight (8) biosolids management methods were utilized by the 48 largest utilities in California. 35 percent of the biosolids produced by the largest WRFs were transported to a third-party facility for further processing, with compost accounting for 93 percent of the third-party processing. Nineteen (19) percent of 2017 biosolids was directly land applied by third-party land application companies. The number of dry metric tons in each biosolids management category is summarized in Figure ES.3.

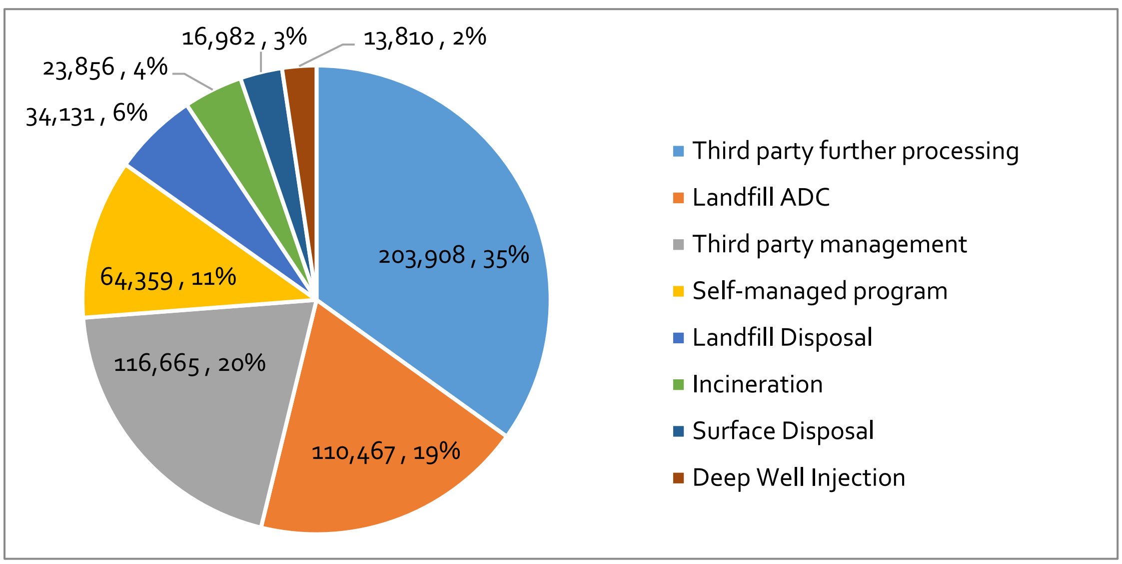


Figure ES.3 Biosolids Management Methods Used in 2017 for Biosolids Produced by California's 48 Largest WRFs (excluding Fresno)

ES.3.3 Biosolids Market Assessment

An overview of the biosolids market assessment is depicted in Table ES.5.

Table ES.5 Biosolids Market Assessment Summary

Product	Market						
	Food Crops	Feed and Fiber Crops	Rangeland	Energy	Landscape Supply/ Soil Blender	Golf Courses	Land Restoration
Class B Biosolids		✓	✓				
Class A/EQ Liquid	✓	✓	✓				✓
Class A/EQ Cake			✓				✓
Biochar	✓✓	✓	✓		✓	✓	✓✓
Thermally Dried Granules			✓	✓		✓	✓
Compost	✓✓	✓✓	✓		✓✓		✓✓

Notes:

(1) Very low interest level or not applicable: Blank

(2) Low interest level; will require significant effort to develop market: ✓

(3) Moderate interest level; will require moderate effort to develop market: ✓✓

(4) High interest level; already an established market for biosolids products that requires little to no effort to develop market: ✓✓✓

The market assessment revealed that Class A/EQ compost is the biosolids product preferred by most local markets. This is because biosolids compost can be a direct substitute for other compost products (i.e., green waste compost and manure compost) that are commonly utilized by growers of food crops and by landscape supply companies in the region. While compost appears to be the most favored product, its use is limited in some markets due to standards set by an international food organization (Global GAP) and food companies that ban the use of biosolids products.

In contrast, most interviewed customers were either unfamiliar with or previously used biochar and did not see benefits to warrant typical market price of $500+ per ton. While biochar is not well known, it appears there is an opportunity to develop the biochar market through partnership with local Universities and the Governor's Office of Planning and Research, which are engaged in multiple biochar research projects across the state.

Thermally dried granules are also favorable for some specialty markets, such as golf courses. They too can be a low-cost substitute for growers that use granular fertilizer (note there is an increasing trend for many growers in the region to administer liquid fertilizer through drip irrigation).

Most interviewed customers maintain a strong negative perception of Class A/EQ Cake and Class B Cake products due to history with biosolids being imported into the San Joaquin Valley from the Los Angeles area.

Based on the information gathered during the market assessment, Material Matters also estimated the annual outside-the-gate costs (and revenues) associated with each product

(Table ES.6). With these cost estimates, compost has the lowest outside the gate costs at a revenue of approximately $5,000 per year, and the Lystek product has the greatest outside the gate cost of $4.47 million per year.

Table ES.6 Outside-the-Gate Expenses and Revenues

Product	Management Method	Total Revenue or Expense per WT	Tonnage	Annual Marketing Cost	Total Outside-the-Gate Costs or Revenues
Class B Biosolids	Third-Party	($34.00)	88,000	NA(1)	($2,992,000)
Class A/EQ Cake	Third-Party	($34.00)	46,000	NA(1)	($1,564,000)
Class A/EQ Liquid	Third-Party	($34.00)	131,400	NA(1)	($4,468,000)
Biochar	Self-Managed	$1.50	8,900	$100,000	($86,650)
Thermally Dried Granules	Self-Managed	$1.50	20,800	$100,000	($68,800)
Compost	Self-Managed	$1.50	69,700	$100,000	$4,550

Notes:
(1) Not Applicable

While some markets do have a stronger interest in biosolids products than others, penetration into any local markets will require substantial marketing effort, which may include collaboration with the Fresno Farm Bureau and a partnership with Fresno State University to conduct demonstrations and trials. Distribution of any biosolids product will also require substantial public outreach and education to gain acceptance from the local community.

ES.4 Evaluation of Biosolids Management Alternatives

Chapter 4 presents the biosolids management alternatives evaluation, including descriptions of the alternatives, the methodology used, and the results and recommendations. This summary gives a brief overview of the evaluation methodology and alternatives evaluated, but focuses mostly on the findings, recommendations, and implementation plan. For more detailed descriptions of the alternatives, evaluation methodology, and results, please refer to Chapter 4.

ES.4.1 Evaluation Methodology

As a first step, pass/fail initial screening criteria were used to eliminate alternatives deemed infeasible or impractical at this point in time. The remaining alternatives underwent a detailed evaluation based on financial (life cycle costs) and non-financial (technical, social, and environmental) criteria. The financial evaluation considers capital and operation and maintenance (O&M) costs presented as life cycle costs. The non-financial evaluation of the alternatives was performed by multiplying the criteria scores by the criteria weights which were both based on City of Fresno (City) input. The evaluations resulted in short- and long-term recommendations for biosolids management at the RWRF.

ES.4.2 Alternatives Evaluated

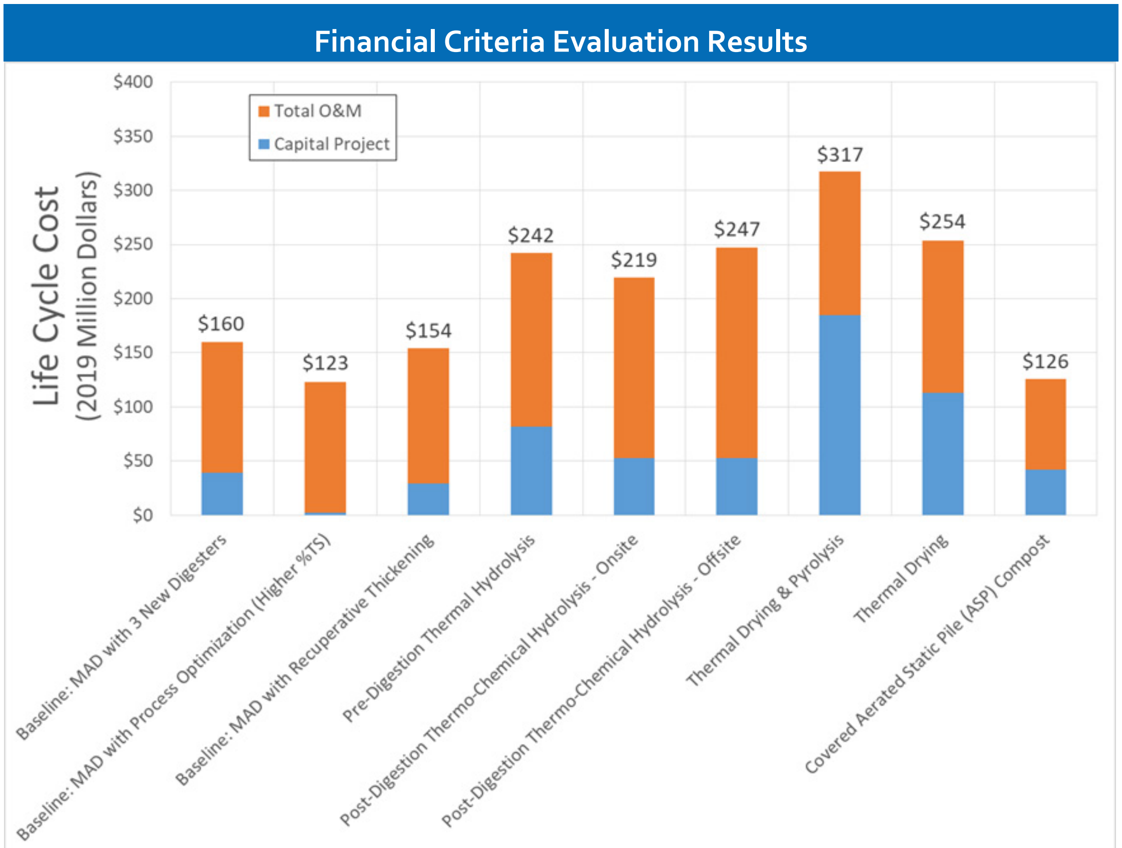
The following alternatives passed the initial screening and underwent a detailed financial and non-financial evaluation:

1. **Baseline: Mesophilic Anaerobic Digestion (MAD)**: Involves construction of three new large digesters by 2024, 2032, and 2038. All solids handling processes would operate similar to current operations. Produces Class B cake.
2. **Baseline: MAD with Process Optimization (Higher %TS):** Involves optimizing the primary clarifiers and DAFT to achieve thicker solids feed to digestion. Since the digesters are hydraulic loading limited, operating at a higher solids concentration defers construction of new digesters. This involves replacing primary sludge pumps and TWAS pumps to handle thicker solids. Produces Class B cake.
3. **Baseline: MAD with Recuperative Thickening:** Recuperative thickening is a modified version of the MAD process in which digested solids are thickened and recirculated to increase the solids concentration in the digester, maximizing digestion capacity. The proposed configuration involves converting digesters 9 through 12 to recuperative thickening, which requires three new mixers per digester, and four sludge screw thickeners. Produces Class B cake.
4. **Pre-Digestion Thermal Hydrolysis**: Pre-digestion Thermal Hydrolysis Process (THP) is a process that uses high temperature and pressure to break down cells and large organic molecules in the solids, making them more amenable for anaerobic digestion, and increasing their dewaterability. It involves installing three large skid-mounted THP trains and the ancillary equipment associated with this process, which includes pre-THP centrifuges, sludge silos, cake pumps, steam boilers, and cooling heat exchangers. It requires construction of two new structures to house pre-dewatering centrifuges and new boilers and electrical equipment. Produces Class A cake.
5. **Post-Digestion Thermo-Chemical Hydrolysis – Onsite:** Post-digestion thermo-chemical hydrolysis is a process that uses a caustic chemical, low temperature, and high shear mixing to produce a liquid fertilizer. The process occurs in a reactor after digestion and dewatering. The proposed configuration would require a new building to house the five treatment reactors, chemical storage and feed system, and electrical equipment. The product is pumped to on-site lined and covered lagoons for storage. Produces Class A liquid fertilizer.
6. **Post -Digestion Thermo-Chemical Hydrolysis – Offsite:** During this project, the City was notified of a potential partnership between Lystek, a post-digestion thermo-chemical hydrolysis company, and the Selma-Kingsburg-Fowler (SKF) County Sanitation District. Lystek is in the early stages of evaluating the viability of constructing a regional thermo-chemical hydrolysis facility at SKF, located approximately 25 miles from the RWRF. Under this alternative, the City would produce a sub-Class B cake, then pay a tipping fee for hauling and processing at the off-site facility at SKF. Produces Class A liquid fertilizer.
7. **Thermal Drying & Pyrolysis:** Pyrolysis is a thermal oxidation process that subjects dried sludge to high temperatures, without oxygen, producing pyrogas and biochar. A thermal drier is needed upstream of pyrolysis to dry the cake to 90 percent solids concentration. The proposed configuration involves 8 belt dryers and 12 pyrolysis skids, two product storage tanks, and a load-out station. Produces biochar.

8. **Thermal Drying:** Thermal drying uses thermal energy to evaporate moisture from cake to 80 to 90 percent solids. The proposed configuration involves installing two rotary drum dryers and the associated ancillary equipment for solids and product handling, and emissions and odor control. Produces Class A dried product.
9. **Covered Aerated Static Pile (ASP) Compost:** Composting is a solids stabilization process whereby aerobic organisms decompose organic matter. Cake is combined with a bulking agent, commonly woody waste to achieve the required porosity and carbon to nitrogen ratio. With ASP composting, piles are formed over perforated pipes that use blowers to aerate the solids. Covered ASP composting uses a plastic barrier over the piles to reduces odors and emissions. The proposed configuration would include a receiving structure, four industrial mixers, two screens, 64 bunkers (includes cover, blower, and leachate collection), end-product storage pad, leachate tank and pumps, and would occupy about 20 acres of land. Produces Class A Compost.

ES.4.3 Findings

Figures ES.4 and ES.5 summarize the findings of the financial and non-financial criteria evaluation.



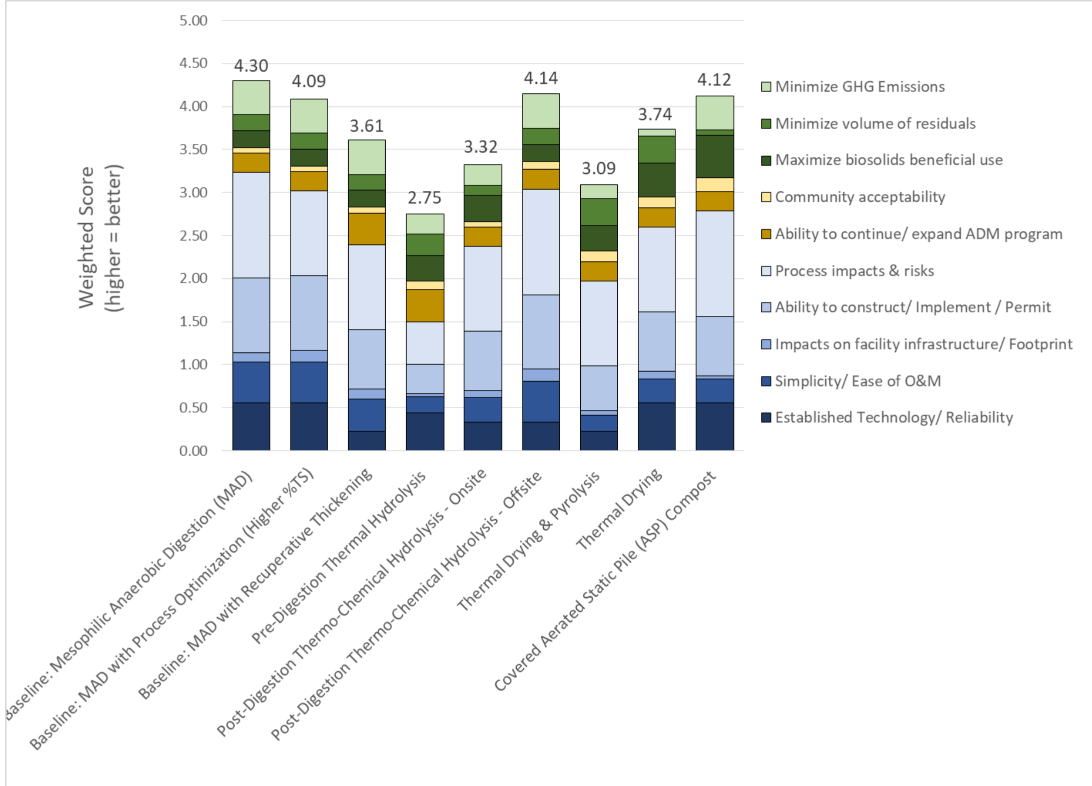
Most cost-effective alternatives:

1. Baseline: MAD with Process Optimization (-23 percent)*
2. Covered ASP Composting (-21 percent)*
3. Baseline: MAD with Recuperative Thickening (-3 percent)*
4. Baseline: MAD

**Percentage differences provided are relative to Baseline: MAD.*

Figure ES.4 Summary of Findings from Financial Criteria Evaluations

Non-Financial Criteria Evaluation Results



Highest scoring alternatives:

1. Baseline: MAD (4.30)
2. Thermo-chemical Hydrolysis Offsite (4.14)
3. Covered ASP Composting (4.12)
4. Baseline: MAD with Process Optimization (4.09)

Figure ES.5 Summary of Findings from Non-Financial Criteria Evaluations

The results from the financial and non-financial evaluations largely reinforce each other. The most cost-effective alternatives are Covered ASP Composting and Baseline MAD with Process Optimization followed by Baseline MAD with Three New Digesters, then Baseline MAD with Recuperative Thickening. The highest scoring alternatives from the non-financial evaluation are Baseline MAD with Three New Digesters followed by Post-digestion Thermo-Chemical Hydrolysis – Offsite, Covered ASP Composting, and Baseline MAD with Process Optimization.

Baseline MAD with Process Optimization (higher %TS) is estimated to have a 23 percent lower life cycle cost compared to Baseline MAD with Three New Digesters because it defers the cost of three additional large digesters. It also scored high on the non-financial evaluation because it does not introduce a new process, only requires minor modifications, and has little impact on other solids handling processes.

Covered ASP Composting is estimated to have a 21 percent lower life cycle cost compared to Baseline MAD with Three New Digesters largely because the City would no longer have to pay hauling and disposal costs. Additionally, it scored highly on the non-financial evaluation because it is a relatively simple process, has little to no impact on upstream processes, and produces the most marketable biosolids product. It requires several acres of land; however, this is likely not a concern because the City owns plenty of land around the RWRF.

Baseline MAD with Recuperative Thickening was found to have a similar cost to Baseline MAD with Three New Digesters. However, according to the results of the non-financial evaluation, it is less favorable than digestion due to the increased operational complexity. The City may also consider building new digesters with recuperative thickening, which would be easier to construct than retrofitting existing digesters.

Post-Digestion Thermo-Chemical Hydrolysis (Offsite) is estimated to have a 55 percent higher life cycle cost compared to Baseline MAD with Three New Digesters. However, it scored highly in the non-financial evaluation because it is the only alternative where the City is not responsible for the treatment process. This allows the City to limit potential process impacts or any constructability issues, which are the two highest weighted criteria. However, the City could explore opportunities for public-private partnerships for other alternatives as well, including composting, thermal drying, or pyrolysis. That approach would likely result in a better score on the non-financial evaluation for those processes as well.

ES.4.4 Recommendations

Based on the findings of the financial and non-financial criteria evaluation of the biosolids management alternatives considered for this Master Plan and described in this Chapter, Figure ES.6 summarizes Carollo's recommendations for the RWRF in the near- and long-term. The recommendations reflect the need to address the near-term capacity limitation of the existing digesters, as well as the City's desire for the beneficial reuse of biosolids products in the long-term.

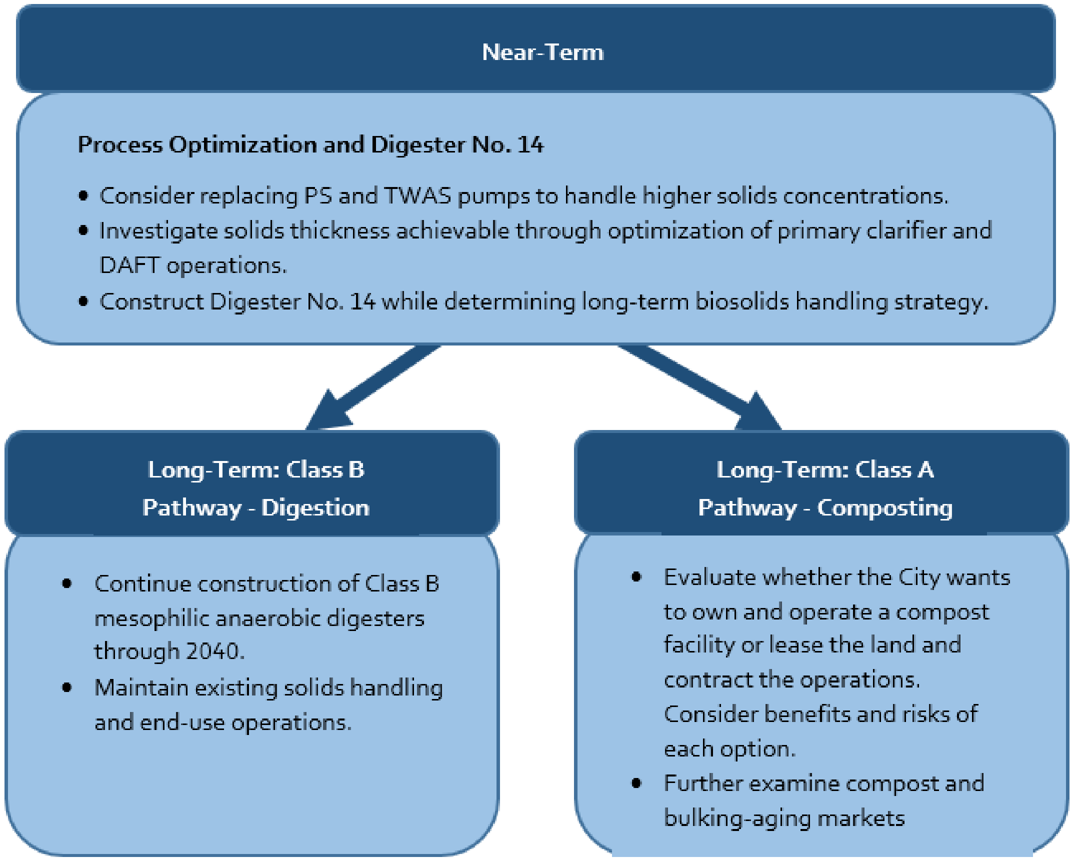


Figure ES.6 RWRF Biosolids Master Plan Near and Long-Term Recommendations

ES.5 Implementation Plan

Chapter 5 presents the implementation plan, which provides a detailed breakdown of project phasing and associated capital project costs for the recommended near- and long-term solids handling improvements. Because the implementation plan is the final outcome of the BMP, it is repeated in this Executive Summary in its completion.

Two pathways are presented, as summarized in Figure ES.7, a Class B pathway based on continuing the Baseline MAD alternative, and a Class A pathway based on the Composting alternative. Process Optimization and the construction of Digester No. 14 are included in both pathways to provide capacity through year 2032, when additional biosolids handling capacity will be needed. While Process Optimization is included as a near-term project, the implementation plan assumes a worst-case scenario (i.e., no solids concentration improvements can be achieved through process optimization) to develop conservative life cycle cost estimates.

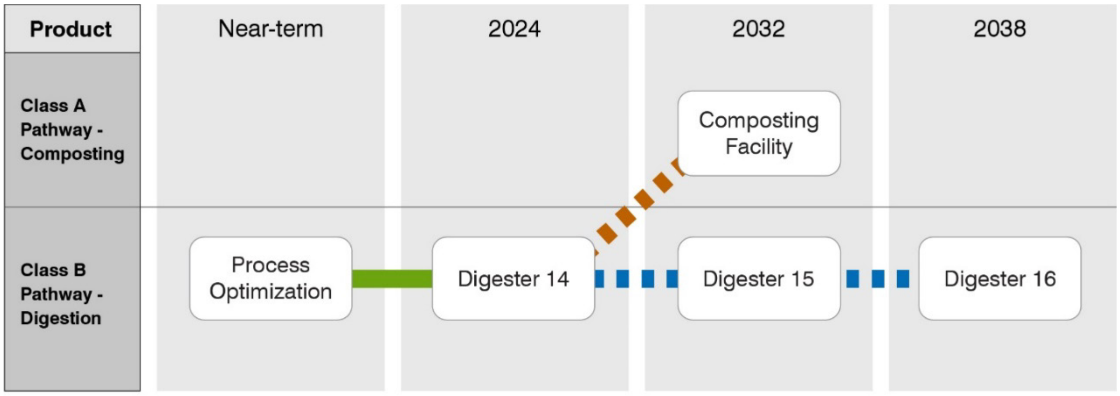
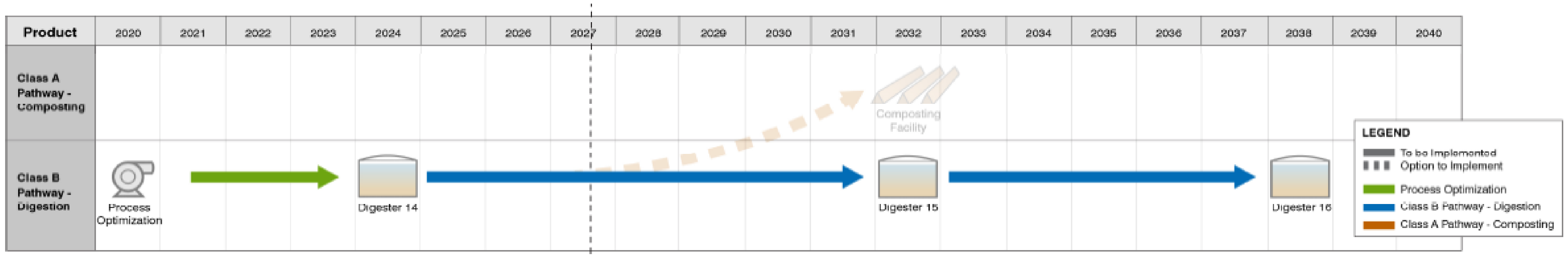


Figure ES.7 Implementation Plan for Class A and Class B Pathways

The City needs to decide which pathway it will carry forward by 2028, at which point the City needs to begin the procurement and preliminary design of the selected alternative in order to maintain the same level of service to customers. By then, the City will have additional information to make an informed decision including understanding the effectiveness of the process optimization, as well as a better understanding of the compost market. Additionally, the City should also consider the impact of potential regulatory and financial drivers on the decision between the two pathways, which is summarized in Section 4.5.5.

Figures ES.8 and ES.9 present the detailed implementation plan (schedule for planning through construction services and capital costs, followed by the site map) for the Class B pathway, and Figures ES.10 and ES.11 show the same for the Class A pathway. Project schedules are broken down by quarter and estimated duration of project phases are provided. Estimated project costs are comprised of procurement, preliminary design, final design, bidding and award, construction, and project closeout.



PROJECTED IMPLEMENTATION SCHEDULE		Cost (Millions)
	Projects	
1	Process Optimization	$2.6
2	Mesophilic Anaerobic Digester No. 14	$13.6
3	Mesophilic Anaerobic Digester No. 15	$17.1
4	Mesophilic Anaerobic Digester No. 16	$20.3

Procurement	Preliminary Design	Final Design	Bidding and Award	Construction	Project Closeout

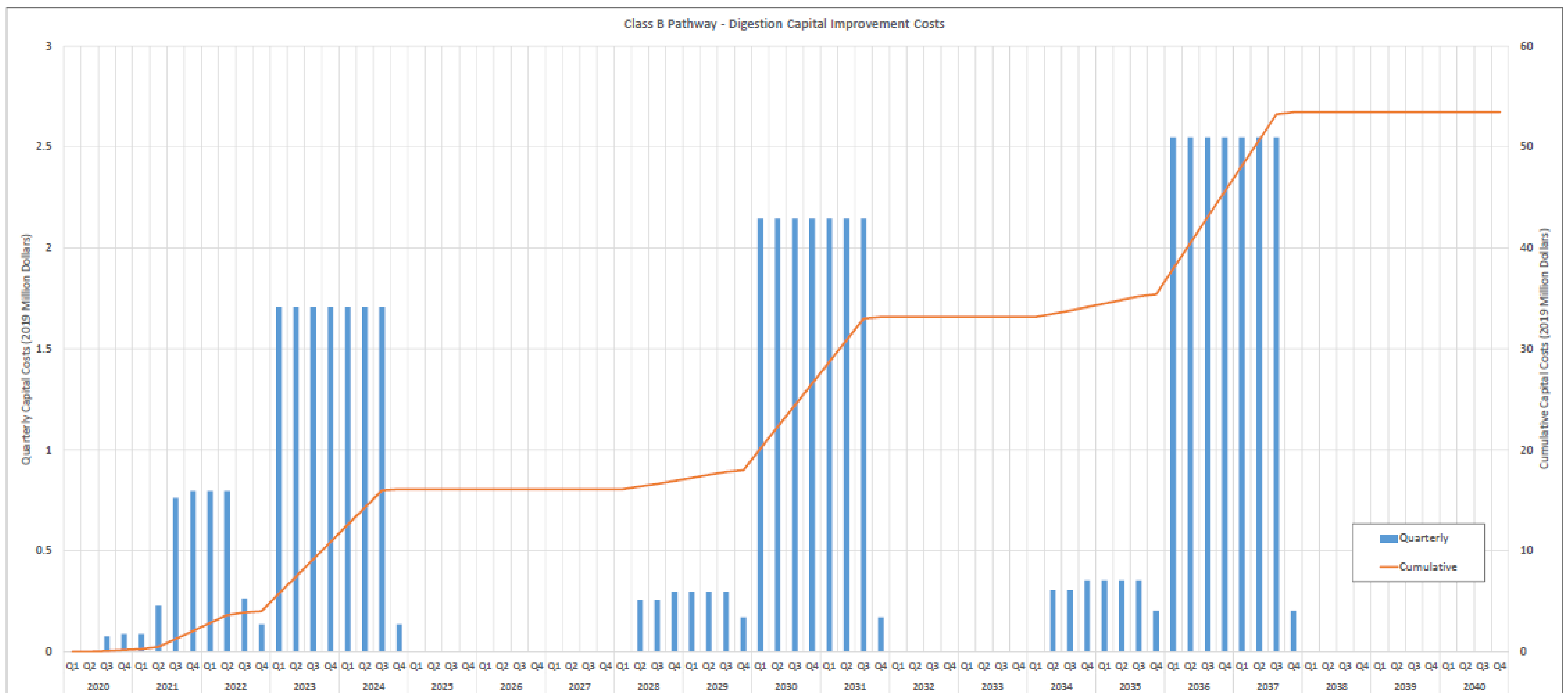


Figure ES.8 Implementation Schedule and Estimated Project Costs by Phase – Class B Pathway: Mesophilic Anaerobic Digestion

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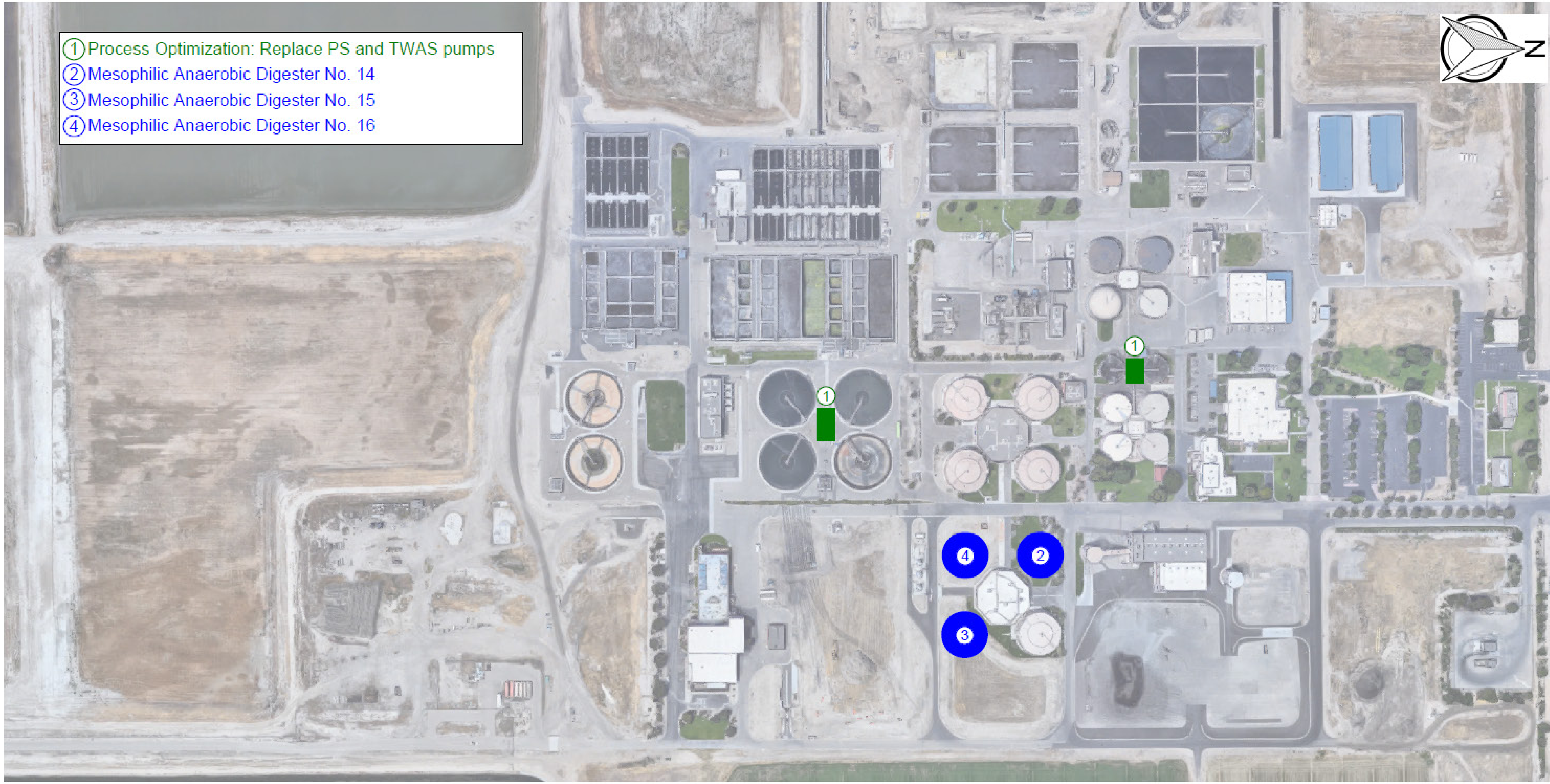

Figure ES.9 Implementation Site Plan – Class B Pathway: Mesophilic Anaerobic Digestion

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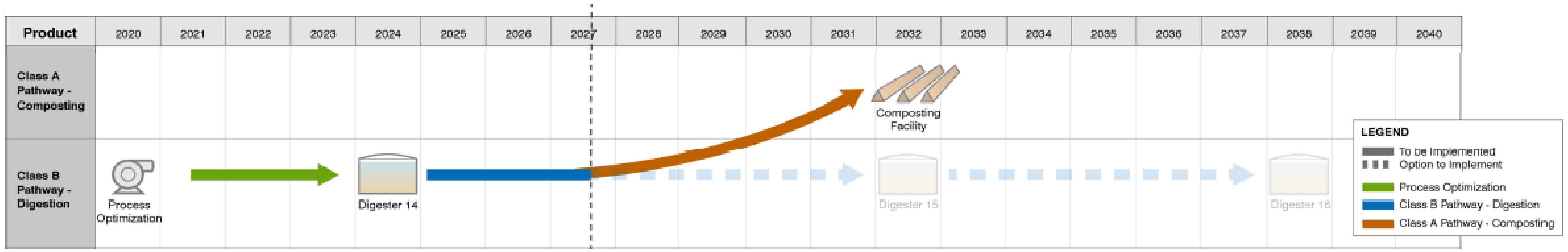

PROJECTED IMPLEMENTATION SCHEDULE		Cost (Millions)
	Projects	
1	Process Optimization	$2.6
2	Mesophilic Anaerobic Digester No. 14	$13.6
3	Composting Facility	$53.3

Procurement	Preliminary Design	Final Design	Bidding and Award	Construction	Project Closeout

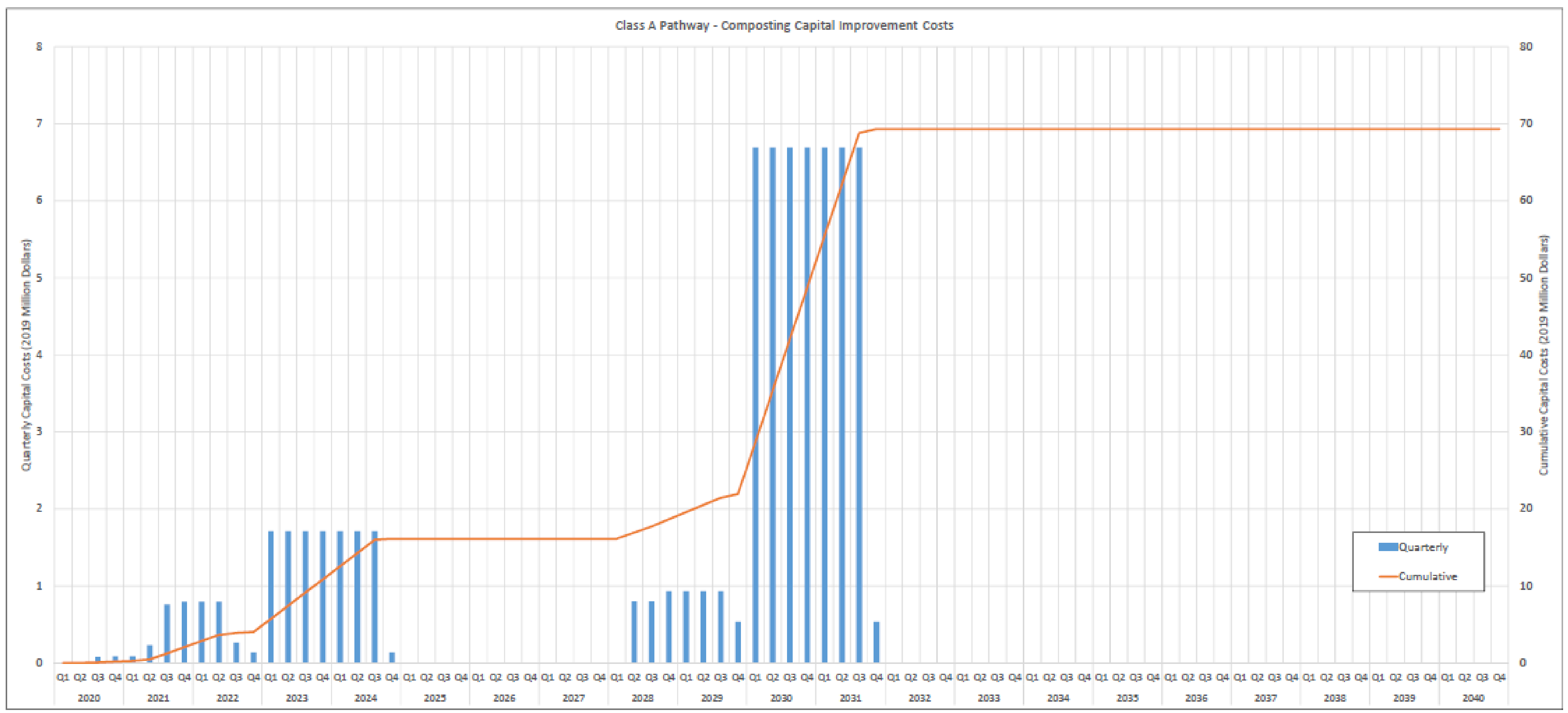

Figure ES.10 Implementation Schedule and Estimated Project Costs by Phase- Class A Pathway: Composting

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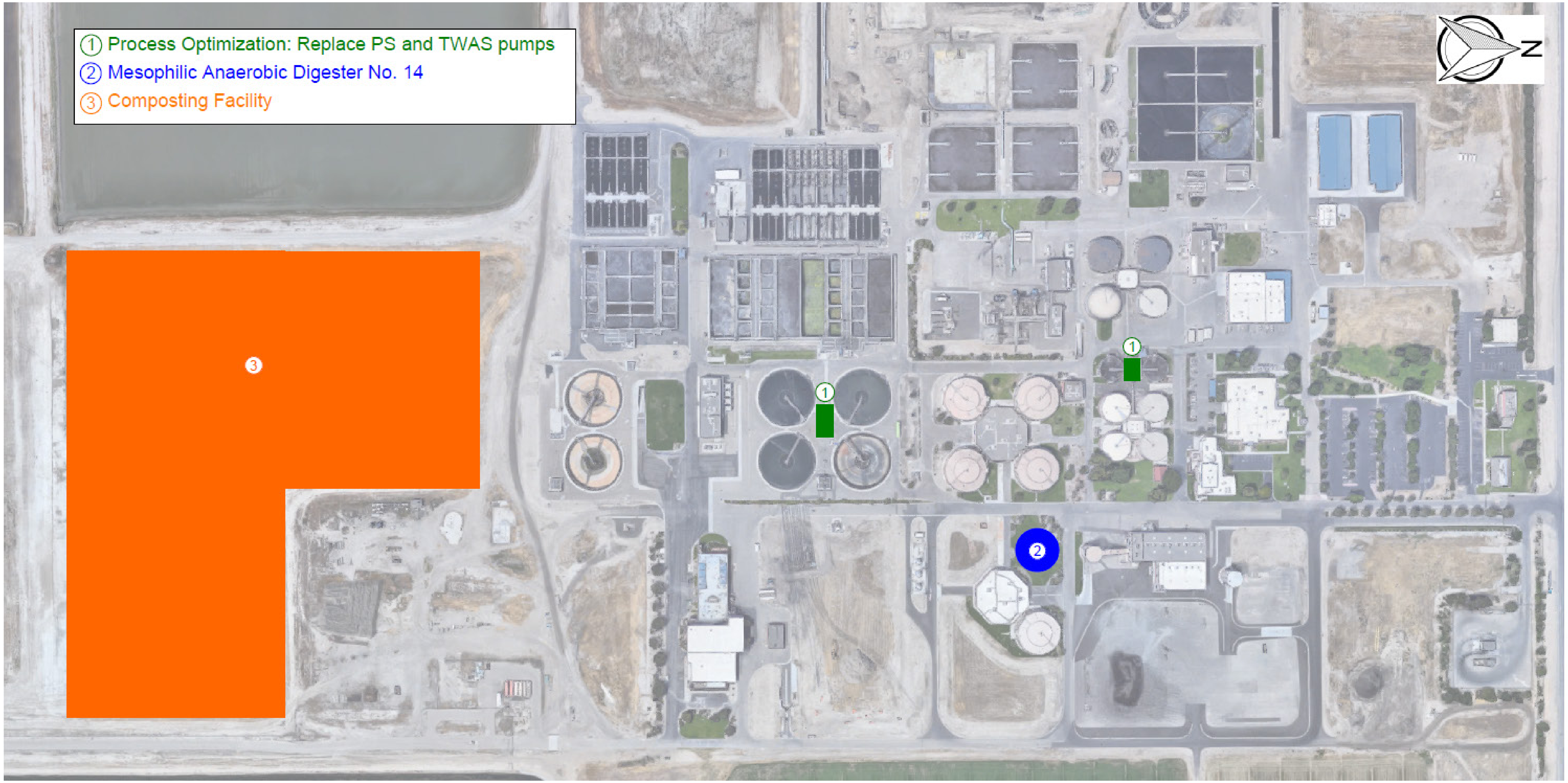

Figure ES.11 Implementation Site Plan – Class A Pathway: Composting

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Table ES.7 provides the breakdown of estimated project costs distributed evenly over the project phases. As detailed in Chapter 4, Design, Legal, and Administration Fees are estimated to be 15 percent of the total project cost, while Construction Management is estimated to be 10 percent, for a total of 25 percent of the total project costs. The remainder of the total project cost is construction cost, and is expended during the construction phase of the project.

Table ES.7 Estimated Project Costs Broken Down into Project Phases

Project Phase	City	Designer	Construction Management	Total
Procurement	--	--	--	--
Preliminary Design	1%	2%	--	**3%**
Final Design	1%	6%	--	**7%**
Bidding and Award	1%	--	--	**1%**
Construction	2%	2%	9%	**13%**
Project Closeout	--	--	1%	**1%**
Total	**5%**	**10%**	**10%**	**25%**

The estimated total project costs are consistent with those provided in Chapter 4 with the only difference being the escalation to mid-point. While the implementation plan provides a timeline for new construction, the evaluation of alternatives assumed all projects would be constructed by 2024 in order to compare alternatives equally. Therefore, both alternatives will show higher project costs than previously presented due to the later construction date considered in the implementation plan.

The following sections describe each recommended improvement and future pathway

ES.5.1 Process Optimization

The more the solids concentration to the digester can be increased, the more the hydraulic loading can be decreased. This operational optimization can significantly defer the need for new digester construction while still achieving and maintaining Class B requirements.

Higher primary sludge (PS) concentrations might be achieved by maintaining a deeper sludge blanket in the primary clarifiers, changing pumping frequency, utilizing inline automation to target a solids concentration and tying in pump controls accordingly, and/or using chemically enhanced primary treatment (CEPT). The thickened waste activated sludge (TWAS) solids concentration might be increased by optimizing DAFT operations including polymer selection and dosage, changing mechanism speed, and confirming that ancillary systems to the DAFT (e.g., air saturation system) are performing to their specifications. To determine the achievable solids concentrations, plant staff would need to modify operations and monitor the effects.

Plant staff stated their concerns with pumping TWAS at concentrations greater than five percent. During optimization, TWAS and PS pumps should be closely monitored to ensure adequate pumping capacity is maintained. Both sets of PS and TWAS pumps may also need to be replaced to reliably pump thickened solids at higher concentrations.

The process optimization project assumes replacement of twelve PS and six TWAS pumps at an estimated project cost of $2.6M. Operational modifications noted above to produce thicker solids can be implemented as soon as practical for the City to determine the extent of achievable process improvements. Pump replacement, if necessary, will require design and subsequent construction.

ES.5.2 Digester No. 14

If process optimization significantly improves solids handling operations (i.e., increases digestion capacity across the existing digester volume), digester construction may be deferred several years. However, the implementation plan conservatively assumes process optimization does not improve digestion capacity, and Digester No. 14 would need to be constructed by 2024.

Digester No. 13 and its control building were constructed as part of the Organics Upgrade project in 2007. The control building was constructed with space to accommodate future Digester Nos. 14, 15, and 16. Digester No. 14 would be similar in design to Digester No. 13, with a 105-foot diameter and 1.88 million gallon capacity. Digester No. 14 would be located on the northwest corner of the digester control building.

The total project cost for constructing Digester No. 14 by 2024 is estimated at approximately $13.6M.

ES.5.3 Class B Pathway: Mesophilic Anaerobic Digestion

Under the Class B pathway, it is assumed the City continues expanding mesophilic anaerobic digestion capacity and producing Class B cake. Assuming no solids concentration improvements can be achieved through process optimization, the City would then need to build Digester No. 15 by 2032 and Digester No. 16 by 2038 to maintain a minimum 15-day average SRT to maintain regulatory compliance. The total project cost for constructing Digester No. 15 and Digester No. 16 is approximately $17.1 and $20.3M, respectively.

ES.5.4 Class A Pathway: Composting

The alternatives analysis identified composting as the highest ranked alternative, producing a Class A product, with a high score in the non-financial evaluation, and a roughly 20 percent lower life-cycle cost compared to Baseline MAD with three new digesters. The capital cost for constructing a composting facility is comparable to the cost of constructing three new mesophilic anaerobic digesters with equal solids handling capacities. However, the annual operation and maintenance (O&M) costs for a composting facility are roughly 30% lower than the O&M for new digesters, largely because of the cost associated with biosolids end-use (hauling and tipping fee). The alternatives analysis assumed Class A compost could be marketed and sold for revenue at $1.50 per ton, whereas Class B cake is hauled and further processed at a current cost of $34/ton.

Under the Class A pathway, the City would build an on-site composting facility by 2032 to process 100% of the digested sludge. The equipment and facilities sized for the projected 2040 biosolids load include four industrial mixers, two screens, and 64 composting bunkers, each with their own dedicated ancillary equipment.

No additional anaerobic digestion capacity would be needed after the construction of Digester No. 14, since the City could achieve the Class A pathogen reduction requirement through the composting process. However, if the City wanted to diversify their product and have the ability to produce both Class B cake and Class A compost, then they would need to build both the composting facility and Digester No.'s 15 and 16, which would almost double the total project costs incurred through 2040.

The City should investigate the compost and bulking agent markets. This analysis assumes the City will be able to receive pre-ground agricultural woody waste for free. Further analysis is recommended to determine whether the City would need to pay a fee for pre-ground agricultural woody waste, or if they could charge a tipping fee for processing it.

The City investigated a potential partnership with the solid waste department to use green waste as the bulking agent for compost, but the solid waste department expressed a preference to compost green waste separate from biosolids at this point in time. Municipal green waste has higher contamination rates than agricultural waste, which would require increased labor for the removal of contaminants and may require additional mechanical equipment such as grinders and/or more screens.

The City can better understand the composting process and operation by visiting other similar composting facilities, such as the Mid Valley Disposal composting facility in Kerman. This facility uses the same recommended bunker system with GORE® covers that were included in this analysis.

A major decision related to the final implementation of a compost facility is deciding whether to fund and/or operate the compost facility with City resources or to engage with a third party to assist with compost facility funding and/or operations. The costs shown in Figure ES.10 assume the City owns and operates the new composting facility. In either case, the compost operation will be influenced by the party responsible for operating the facility and marketing the final compost product. While both options have been successfully implemented by utilities across the United States, each has its own set of benefits and considerations that should be understood and evaluated when determining the best management option specifically for the City.

The team has identified four major areas in which public operations will differ from a privately-operated facility, including management of daily compost activities, marketing efforts, potential for regionalization, and product quality (summarized in Table ES.8). Overall, a publicly operated facility will provide the City with more control over the composting effort, including processing, marketing, product quality, and pricing, whereas the privately-operated facility could allow for management of the facility by experienced composting experts.

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Table ES.8 Benefits and Considerations of Publicly vs. Privately Operating a Compost Facility

Parameter	Public Operation		Private Operation	
	Benefits	Consideration	Benefits	Considerations
Management of Daily Compost Activities Includes sourcing carbon-rich material, grinding woody waste, managing piles, and recordkeeping.	• Allows City to choose feedstocks, refine operation to meet City needs, and control product quality • Promotes synergy with public works and local agricultural community	• Will require City personnel training • Will take time to learn/optimize process • Additional full-time equivalent (FTE) employees may be required	• Private firm has experience with composting process • Shorter timeframe for process start-up & optimization • Fewer City FTEs required	• City will have less control over source of feedstocks & outlets • Private firm responsible for final product quality • Must gauge risk / reliability (facility failure, compliance, tipping fee increases, etc.) with private firm
Marketing Efforts Includes branding, market studies, website, social media, customer identification, etc.	• Positive association between City & compost product • City controls where and how product is distributed • Option to target low- or high-value markets • Potential use for City projects	• City resources or outside firm to brand / market program • City responsible for seasonal distribution • Potential to have surplus product during slow season	• Private firm assumes full responsibility for branding / marketing biosolids compost	• Private firm economics typically driven by reliance on tipping fees alone • Less incentive for private firm to market to higher value outlets
Biosolids Source(s) / Regionalization Includes option to accept Fresno biosolids only, or to also accept solids from other municipal water resource recovery facilities.	• City controls pursuit of regional options • Quality of material (i.e., stabilized or unstabilized) dictated by City • Responsible to operate facility to minimize potential for odors	• City responsible for managing sources other than Fresno • Site selection may present challenges from community	• Regionalization may result in reduced tipping fee for City (i.e., other sources share financial obligation)	• Incentive to accept biosolids / unstabilized solids from other treatment plants • Increased potential for nuisances associated with traffic and odors • Site selection & permitting may present challenges from community
Product Quality Related to level of product stability, including potential to generate odors.	• City controls source material, compost duration, and quality of final product quality to meet customer preferences • Less potential to produce malodor complaints	• City responsible for maintaining quality control	• Experience to meet targeted customer preferences / needs	• Economics may favor lower value outlets • Incentive to operate compost process to meet minimum requirements without proper curing • May result in poorly stabilized product

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ES.5.5 Impact of Potential Regulatory and Financial Drivers

Table ES.9 highlights key, potential regulatory and financial drivers that may affect the City's decision between the two pathways, as well as the timing of proposed projects. Refer to Chapter 2 for a comprehensive assessment of current and future regulations that may impact biosolids management.

Table ES.9 Summary of Potential Regulatory and Financial Drivers and Associated Impacts

Regulatory and Financial Drivers	Likelihood	Potential Impact
Class B biosolids end-use cost increase, similar to other regions in California.	High	Class A compost becomes more favorable relative to MAD.
SB 1383 overturns Fresno county's ordinance banning Class B biosolids land application, reducing the hauling and land application cost of Class B biosolids.	Low	Class A compost becomes less favorable relative to MAD.
SB 1383 increases the market supply of organic wastes diverted from landfills, reducing the cost of pre-ground agricultural woody waste, and other compost amendments.	Medium	Class A compost becomes more favorable relative to MAD.
SB 1383 drives private composting and organic waste management companies to build more composting facilities in the area, resulting in increased potential for partnership, increased demand for compost amendments and increased supply of compost.	High	Potential for partnership with an off-site facility for composting the City's biosolids, as well as increased opportunities for partnership with private companies interested in owning and operating an on-site composting facility, make the Class A Pathway (Compost) more favorable. Increased demand for compost amendments could drive up the cost of pre-ground agricultural woody waste, and could also drive down the cost of compost, making the Compost pathway less favorable.
SB 1383 increases the market supply of organic wastes, providing an opportunity for Fresno to maximize their codigestion program and charge higher tipping fees.	High	Will increase O&M costs associated with ADM program. May need additional anaerobic digestion capacity sooner than expected. Additional capacity could be provided through process optimization or anaerobic digestion expansion.
PFOS/PFOA regulation or restrictions applicable to biosolids products and their use become more stringent.	Low	Stringent PFOS/PFOA regulations could significantly impede biosolids management options (e.g., land application). The current state of knowledge relative to biosolids (e.g., test methods for biosolids and proven technologies resulting in PFAS destruction in biosolids) is limited. Considerable applied research is necessary before proven mitigation measures are identified and recommended.
Regional to international pressures against food crops grown using biosolids products increase.	Medium	The market of Class A and Class B biosolids products for beneficial use on crops for human consumption may become more limited.

ES.5.6 Conclusion

The results of the background information, regulatory review, market assessment, and alternatives evaluation performed as part of this Master Plan provided a basis for developing the implementation plan for the recommendations. Two alternatives (thus, two pathways) are shown for the RWRF biosolids handling through 2040. One option is to continue the existing practice of solids stabilization through mesophilic anaerobic digestion to achieve Class B cake. Alternatively, constructing a composting facility within the next ten years provides a means of producing a higher quality end-product (in addition to Class B product) with an estimated life cycle cost lower than the baseline. Regardless of the long-term alternative selected, short-term recommendations are described that include process optimization improvements and construction of Digester No. 14. The implementation plan provides total project costs, schedule, regulatory and financial drivers, and a discussion of additional considerations to facilitate the City's decision regarding the fate (long-term beneficial use) of their biosolids.

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Chapter 1

BACKGROUND INFORMATION

1.1 Purpose

The purpose of this chapter is to summarize the capacity and performance of existing solids and biogas processes at the City of Fresno's (City) Fresno-Clovis Regional Wastewater Reclamation Facility (RWRF) relative to current and projected solids loads through the year 2040. Constraints are identified for processes that are found to have insufficient capacity to handle projected loads. This chapter also documents feedback from the City regarding operational challenges that can create capacity constraints and discusses potential solutions to reported issues. Finally, the current operating costs for solids processing and biosolids use are summarized in this chapter. These costs will be used in subsequent tasks where alternative solids processes are evaluated.

1.2 Background

1.2.1 Fresno-Clovis Regional Wastewater Reclamation Facility

The RWRF service area, shown in Figure 1.1, encompasses the City of Fresno and a portion of the City of Clovis. The RWRF has an average daily maximum month (ADMMF) design flow of 91 million gallons per day (mgd).

The treatment process flow at the RWRF is shown in Figure 1.2. Raw wastewater is pumped into the plant's headworks, which includes bar screens and vortex grit removal. Screenings and grit are collected and disposed of at American Avenue landfill. The screened influent is distributed among the plant's primary clarifiers where primary sludge (PS) is thickened and subsequently pumped to the solids handling system. Primary effluent splits to three conventional activated sludge trains comprised of aeration basins and secondary clarifiers. A portion of primary effluent flows by gravity to a newer membrane bioreactor (MBR) train.

The post-primary treatment processes at RWRF are characterized by four distinct parallel treatment trains, referred to as A-Side, B-Side, C-Side, and tertiary. The A-, B-, and C-Side treatment trains utilize the conventional activated sludge process. The A-Side was constructed in the 1970s and 1980s and consists of complete-mix reactor Aeration Basins 1 through 4 and Secondary Clarifiers 1 through 5. Aeration Basin 4 has since been converted to a recycled water reservoir. Secondary Clarifiers 1 through 4 are square basins, number 5 is a circular basin and all have a circular drive mechanism. The B-Side, constructed in the 1990s, consists of plug flow Aeration Basins 5-8 and Secondary Sedimentation Basins 6 through 13. The C-Side consists of plug flow Aeration Basins 9-10 and Secondary Sedimentation Basins 14 through 17. The tertiary side consists of fine screens, two aeration basins, MBR basins, in-line UV disinfection and recycled water storage. All aeration basins are equipped with fine bubble diffusers and the MBR system has hollow fiber membranes.

Return activated sludge (RAS) is pumped back to the aeration basins. Waste activated sludge (WAS) is withdrawn and sent to the solids treatment train at rates that maintain desired mixed liquor suspended solids (MLSS) concentrations and solids retention times (SRT). Secondary effluent from the conventional activated sludge treatment trains is discharged to percolation ponds. Effluent from the MBR train is further treated with ultraviolet (UV) disinfection to produce Title 22 Recycled Water for reuse.

The solids streams (PS and WAS) are sent to additional treatment processes as illustrated in Figure 1.3. The PS is thickened in the primary clarifiers and fed to the anaerobic digesters. The WAS is thickened by dissolved air flotation thickeners (DAFTs) to produce thickened WAS (TWAS), which is subsequently also fed to the digesters. The RWRF receives anaerobically digestible material (ADM) from various haulers who have established contracts with the City. The PS and TWAS are fed to all operating digesters, whereas the ADM is fed only to Digesters 9 through 13. The digesters are mixed and operated at mesophilic temperatures for stabilization. Digested sludge (biosolids) is conveyed to one of two digesters that operate as biosolids storage tanks upstream of the dewatering system. Biogas generated by the digesters is routed to the plant's digester gas system. Dewatering belt filter presses (BFPs) and centrifuges produce dewatered cake, which is stored in silos prior to being loaded into trucks and hauled away for beneficial use or disposal by a third-party contract hauler.

At this time, the majority of biogas produced at the plant is flared to prevent digester gas from venting to the atmosphere. A portion of biogas is consumed to operate a boiler, which is used for digester heating. The RWRF installed a biogas conditioning system in 2012 to remove impurities and carbon dioxide, and produce a high-energy biomethane for use in gas turbines. However, the gas turbines were decommissioned in 2016, and the biogas conditioning system is not needed until a beneficial use of the biomethane is determined.

1.2.2 Basis for Performance and Capacity Analyses

Each solids process was evaluated relative to its capacity and performance to determine whether the existing solids systems have sufficient capacity to handle projected loads. The design capacity and performance baseline for each solids treatment process was determined using design/as-built documentation (i.e., drawings and reports) and the five most recent calendar years (2013 through 2017) of operational data obtained from RWRF staff. The solids loads from both the influent wastewater and delivered ADM were projected through year 2040 and compared against the identified treatment process design capacities.

Projections were based on population growth (to estimate future solids loading rates) and anticipated receipt of ADM. Population growth for the service area was determined using information in the City's most recent General Plan, which identifies a population increase of roughly 55 percent from 2015 to 2040. Average annual historical values were divided by population to obtain a per capita factor. Averaging five years of per capita flow and load factors and using the estimated 2040 population, projected flows and loads were calculated for each treatment process and compared to their existing capacities.

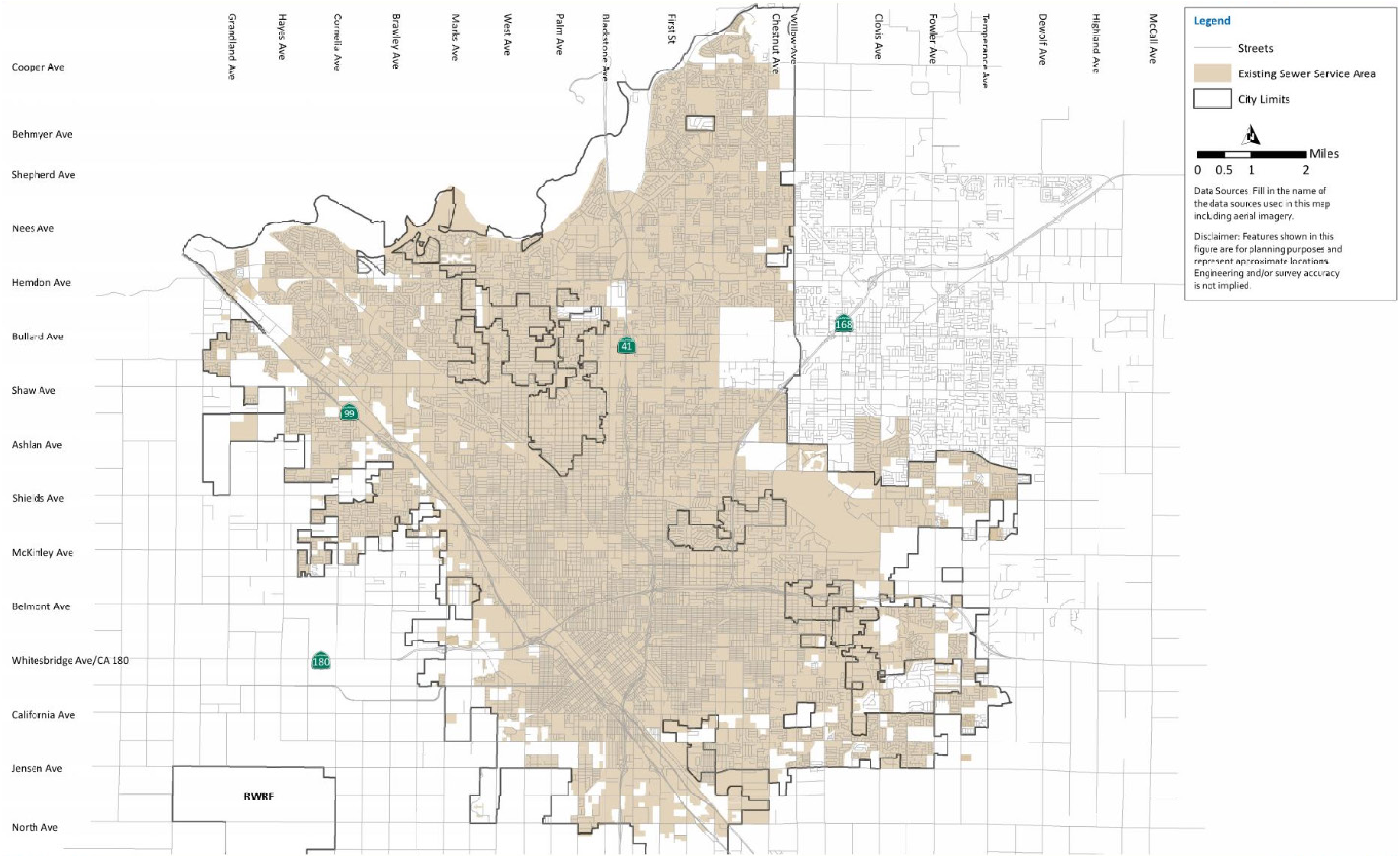

Figure 1.1 Fresno-Clovis RWRF Service Area

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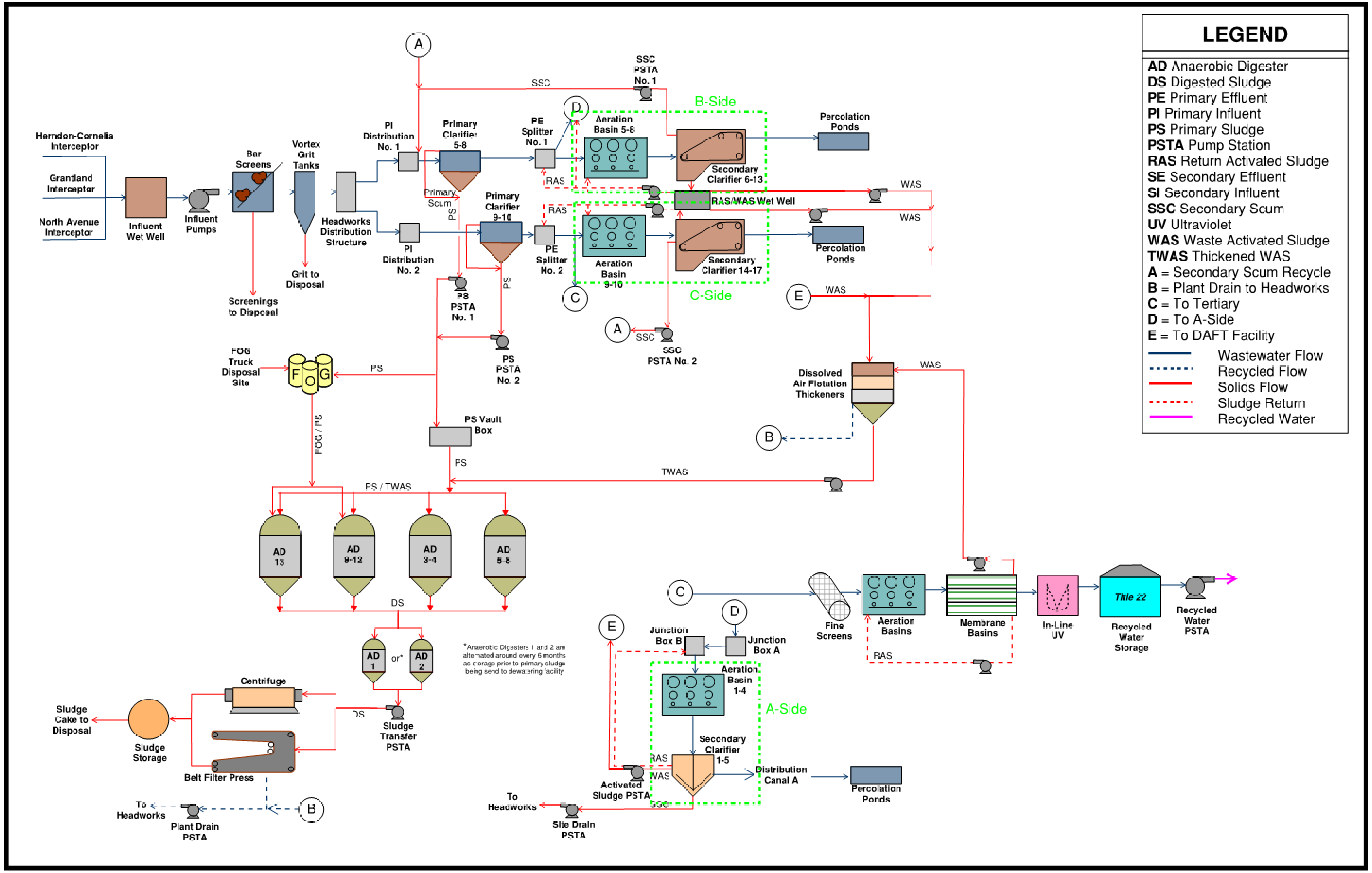

Figure 1.2 Fresno-Clovis RWRF Flow Schematic

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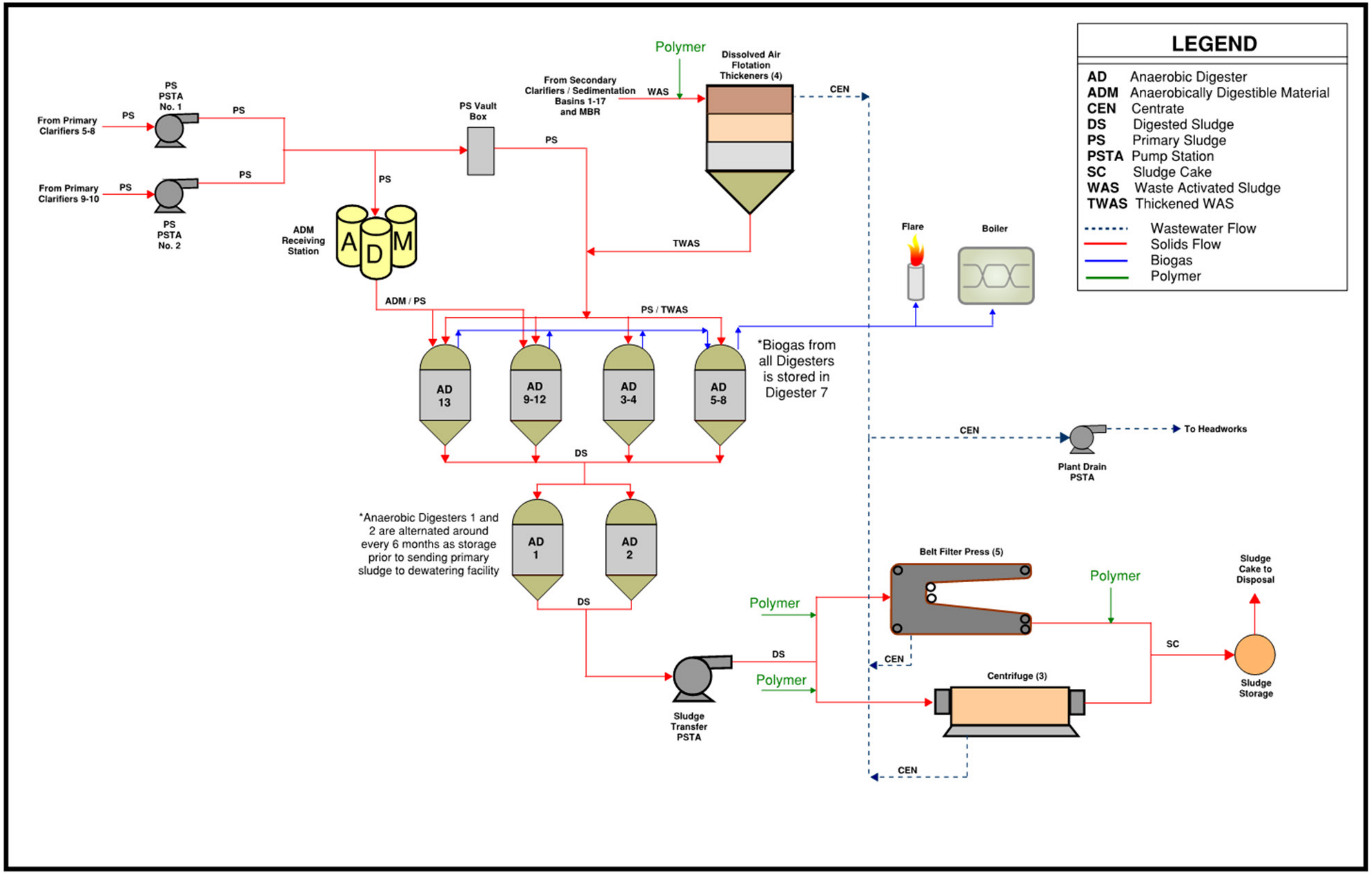

Figure 1.3 Fresno-Clovis RWRF Solids Flow Schematic

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1.3 Solids Flows, Loads, and Biosolids Production

1.3.1 Current Conditions

Table 1.1 shows the RWRF influent flow, as well as biochemical oxygen demand (BOD) and total suspended solids (TSS), from 2013 to 2017.

Table 1.1 Current Conditions – Influent Loads

Parameter	Units	Average	Maximum Day(1)	Ratio of Maximum Flow to Average Flow
Flow	mgd	57.8	63.9	1.10
BOD Concentration	mg/L	355	443	1.25
BOD Loading	lb/day	172,000	221,000	1.29
TSS Concentration	mg/L	313	393	1.26
TSS Loading	lb/day	153,000	201,000	1.31

Notes:
(1) Maximum day values were calculated as the 95th percentile of the daily data provided. This percentile was used to exclude data outliers.

Table 1.2 summarizes the flow and solids loading throughout the solids handling facilities. Pre-digestion, maximum daily values are calculated using the 95th percentile of the daily data from 2013 through 2017. This accounts for anomalies in operation and errors in data collection. Post-digestion, maximum daily values are calculated using the 90th percentile of the daily data from 2013 through 2017. This also accounts for anomalies in operation and errors in data collection but recognizes the ability of the digesters and solids storage to dampen peak flows before dewatering. Because of the significant increase in the ADM receiving station over the last several years, ADM values are calculated based on 2017 data only. Solids loading and percent solids are based on average values.

Table 1.2 Current Conditions - Solids Production

Parameter	Average Total Solids Loading, lb-TS/day	Average Total Solids (%)	Average Volatile Solids Loading, lb-VS/day	Average Volatile Solids (%)	Average Flow (mgd)	Maximum Daily Flow (mgd)(1)	Ratio of Maximum Flow to Average Flow
Primary Sludge	129,000	4.2	104,000	3.4	0.375	0.497	1.32
WAS	77,900	0.81	--(2)	--(2)	1.17	1.43	1.22
Thickened WAS	76,500	4.4	61,600	3.5	0.213	0.270	1.27
ADM(3)	20,500	7.7	18,800	7.1	0.031	0.038	1.24
Digester Feed	226,000	4.6	184,400	3.8	0.66	0.87	1.33
Dewatering Feed	112,900	1.9	77,200	1.3	0.66	0.82	1.24
Dewatered Cake(7)	103,000	21	--(2)	--(2)	0.063	0.084	1.33

Notes:
(1) The 95th percentile was used to determine maximum day flow for parameters measured before digestion and the 90th percentile was used to determine the maximum daily flow post digestion. These percentiles were used to exclude data outliers.
(2) Information not available.
(3) 2017 values only.

1.3.2 Future Conditions

1.3.2.1 Basis of Analysis

The analysis of future solids production is based on the service area population growth over the planning horizon. The RWRF service area encompasses the City of Fresno and a portion of the City of Clovis. Clovis has rights to discharge 9.3 mgd into the collection system. The growth outlined in the City's most recent General Plan was used to approximate future flows. The General Plan estimates an annual population increase of roughly 2 percent, rising to nearly 850,000 in 2040, a 55 percent increase from the 2015 population. Figure 1.4 shows the projected service area population through the planning horizon.

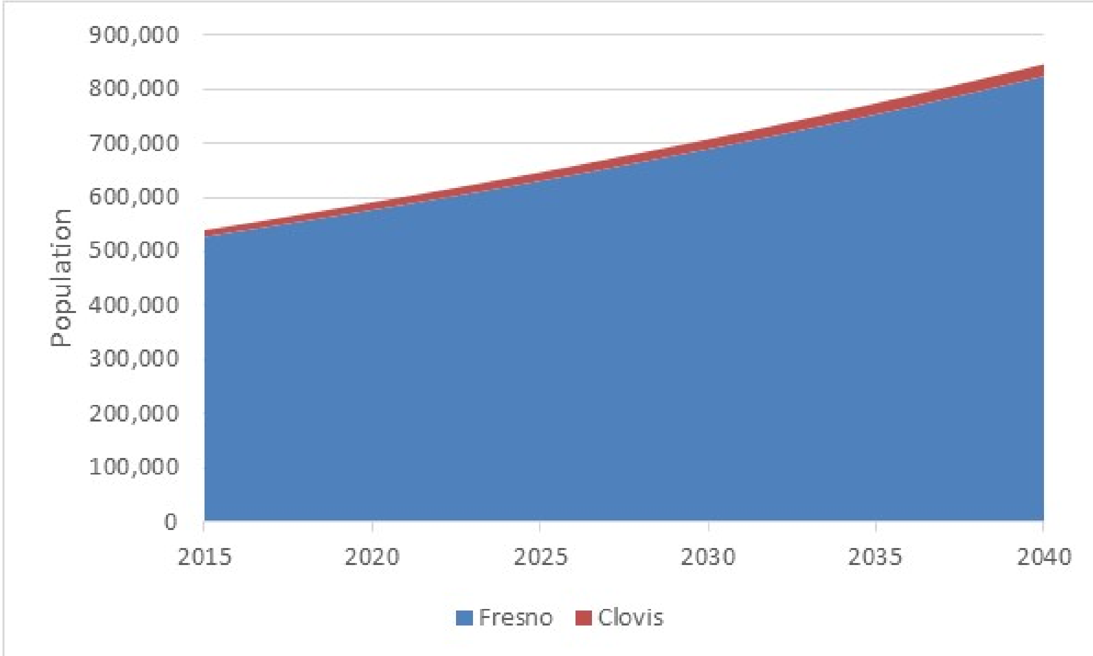

Figure 1.4 Fresno-Clovis RWRF Service Area Population

In order to determine future solids production, annual per capita loading values were calculated by dividing average solids loading by population. Then, the average per capita loading value was multiplied by the estimated 2040 population to determine future solids loading. Percent solids was assumed to remain constant from 2017 through 2040. A ratio was calculated from historic data as the maximum daily flow over the average flow. Future average flows were multiplied by this ratio to estimate future maximum daily flow. The future maximum daily and average flows were then compared to the capacities of the existing equipment. Because projections are based on population growth, PS and TWAS flows and loads increase proportionally to population.

Several assumptions were made in order to approximate ADM loading projections. The average daily volume of ADM received has steadily increased from 2014 through 2017. Thus, in order to project future ADM loads, the percent volatile solids in each ADM load was assumed to remain constant at 2017 values (7.1 percent volatile solids). Similarly, it was assumed that the volatile solids contribution from ADM to the digesters, relative to the volatile solids loading from the PS and TWAS, would remain constant at just under 10 percent. Therefore, the ADM projections track closely with the anticipated population growth. As was done for the PS, WAS, and TWAS, the ratio of the 95th percentile volume over the average volume was used to estimate the maximum ADM loading in 2040.

The sum of the projected PS, TWAS, and ADM solids loading rates and flow rates were used to calculate the projected digester feed.

Projected methane production was calculated based on volatile solids reduction (VSR) in the digesters. The chemical oxygen demand to volatile suspended solids ratio (COD:VSS) is a way to calculate the amount of COD removed through digestion based on the VSR. The amount of methane produced is proportional to the amount of COD removed. It is assumed that conventional sludge (PS and TWAS) has a COD:VSS ratio of 1.55 based on literature (Rittmann and McCarty, 2001), (O'Rourke, 1968)[1]. The COD:VSS ratio for the ADM loads was calculated using the 2017 data and has a value of 2.25. From literature, for every pound of COD removed, 5.6 cubic feet of methane is produced.

The projections of dewatering feed solids were based on the total solids fed to the digesters, the volatile solids contribution of each waste stream, and the respective volatile solids reduction in the digesters. It is assumed that the inert solids (the difference between total solids and volatile solids) completely pass through the digesters. Furthermore, liquid volume remains unchanged from digester feed to the dewatering feed. Based on historical data, the average volatile solids reduction for non ADM digesters is 60.4 percent. It was assumed that ADM volatile solids reduction is 90 percent because its composition is much higher in fatty acids and energy dense compounds, rather than inert solids typical in wastewater.

The remaining solids after digestion are sent to the belt filter presses and centrifuges for dewatering. The daily tons and cubic yards of cake produced were estimated based on the historical flow split between BFPs and centrifuges, percent solids capture, and percent solids in the cake. The historical average flow split by volume has been roughly 30/70 with the centrifuges processing more flow. However, the equipment run times are similar since the centrifuges can handle loads twice that of the BFPs. The average percent solids of the cake is 17.2 percent and 23.3 percent for the BFPs and centrifuges, respectively. Percent solids capture is 96.7 percent for the centrifuges. Although solids capture is not monitored for BFPs, it was assumed to be the same as that for centrifuges. Volume of biosolids produced was estimated by assuming a cake density of 45 pounds per cubic foot (Glover, 1997)[2] for BFPs and centrifuges.

1.3.2.2 Projected Solids Production (in 2040)

Table 1.3 reports the projected solids production for the individual solids processes in 2040. The pre-digestion percent total solids and volatile solids, and peaking factors were assumed to be the same as current values. Post-digestion parameters were calculated based on the methods described above. The pre-digestion solids loading and biogas production values shown in Table 1.3 are similar to the values estimated by the Black & Veatch Fresno-Clovis Regional Wastewater Reclamation Facility Digestion Optimization Evaluation (B&V report). Black & Veatch projected 2040 flows and loads for PS, WAS, and ADM. They also projected the resulting biogas production in 2040. A comparison of their estimates to the estimates used in this report is shown in Table 1.4. As Black & Veatch's focus was on digestion optimization, they did not provide projections for biosolids.

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[1] A digester feed COD:VSS ratio of is based on a 2:1 blend of primary sludge, with a particulate COD:VSS ratio of 1.60 (O'Rourke, 1968), and thickened waste activated sludge, with a COD:VSS ratio of 1.48. The thickened waste activated sludge COD:VSS ratio of 1.48 is, in turn, based on a blend of biomass, with a COD:VSS ratio of 1.42 (Rittmann and McCarty, 2001), and unbiodegradable primary effluent VSS, with a COD:VSS ratio of 1.60.

[2] Glover, Thomas J. Pocket Ref. Sequoia Publishing, Inc., 1997. ISBN 1-885071-oo-0. Page 435. Used and cited at 1,215 pounds/cubic yard (45 lb /cf) for dewatered sewage sludge in Cost and Benefit Changes Since Proposal for Standards of Performance for New Stationary Sources and Emission Guidelines for Existing Sources: Sewage Sludge Incineration Units, USEPA, January 2011.

Table 1.3 Future Conditions (2040) – Solids Production

Parameter	Average Total Solids per capita (lb-TS/cap-day)	Average Total Solids Loading (lb-TS/day)	Average Percent Total Solids (percent)	Average Volatile Solids per capita (lb-VS/cap-day)	Average Volatile Solids Loading (lb-VS/day)	Average Percent Volatile Solids (percent)	Average Flow (mgd)	Maximum Daily Flow (mgd)	Ratio of Maximum Flow to Average Flow
Primary Sludge	0.23	198,000	4.2	0.19	159,000	3.4	0.57	0.75	1.32
Waste Activated Sludge	0.13	125,700	0.81	--(1)	--(1)	--(1)	1.86	2.28	1.22
Thickened WAS	0.15	124,000	4.4	0.12	102,000	3.5	0.35	0.44	1.27
ADM	0.037	31,300	7.7	0.034	29,000	7.1	0.049	0.060	1.24
Digester Feed	0.42	353,300	4.6	0.34	290,000	3.8	1.00	1.33	1.33
Dewatering Feed	0.20	173,000	2.1	0.13	106,000	1.3	1.00	1.24	1.24
Dewatered Cake	0.19	167,500	21	--(1)	--(1)	--(1)	0.096	0.13	1.33

Notes:
(1) Information needed for projecting this value was not available.

Table 1.4 Comparison of Black & Veatch Projections and Projections used in this Analysis

Parameter	Units	2040 Black & Veatch Projections(1)	2040 Projections used in this Analysis(2)
Primary Sludge	lb/day	183,000	198,000
Thickened Waste Activated Sludge	lb/day	117,000	124,000
ADM	lb/day	56,000 to 154,000(3)	49,000
Digester Gas	scfm	2,140 to 2,700(3)	2,185

Notes:
(1) Source: Black & Veatch Fresno-Clovis Regional Wastewater Reclamation Facility Digestion Optimization Evaluation, 2017. The goal of the Black & Veatch evaluation was to optimize digester operation and performance, as well as identify sources of high strength wastes for co-digestion and biogas generation.
(2) Projected values are based on historical per capita sludge production and projected population growth through 2040.
(3) Four scenarios were evaluated in Black & Veatch's evaluation resulting in a range of projected values.

1.4 Analyses of Existing Solids Handling Facilities

The sections that follow provide a summary by solids treatment process, including the design criteria and capacity and performance assessment for each.

1.4.1 Primary and Waste Activated Sludge Handling

1.4.1.1 Description

After preliminary treatment, the flow is split among circular primary clarifiers. There are six primary clarifiers, three duty and three standby, numbered 5 through 10. The primary scum and sludge collected in the clarifiers is pumped into a common discharge pipe and sent to the anaerobic digesters. Primary Sludge Pump Station 1 serves Primary Clarifiers 5 through 8 and Primary Sludge Pump Station 2 serves Primary Clarifiers 9 and 10. Due to hydraulic issues between the primary clarifiers and secondary treatment trains, plant staff prefer not to operate Primary Clarifiers 9 and 10 unless needed. This allows for a more even flow split among duty primary clarifiers.

After primary treatment, primary effluent is routed to several junction boxes that feed A-, B-, and C-Side secondary treatment processes. Following secondary clarification and sedimentation, WAS is pump to dissolved air flotation thickeners (DAFT) for thickening. WAS produced in the MBR units is also sent to DAFT. A-Side treatment and MBR units have their own dedicated RAS/WAS pump station. B and C Side treatment have separate RAS/WAS pump stations in a common building. WAS from each pump station is pumped continuously to a common headbox at the DAFT units. Secondary scum is pumped upstream of the primary clarifiers.

1.4.1.2 Original Design Criteria

The PS pumps in each Primary Sludge Pump Station have common suction and discharge manifolds. Pumps operate through the actuation of valves that control the removal of PS from each clarifier. The PS pumps are air operated diaphragm pumps, which utilize compressed air to move pistons, creating the suction and discharge pressures capable of transporting the combined sludge and scum.

The secondary sedimentation basins, secondary clarifiers, and MBR units each have a dedicated RAS/WAS pump station. One WAS pump for each treatment train operates continuously with additional pumps turning on as needed based on required operating conditions.

Table 1.5 summarizes the original design criteria for the PS Pumps and the WAS Pumps.

Table 1.5 Original Design Criteria for PS and WAS Pumps

Parameter	Unit	Design Criteria			
Primary Sludge Pumps		Primary Clarifiers 5-8 Primary Sludge Pump Station 1		Primary Clarifiers 9-10 Primary Sludge Pump Station 2	
Number of Pumps	-	4 Duty + 4 Standby		2 Duty + 2 Standby	
Type	-	Air Diaphragm		Air Diaphragm	
Capacity, each	gpm	140		140	
Capacity, total(1)	mgd	1.6		0.8	
Capacity, firm(2)	mgd	0.8		0.4	
Horsepower, each	hp	NA(3)		NA(3)	
Waste Activated Sludge Pumps		A-Side Secondary Clarifiers 1-5	B-Side Secondary Sedimentation Basins 6-13	C-Side Secondary Sedimentation Basins 14-17	MBR
Number of Pumps(4)	-	1 Duty + 4 Standby	1 Duty + 2 Standby	1 Duty + 1 Standby	1 Duty + 1 Standby
Type	-	Centrifugal	Centrifugal	Centrifugal	Centrifugal
Capacity, each	gpm	700	700	700	100
Capacity, total(1)	mgd	5.0	3.0	2.0	0.29
Capacity firm(2)	mgd	1.0	1.0	1.0	0.14
Horsepower, each	hp	20	20	20	5

Notes:
(1) Total capacity calculated with all pumps in service, operating continuously
(2) Firm capacity calculated with only duty pumps in service, operating continuously
(3) Primary sludge pumps are air-operated diaphragm type, which do not have motors.
(4) One pump operates continuously for each treatment train with additional pumps turning on as needed.

1.4.1.3 Capacity and Performance Assessment

Table 1.6 compares the current and projected sludge flows to the original design criteria for the PS and WAS pumps to assess whether or not there is sufficient capacity. As indicated in the table, there is sufficient capacity under current conditions. Under future conditions, only B-side WAS pumps appear limited in firm capacity. However, the B-side pump station has two standby pumps, so in the future, two pumps could be operated as duty units with a single standby. No additional pumps are needed based on this capacity analysis.

The City has not expressed concerns about the operational performance or capacity of the PS or WAS pumps. Each duty pump has at least one standby pump, providing adequate capacity and ability to maintain functionality during pump maintenance. The only operational change that the City needs to complete is related to continuous measurement of WAS from the MBR train. There is currently no flow meter measuring the MBR train WAS flows, so they are approximated by staff. However, the City intends to install a flow meter in the near future to maintain more accurate operating records.

Table 1.6 Capacity Assessment – PS and WAS Pumps

Parameter	Unit	Capacity	Current		Future	
			Capacity Needs	Sufficient Processing Capacity?	Capacity Needs	Sufficient Processing Capacity?
Primary Sludge Pump Firm Capacity	**mgd**	**0.8**				
Average Daily			0.38	Yes	0.58	Yes
Maximum Daily(1)			0.50	Yes	0.70	Yes
Waste Activated Sludge Pump Firm Capacity						
A-Side	**mgd**	**1.0**				
Average Daily			0.26	Yes	0.43	Yes
Maximum Daily(1)			0.45	Yes	0.74	Yes
B-Side	**mgd**	**1.0**				
Average Daily			0.54	Yes	0.85	Yes
Maximum Daily(1)			0.78	Yes	1.23	No
C-Side	**mgd**	**1.0**				
Average Daily			0.38	Yes	0.59	Yes
Maximum Daily(1)			0.56	Yes	0.87	Yes
MBR	**mgd**	**0.14**				
Average Daily			0.05(2)	Yes	0.08	Yes
Maximum Daily(1)			0.05(2)	Yes	0.08	Yes

Notes:
(1) Calculated as 95th percentile of daily flows. This percentile was used to exclude data outliers.
(2) Flows not metered. Values estimated to be 85 gpm running 10.1 hours per day per communication with City staff.

1.4.2 Sludge Thickening

1.4.2.1 Description

Primary sludge is thickened in the primary clarifiers. Per City input, this process performs to their expectations. The currently available digestion capacity is sufficient to handle this solids concentration and staff is wary of pumping problems if they operated at thicker solids concentrations.

The RWRF uses DAFTs for WAS thickening. There are four DAFTs at the RWRF. Currently, only the two larger DAFT units (3 and 4), are in operation in a duty/standby configuration. The WAS from the activated sludge process and MBR basins is pumped to a common header box at DAFT Nos. 3 and 4. From this box, the WAS is fed by gravity to the operating DAFT for thickening prior to digestion. The DAFT units operate for roughly one month at a time before switching between duty and standby. Per the City, the two older, smaller DAFT units (1 and 2) are to be demolished because their ancillary equipment is not functional and their capacity is not needed.

Thickening requires the use of polymer and compressed air. A bulk polymer tank stores neat emulsion polymer, which is combined with non-potable dilution water in polymer blending units to produce a dilute polymer solution. The polymer solution is then injected into the WAS pipe just upstream the DAFT units. The polymer neutralizes the negative surface charge of the sludge and promotes floc formation of the WAS solids.

Compressed air is injected into the pressurized recycle stream that is pumped into the DAFT. Once the combined sludge and air stream is released into the DAFT, the air bubbles come out of solution and float to the top of the thickener. The solids flocs adhere to the bubbles and float to the surface of the basin where they concentrate. A skimming arm rotates around the water surface of the basin and pushes the floating sludge, now referred to as TWAS, into the float box, which is connected to the TWAS Float Pump header. Heavier solids settle to the bottom of the basin. The DAFT collector mechanism conveys the bottom sludge into a sump. Bottom sludge pumps currently operate based on time (eight minutes every hour) and pump the settled sludge into a common discharge with the TWAS. The combined TWAS and bottom sludge is pumped to the anaerobic digesters.

Supernatant that flows under a baffle and over a weir within the DAFT is sent to a site drain pump station and pumped back to the headworks.

1.4.2.2 Original Design Criteria

Table 1.7 summarizes the original design criteria for DAFT Nos. 3 and 4 and the ancillary equipment associated with the thickening process. The design criteria values are based on one DAFT operating continuously.

Table 1.7 Original Design Criteria for DAFT Nos. 3 and 4, Polymer System, & TWAS Pumps

Parameter	Units	Value
DAFT Nos. 3 and 4		
Year Constructed	-	1974 (2006 retrofit)
Diameter	ft	60
Side Water Depth	ft	11
Total Surface Area	ft^2	5,700
Design Solids Loading Rate	$lb/hr/ft^2$	2
Hydraulic Loading Rate	gpm/ ft^2	1.1
Design Solids Loading Capacity, total	lb/day	136,800
Design Hydraulic Loading Capacity, total	gpm	3,120
Design Thickened Solids Concentration	%	3 – 7
Design Percent Capture (with polymer addition)	%	95
Polymer System		
Polymer Type		Emulsion
Polymer Activity	%	41
Active Polymer Dose to DAFTs	lb active / dry ton feed solids	4-10
Neat Polymer Storage Tank		
Number	-	1
Size	gallons	6,000
Polymer Blending Units/Polymer Transfer Pumps		
Number	-	3
Capacity, each	gph	0.6-6.0
Horsepower, each	hp	0.5
Dilution Water Flow Rate	gph	120-1200
Thickened WAS Pumps		
TWAS Bottom Sludge Pumps		
Number(1)	-	2 Duty + 1 Standby
Type	-	Progressive Cavity
Capacity, each	gpm	100
Horsepower, each	hp	10
TWAS Float Pumps		
Number(2)	-	4 Duty + 2 Standby
Type	-	Progressive Cavity
Capacity, each	gpm	200
Horsepower, each	hp	15

Notes:
(1) Each DAFT unit has one dedicated bottom sludge pump and a common standby pump.
(2) Each DAFT unit has two duty TWAS float pumps and a standby pump.

1.4.2.3 Capacity and Performance Assessment

Table 1.8 compares the current and projected WAS flows and loads to the original design criteria for the DAFT system. Table 1.9 summarizes current performance relative to thickened sludge concentration, polymer consumption, and percent capture. As shown in Table 1.8, the DAFTs and TWAS pumps are expected to operate within their design criteria for both solids and hydraulic loading under current and most projected conditions. The maximum daily solids loading to the DAFTs is projected to be slightly above the design criteria in 2040. If the DAFT units are loaded beyond the design criteria, the solids capture efficiency could decrease. One way to address this could be to operate both DAFT units concurrently during anticipated periods of peak flows. Table 1.9 shows the capacity of the polymer system. The projected maximum polymer usage exceeds the capacity of the existing polymer pump. Additional capacity can be added by utilizing existing standby polymer units.

Table 1.8 Capacity Assessment – DAFTs, Polymer, and TWAS Pumps

Parameter	Unit	Design Criteria/ Capacity	Current		Future	
			Capacity Needs	Sufficient Processing Capacity?	Future Capacity Needs	Sufficient Processing Capacity?
DAFT						
Solids Loading Rate	**lb/hr/ft^2**	**2.0**				
Average Daily			1.14	Yes	1.8	Yes
Maximum Daily(1)			1.40	Yes	2.2	No
Hydraulic Loading Rate	**gpm/ft^2**	**1.1**				
Average Daily			0.29	Yes	0.45	Yes
Maximum Daily(1)			0.35	Yes	0.56	Yes
TWAS Float Pump						
Capacity(2)	gpm	400				
Average Daily			148	Yes	240	Yes
Maximum Daily(1)			187	Yes	304	Yes
Polymer Pump						
Capacity	gph	6				
Average Daily			2.7	Yes	4.3	Yes
Maximum Daily(1)			4.0	Yes	6.3	No

Notes:
(1) Calculated as the 95th percentile. This percentile was used to exclude data outliers.
(2) Firm capacity for TWAS float pumps with one DAFT in service. TWAS bottom sludge pumps not included.

Table 1.9 DAFT System Performance

Parameter	Units	Design Criteria	Current Performance	Meeting Performance Criteria?
Thickened Sludge Concentration	**%**	**5**		
Average Daily			4.4	Yes
Maximum Daily(1)			5.3	Yes
Polymer Consumption				
Active Polymer Consumption	lb active / dry ton solids	4 – 10	5.6	Yes
Solids Capture(2)	**%**	**95**		
Average Weekly			90	No
Minimum Weekly(3)			87	No

Notes:
(1) Calculated as the 95th percentile. This percentile was used to exclude data outliers.
(2) Solids capture is sampled weekly.
(3) Calculated as the 5th percentile. This percentile was used to exclude data outliers.

Figures 1.5, 1.6, 1.7, and 1.8 illustrate DAFT loading, TWAS solids concentration, solids capture, and polymer consumption, respectively, for 2013 through 2017. DAFT loading has been well within original design criteria over this range. Figure 1.6 shows that the DAFTs produce TWAS between 3 and 5 percent solids, with an average of 4.2. This is within the expected and desired performance range for the thickening system. While the TWAS float pumps have sufficient hydraulic capacity, staff report that the pumps have issues pumping TWAS when the solids concentration exceeds 5 percent solids. This is not currently a significant concern because of the available digestion capacity. If the need to pump thicker material arises in the future, changes in motor or VFD may be needed to provide sufficient starting torque. Staff noted that when the TWAS pumps were first installed, they would overload at pump start, possibly due to the check valves installed on the vertical discharge lines or the type of VFD installed. However, as the stators of the progressive cavity pumps wore down they operated more reliably.

For convenience, the City utilizes the same polymer type for the thickening and dewatering processes, which simplifies the City's polymer contract, deliveries, maintenance, and operation. However, having the same polymer type sacrifices performance, most notably solids capture in the DAFTs for which the polymer was not optimized. This is illustrated in Figure 1.7. The current polymer was optimized for the dewatering process (i.e., belt filter presses that were installed in 1992). The current polymer dose is within the design dose range, as shown in Figure 1.8, but the inability to meet capture performance criteria may signify that the polymer currently used is not suitable for the DAFT process. This could be improved with the selection of a polymer optimized for the thickening process. The new polymer contract is planned to be based on optimization of the dewatering in the centrifuges. Plant staff stated the DAFT units will likely receive whichever polymer is chosen as a result of the centrifuge optimization.

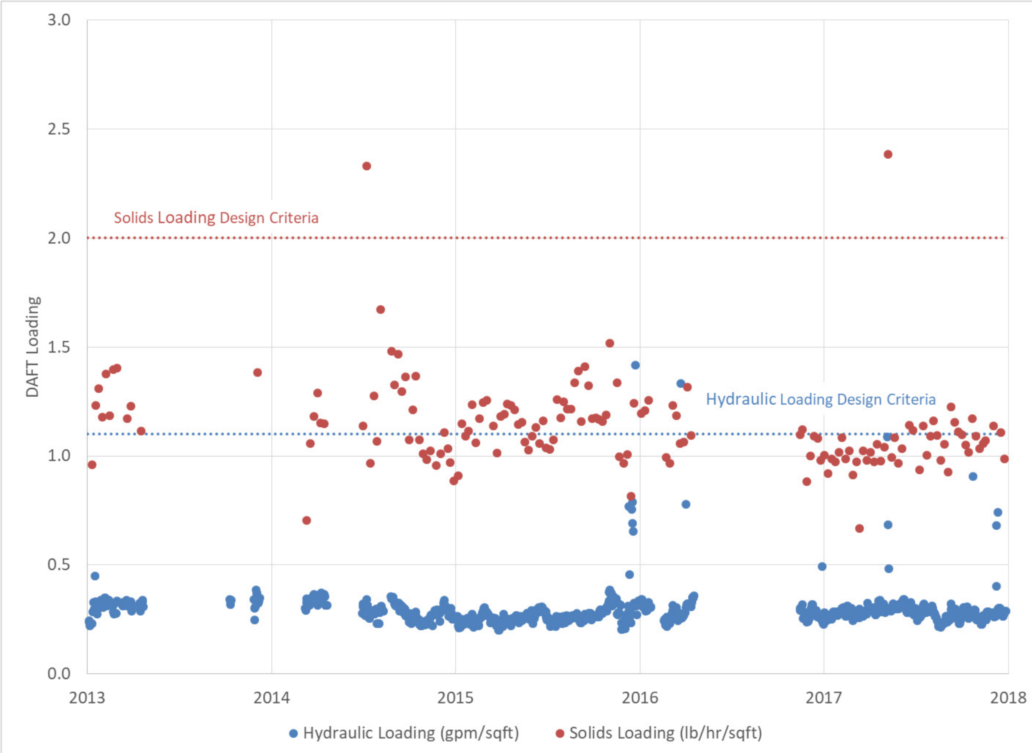

Figure 1.5 DAFT Solids Loading Rate (lb/hr/ft^2) and Hydraulic Loading Rate (gpm/ft^2) Relative to the Design Criteria

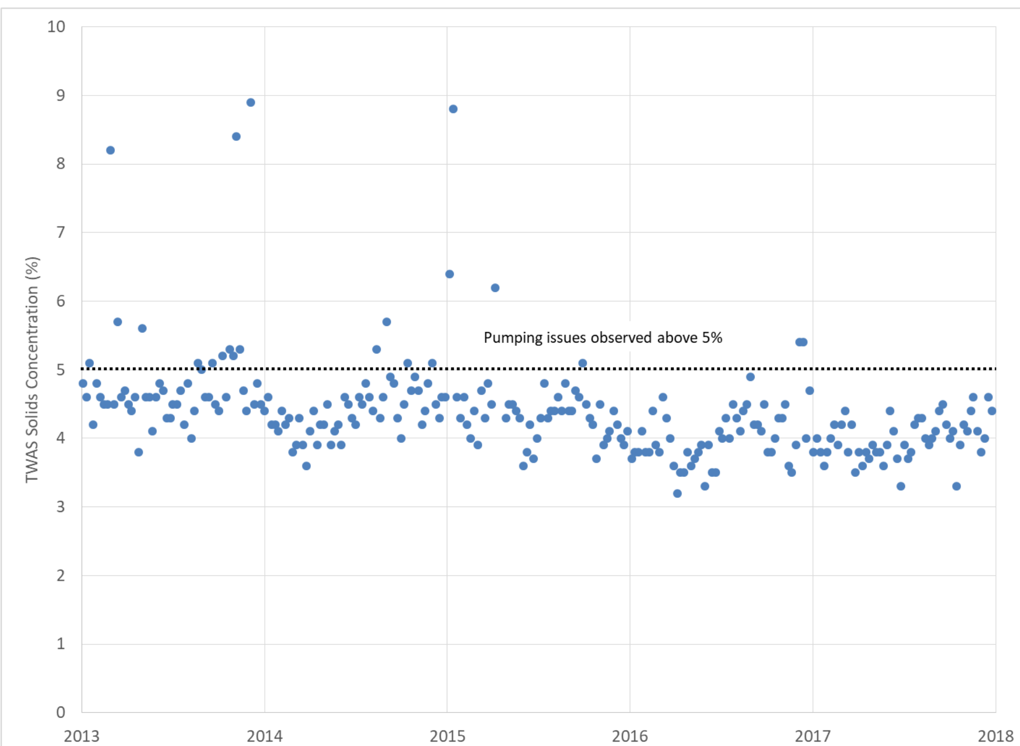

Figure 1.6 DAFT TWAS Percent Solids Concentration

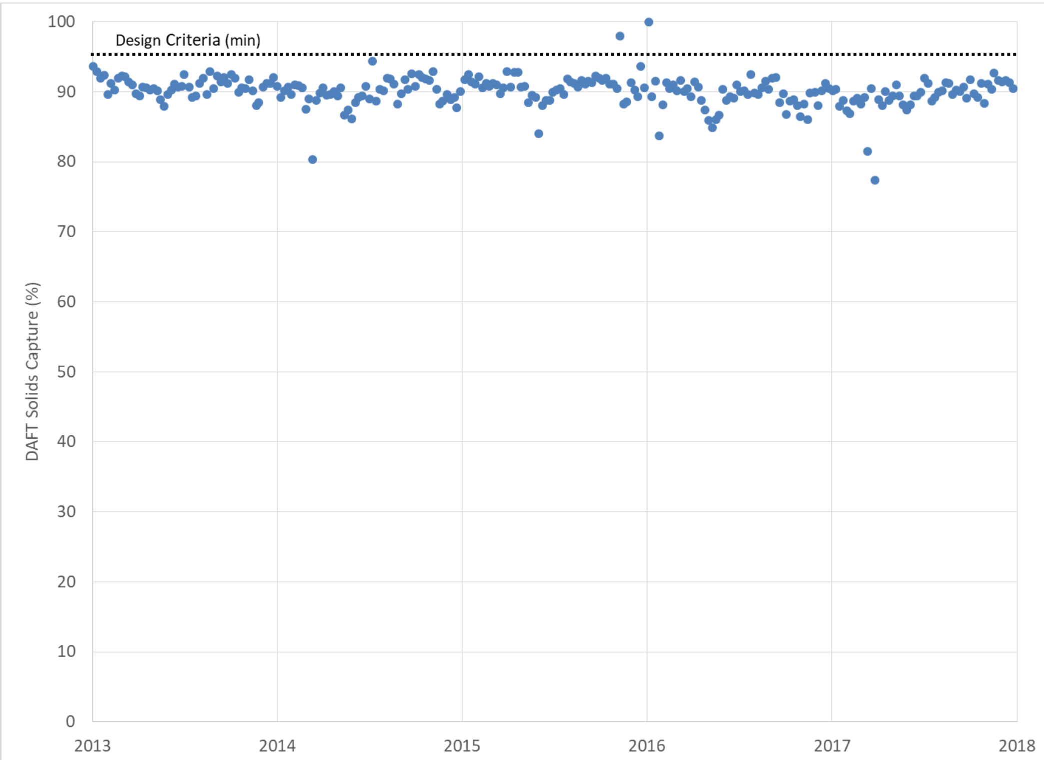

Figure 1.7 DAFT Percent Solids Capture Relative to the Design Capture

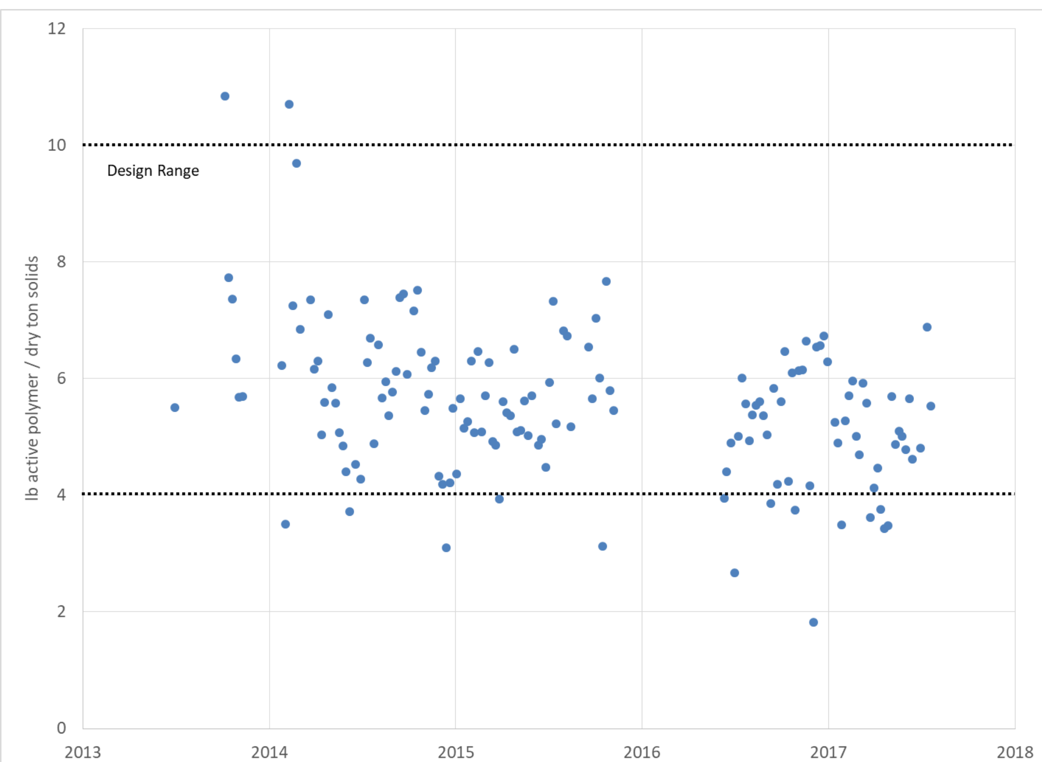

Figure 1.8 DAFT Polymer Consumption (lb active polymer/dry ton feed solids)

1.4.3 Anaerobically Digestible Material Receiving Station

1.4.3.1 Description

In 2009, the RWRF underwent improvements to add an anaerobically digestible material (ADM) receiving station. If discharged into the collection system, liquid waste material, such as fats, oils, and grease (FOG), can congeal in sewer pipelines causing blockages and overflows. FOG also contains high concentrations of volatile solids that can be broken down during anaerobic digestion to increase the production of biogas. While FOG is typically produced by restaurants, other types of ADM include food processing and manufacturing wastes that can also undergo digestion to produce biogas. The City accepts liquid ADM as external feedstock from several hauling companies that have the appropriate permits from the RWRF. The liquid ADM is from various regional facilities including food processing plants, commercial kitchens, and industrial plants. Most haulers are charged a tipping fee of $0.03/gallon.

The facility has historically accepted a variety of ADM, but no longer accepts blood waste due to the increased ammonia load in the return streams, and associated impacts on the liquid treatment processes. Additionally, a food waste slurry acceptance trial was attempted, but quickly ended due to operational issues. This trial was performed in partnership with Colony Energy.

The receiving station includes three 15,000-gallon fiberglass reinforced plastic (FRP) tanks, rock trap grinders, chopper pumps, ADM transfer pumps, and automatic fill, mixing, and drain valves. The tanks have a manway located on top for periodic inspection, maintenance, and cleaning. The ADM receiving station is designed so that haulers can access the waste disposal site at any hour of the day. Plant staff samples every ADM load, which is analyzed for chemical oxygen demand (COD), conductivity, percent total solids, and percent volatile solids. Each tank is equipped with red and green lights indicating if the tank is available to receive a load. An unloading panel near each ADM tank provides the hauler local control of the unloading operation. The hauler connects to one of the cam lock fittings and begins to fill the ADM tank. A rock trap/grinder separates out heavy objects from the load and grinds the remaining debris. This protects downstream mechanical equipment from potential blockage or damage. The ADM fill/mix pump located downstream of the rock trap/grinder is a chopper centrifugal type pump, further reducing the particle size of the debris.

Once the truck unloading operation is complete, a mixing sequence is automatically initiated. During the mixing sequence, a volume of PS equal to 25 percent of the total load is added. Tank contents are constantly mixed while PS is added. After a fixed time, the tank discharge sequence is initiated, which lowers the level in the tank. Mixing continues until the level drops below a set-point. One of two progressive cavity ADM transfer pumps routes the ADM and PS mixture to the anaerobic digesters. The discharge sequence interrupts the digester currently being fed and sends ADM to one of the Anaerobic Digesters 9 through 13 in a consecutive sequence. No other digesters receive ADM. Once the ADM discharge sequence is complete, the system is idle for five minutes before reinitiating the digester feed that was interrupted.

By accepting ADM at the RWRF receiving station, the City mitigates potential blockages in the collection system, increases biogas production in the digesters, and collects a revenue stream from tipping fees.

1.4.3.2 Original Design Criteria

Table 1.10 summarizes the original design criteria for the ADM receiving station.

Table 1.10 Original Design Criteria for the Anaerobically Digestible Material Receiving Station

Parameter	Unit	Design Criteria
Tanks		
Number	--	3
Capacity, each	gallon	15,000
Rock Trap/Grinder		
Number	--	3(1)
Horsepower, each	hp	5
ADM Fill/Mixing Pumps		
Type	--	Chopper Centrifugal
Number	--	3(1)
Capacity, each	gpm	425
Horsepower, each	hp	7.5
ADM Transfer Pumps		
Type	--	Progressive Cavity
Number	--	2
Capacity, each	gpm	200
Horsepower, each	hp	20

Notes:
(1) Each tank has one dedicated grinder and mix/fill pump.

1.4.3.3 Capacity and Performance Assessment

Table 1.11 shows the current and future operating conditions and capacity assessment for the ADM receiving station. The system components have sufficient capacity for current conditions. Future operating conditions were analyzed assuming the contribution of volatile solids from ADM compared to PS and TWAS (10 percent plant-wide) would remain constant from 2017 values. It is assumed that individual ADM load volumes and percent volatile solids would remain constant. Therefore, the tank capacity and drain and fill times would remain the same. However, the number of loads per day would increase. The capacity of the receiving station is sufficient to handle increased daily loads. However, there may be operational constraints with regards to hauling schedules and tank availability. If ADM load frequencies continue to increase, it is recommended to pursue fixed hauler schedules to minimize wait times and allow for more consistent operation.

Table 1.11 Operating Conditions and Capacity Assessment - ADM Receiving Station

Parameter	Unit	Design Criteria	Current		Future	
			Operating Conditions	Sufficient Processing Capacity?	Operating Conditions	Sufficient Processing Capacity
Average Load Volume	gallons/load	NA	4,600	Yes	4,000-6,000	Yes
Average Total Daily Volume Received[(4)]	**gallons/day**	**NA**	**31,600[(5)]**	**NA**	**49,000**	**NA**
Average Tank Usage	**# loads/day**	**NA**	**4.9**		**10.5[(3)]**	**NA**
Tank 1			2.1	NA		
Tank 2			1.3	NA		
Tank 3			1.5	NA		
Tank Capacity	**gallons/tank**	**15,000[(6)]**			**5,300-9,700[(7)]**	**Yes**
Average Tank 1 Utilization			5,900[(7)]	Yes		
Average Tank 2 Utilization			5,300[(7)]	Yes		
Average Tank 3 Utilization			6,000[(7)]	Yes		
Maximum Tank 1 Utilization[(8)]			9,600	Yes		
Maximum Tank 2 Utilization[(8)]			9,600	Yes		
Maximum Tank 3 Utilization[(8)]			9,700	Yes		
Tank Fill Time	min/load	NA	36[(9)]	Yes[(10)]	36[(9)]	Yes[(10)]
Tank Drain Time	min/load	NA	75[(9)]	Yes[(10)]	75[(9)]	Yes[(10)]

Notes:
(1) One load is defined as the volume transferred to the FOG storage tank by one hauler at one time.
(2) Data averaged from 2013 through 2017.
(3) It was assumed that the average load volume would remain the same in the future. However, the number of loads per day would increase to account for projected increases in ADM.
(4) The Total Daily Volume Received is the sum of all the loads received on one day.
(5) Based on 2017 data.
(6) 25 percent of this tank capacity is reserved for PS.
(7) Includes ADM volume plus 25 percent load volume of PS.
(8) The maximum was calculated by taking the 95th percentile of the data. This percentile was used to exclude data outliers.
(9) Time is calculated based on filling/draining a full tank volume (15,000 gallons) divided by the 425 gpm mix/fill pump capacity or the 200 gpm drain pump capacity.
(10) Based on staff agreement that these times are acceptable for ADM station operation.

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The City has expressed no concern with the operation or capacity of equipment related to the ADM receiving station. However, the City did note that the characteristics of the material received varies widely. Staff is concerned that some loads have very low solids concentration (e.g., 1-percent total solids). Because they primarily represent an increased hydraulic load on the digesters, these loads decrease the solids residence time of the digesters without the production of additional biogas.

Haulers can choose to connect to any available ADM tank upon arrival. Because of its location, ADM Tank No. 1 and its associated equipment have experienced higher use than the other loading stations. Plant staff have already replaced the Tank 1 fill pump. To mitigate uneven wear among system components, the City can alter the tank indicator lights programming to show tank availability sequentially. This would more evenly distribute the wear across the three loading stations (tanks and related equipment).

There is sufficient capacity in the existing system to accept larger and/or more frequent ADM loads. Figure 1.9 shows that the average volume of each ADM load has remained fairly constant over the last five years at around 4,600 gallons. The frequency of loads accepted at the RWRF has increased since the receiving station opened. As shown in Figure 1.10, the average daily volume of ADM received has more than doubled from 16,200 gallons in 2013 (or 4 loads per day) to 31,600 gallons at the end of 2017 (this is equivalent to roughly 7 loads per day).

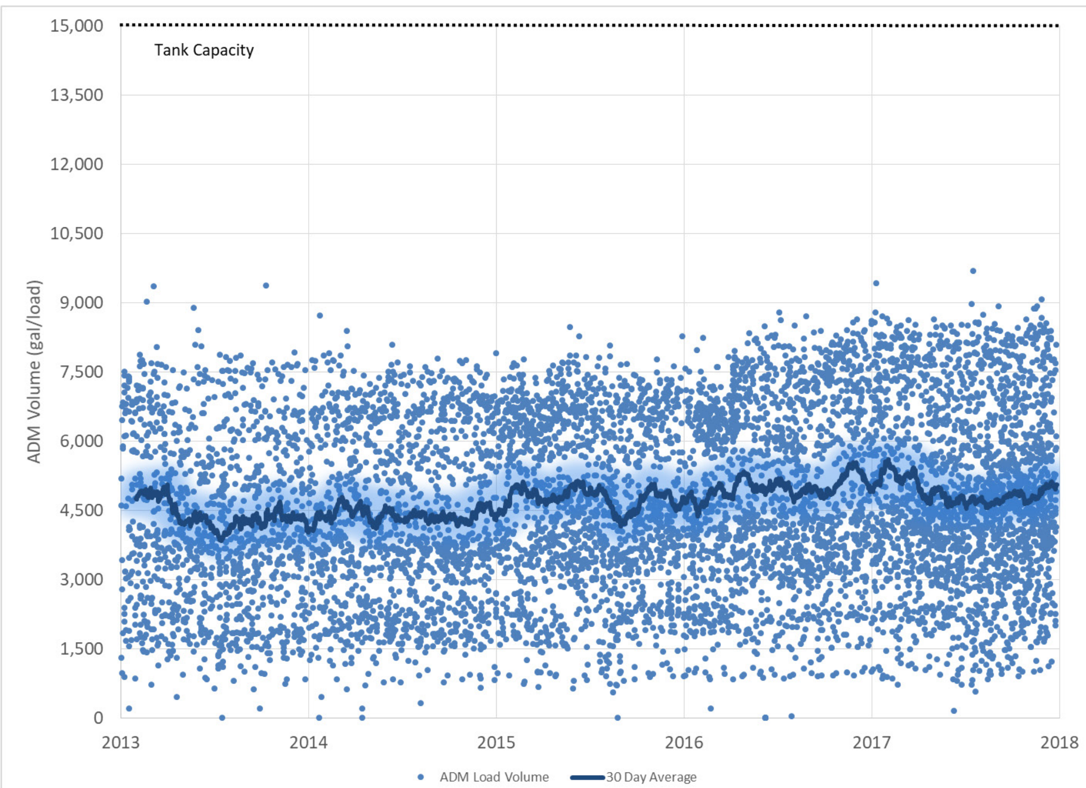

Figure 1.9 Volume Delivered per ADM Load (gal/load)

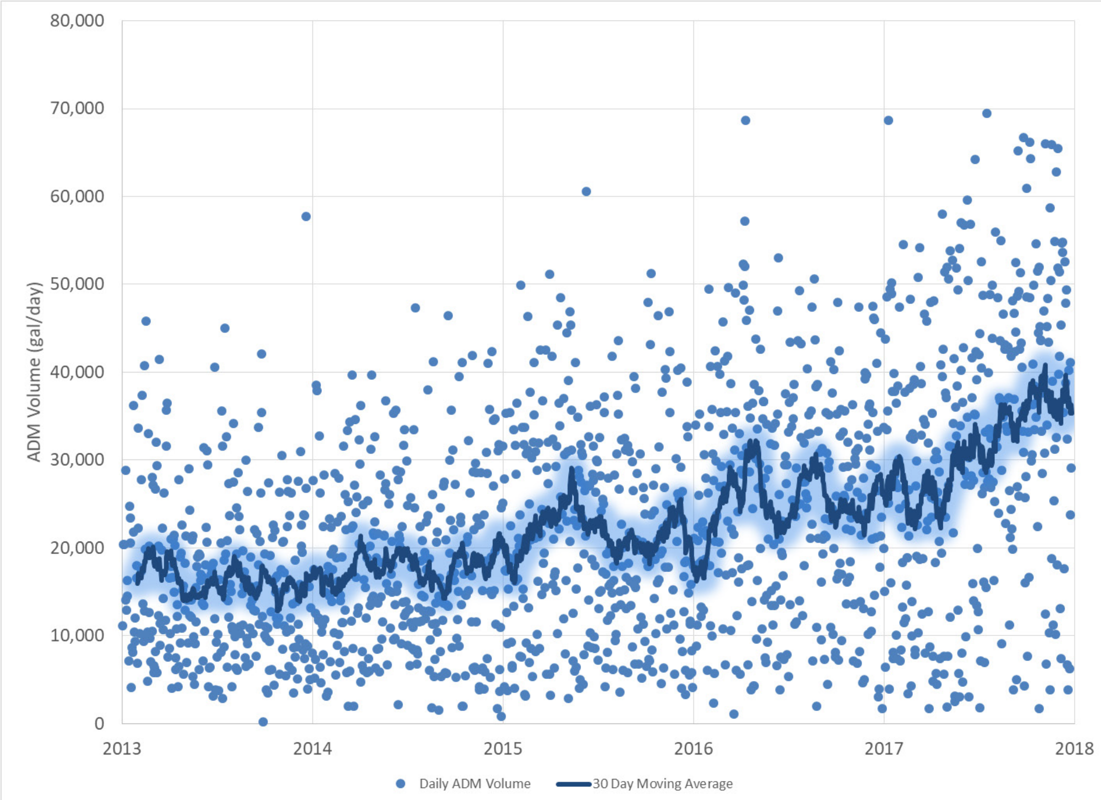

Figure 1.10 Average Daily ADM Load (gal/day)

Figures 1.11 and 1.12 show the daily chemical oxygen demand (COD) loading and volatile suspended solids (VSS), respectively. Both VSS and COD are directly related to biogas production in the anaerobic digesters. The VSS has remained relatively stable over the last four years, while the COD has decreased slightly. The City noted that some haulers bring very dilute loads with low potential biogas production. The City could address (and possibly resolve) this issue by implementing a sliding scale tipping fee for each hauler based on the approximate projected biogas production. Alternatively, the City could reject haulers that do not meet a minimum VSS and/or COD concentration. The City is considering these options.

Based on the capacity and current performance of the ADM receiving station the RWRF has capacity to increase the volume of ADM accepted at the receiving station. However, as more loads are received per day, scheduling haulers to offload their ADM at different times will become increasingly necessary, as it is expected that there will be an average of 11 loads per day in 2040.

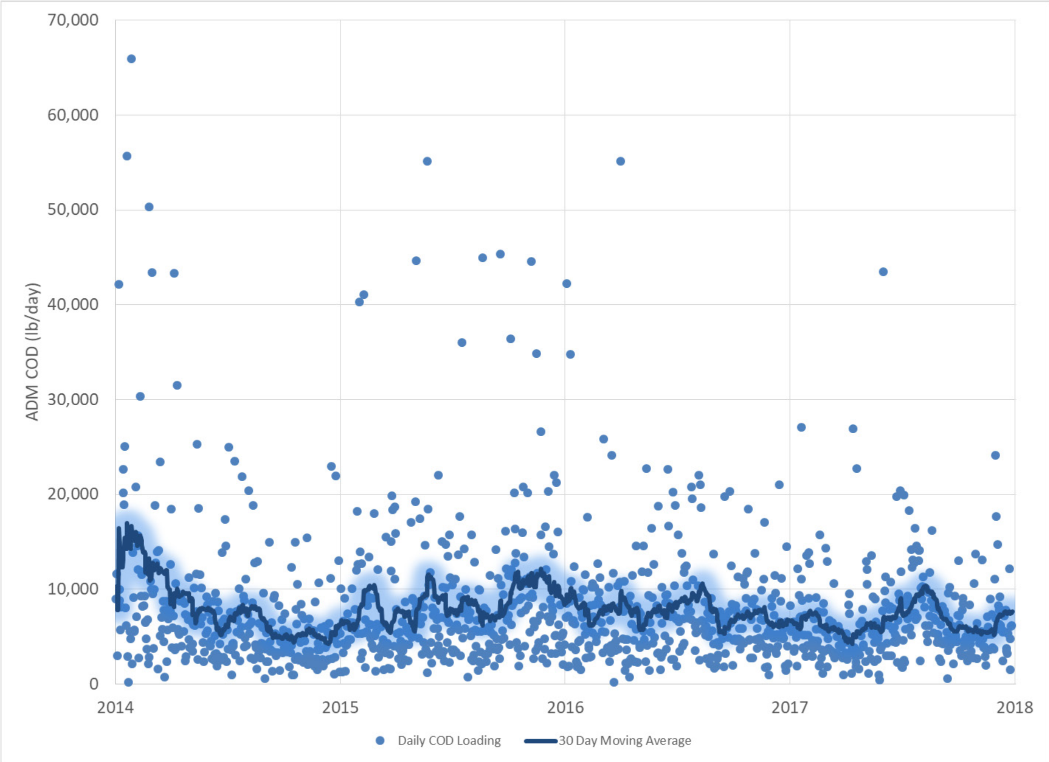

Figure 1.11 Average Daily COD Load (lb/day)

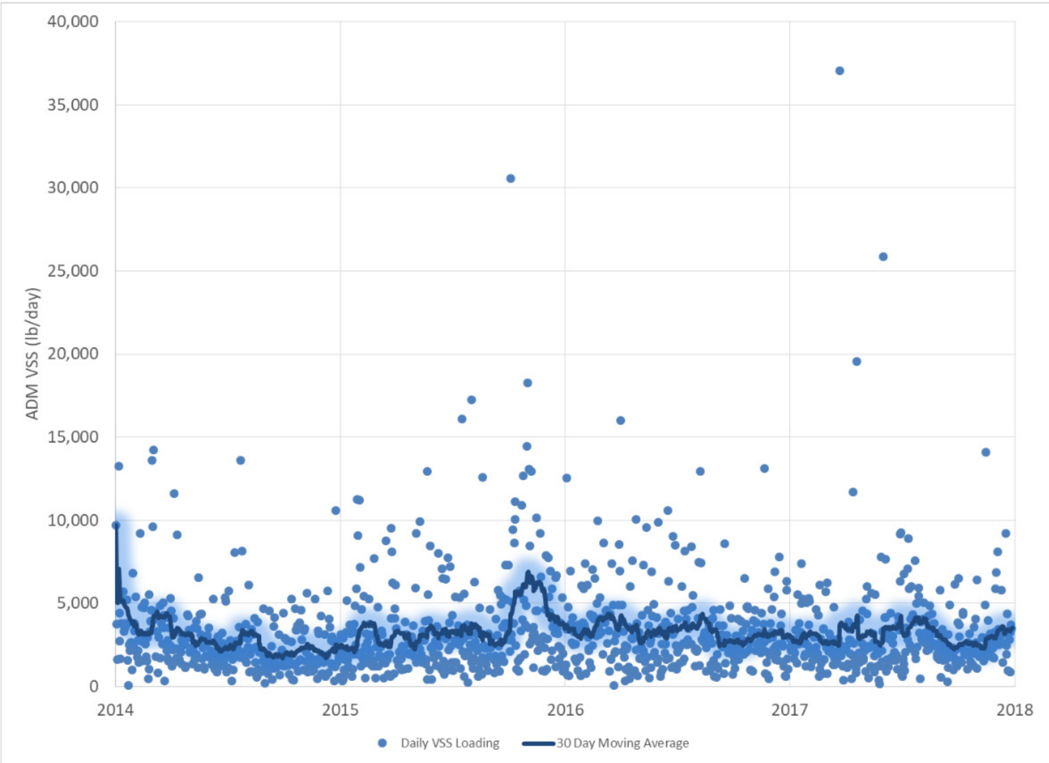

Figure 1.12 Average Daily VSS Load (lb/day)

1.4.4 Anaerobic Digestion

1.4.4.1 Description

Three waste streams (PS, TWAS, and ADM), are sent to anaerobic digesters for stabilization. The RWRF has 13 digesters, with slightly varying configurations, as described in Table 1.12. Digesters 9 through 13 receive solids from all three waste streams, while the other active digesters are loaded with PS and TWAS. After digestion, the biosolids flow by gravity to centrifugal booster pumps where they are pumped to either Digester 1 or 2. Digesters 1 and 2 are the direct feed into the dewatering facilities. Today's operation involves either Digester 1 or 2 being used for biosolids storage while the other is used for digestion. Roughly every 6 months, Digesters 1 and 2 alternate between storage and digestion in order to prevent solids build up. Produced biogas is stored in the Digester 7 Dystor flexible membrane digester cover.

Anaerobic Digestion stabilizes the sludge, which reduces odor and sludge volume and destroys pathogens. Stabilization occurs by breaking down organic matter in the absence of oxygen through three biological processes: hydrolysis, fermentation, and methanogenesis. These processes form soluble organic matter, which is then biologically converted into longer chain volatile fatty acids, acetate, hydrogen gas, and subsequently, methane and carbon dioxide (collectively called biogas).

Important process considerations for optimal digestion are solids residence time (SRT), volatile solids loading rate (VSLR), and operating temperature. These factors drive the sizing of the digester as well as the effectiveness of destroying volatile solids and creating biogas. An additional consideration includes digester mixing.

Federal regulations for pathogen reduction requirements for Class B biosolids require that the SRT and temperature of anaerobic digesters be maintained between 15 days at 35 to 55 degrees Celsius (95 to 131 degrees Fahrenheit [°F]) and 60 days at 20 C (68°F). Various performance parameters, including a minimum volatile solids reduction (VSR) of 38-percent, must also be met for vector attraction reduction requirements. A longer SRT typically correlates to a higher percent VSR and increased biogas production. See Chapter 2: Current and Future Regulatory Requirements, regarding the regulations.

Operating temperature determines whether a digester is mesophilic or thermophilic. Mesophilic digesters operate between 85 and 100 F, whereas thermophilic digesters operate between 122° and 135°F. The digesters at the RWRF are operated in the mesophilic temperature range. Similar to a longer SRT, higher temperatures increase VSR and biogas production. The digesters at the RWRF are operating at a temperature setpoint of 99.5°F. A biogas-fueled 400 hp boiler maintains the temperature of the digesters. Heat is transferred through spiral heat exchangers to the digester sludge. The existing boiler provides sufficient heating for the digesters for most of the year, but can sometimes struggle to meet heat demand when daily lows are in the 40s F for several nights in a row. During times when the operating temperature drops below the setpoint, the SRT is increased in order to maintain Class B biosolids production. A comprehensive heat study of the digestion system is currently underway.

Each digester is equipped with one duty mixing pump. Digesters 9 through 13 also have a standby mixing pump. Mixing is required to prevent solids from settling and accumulating in the digester. A completely mixed digester prevents stratification of solids and allows for continuous contact between substrate and biomass, which enhances stabilization and biogas production.

The digesters are on a seven year cleaning cycle. During cleaning, a digester is offline for several weeks or longer if additional repair or recoating is required. During this process the digester is pumped down and accumulated grit and debris is removed and sent to American Avenue landfill.

1.4.4.2 Original Design Criteria

Table 1.12 shows the design criteria for the digesters. Digesters are laid out in a 'battery' configuration, sets of four digesters sharing a common control building. Digester 13 has its own control building with space available for the construction of future digesters. The dimensions of the digesters vary, changing slightly as new ones were added over the years. However, the design criteria of VSLR and SRT remain the same for all digesters.

1.4.4.3 Current Capacity and Performance Assessment

Table 1.13 outlines the performance of Digesters 1 through 13 under maximum loading conditions. Average performance values are included in Table A.1 in Appendix 1-A. While TWAS and PS are split among all digesters in service, only Digesters 9 through 13 also receive ADM. For Digesters 1 through 8, the maximum VSLR is below the design criteria value of 0.12 lb-VS/cf/d, shown in Figure 1.13. However, in the beginning of 2017 there was a system disturbance that caused the VSLR of the non-ADM digesters to spike above the design value, also shown in Figure 1.13.

Digesters 9 through 13 are loaded with more volatile solids due to the addition of ADM. Therefore, the VSLR in these digesters is higher and varies, often above the original design criteria value of 0.12 lb-VS/cf-d. This trend is shown in Table 1.13 and Figure 1.14. However, the original VSLR design criterion is a conservative value. Recent operating parameters for well-mixed digesters, as described in the Water Environment Federation's (WEF's) Manual of Practice No. 8 (MOP 8), allow for VSLR up to 0.20 lb VS/cf-d. Carollo uses a VSLR of 0.16 lb VS/cf-d as a maximum design parameter for conventional digesters. When ADM is added to a digester, it typically represents a concentrated VS load that is easily digestible and the associated VSLR can appear excessive.

Table 1.12 Original Design Criteria for Anaerobic Digesters

Parameter[1]	Units	Design Criteria					
		No. 1-2	No. 3-5	No. 6-8	No. 9-10	No. 11-12	No. 13
Digesters							
Year Constructed	-	1974	1974	1974	1992	1996	2006
Diameter	ft	75	75	85	105	105	105
Side Water Depth	ft	28	26	27	29	29	29
Volume, each	gal	925,000	860,000	1,147,000	1,879,000	1,879,000	1,879,000
Volatile Solids Loading Rate	lb/ ft^3/d	0.12	0.12	0.12	0.12	0.12	0.12
Solids Retention Time	days	15	15	15	15	15	15
Pump Mixing							
Number per Digester[2]	-	1	1	1	2	2	2
Capacity, each	gpm	5,000	5,000	6,000	5,000	5,000	5,000
Horsepower, each	hp	50	50	40	40	40	40

Notes:
(1) The digester heat demands and digester heating system capacity analysis will be done by others on another project.
(2) Each digester has one duty mixing pump.

Table 1.13 Current Capacity and Performance Assessment – Anaerobic Digestion

Parameter	Current				
	Maximum Daily VSLR ($lb/ft^3/d$)(1)	Minimum Daily SRT (days)(2)	Maximum Daily VA:Alk(1)	Minimum Daily VSR (%)(2)	Digester Meeting Operating Criteria?
Design Criteria	**≤0.16(3)**	**≥15**	**≤0.10**	**≥38(4)**	
Digester 1	0.087	24.1	0.022	57	Yes
Digester 2	0.086	22.9	0.021	55	Yes
Digester 3	0.11	19.1	0.020	53	Yes
Digester 4	0.11	19.3	0.021	53	Yes
Digester 5	0.11	20.1	0.022	54	Yes
Digester 6	0.088	22.6	0.027	55	Yes
Digester 7	0.095	21.6	0.025	56	Yes
Digester 8	0.092	21.4	0.025	55	Yes
Digester 9	0.15	16.1	0.028	53	Yes
Digester 10	0.15	16.5	0.031	52	Yes
Digester 11	0.15	16.7	0.025	54	Yes
Digester 12	0.15	17.4	0.033	54	Yes
Digester 13	0.14	16.5	0.034	55	Yes
All non-ADM Digesters (No. 3-8)	0.10	20.7	NA	54	Yes
All ADM Digesters (No. 9-13)	0.15	16.6	NA	54	Yes
All Digesters	0.12	16.9	NA	54	Yes
Largest Digester Out of Service(5)	0.12	15	NA	NA	Yes

Notes:
(1) Values calculated as 90th percentile, representing maximum loading conditions. This percentile was used to exclude data outliers. Average values for each digester are shown in Table A.1 in Appendix 1-A.
(2) Values calculated as 10th percentile, representing maximum loading conditions. This percentile was used to exclude data outliers. Average values for each digester are shown in Table A.1 in Appendix 1-A.
(3) The original design criteria value of 0.12 $lbVS/ft^3/day$ is conservative as a maximum month condition for well mixed digesters. Carollo currently uses a design criteria value of 0.16 $lbVS/ft^3/day$ for maximum month loading conditions, and values up 0.20 $lbVS//ft^3/day$ have been found acceptable per WEF MOP 8.
(4) While a value was not found in design documents, a a minimum of 38 percent is required under Part 503 for vector attraction reduction if that option is selected for biosolids management.
(5) Calculation assumes a proportional split among digesters based on operating volume.

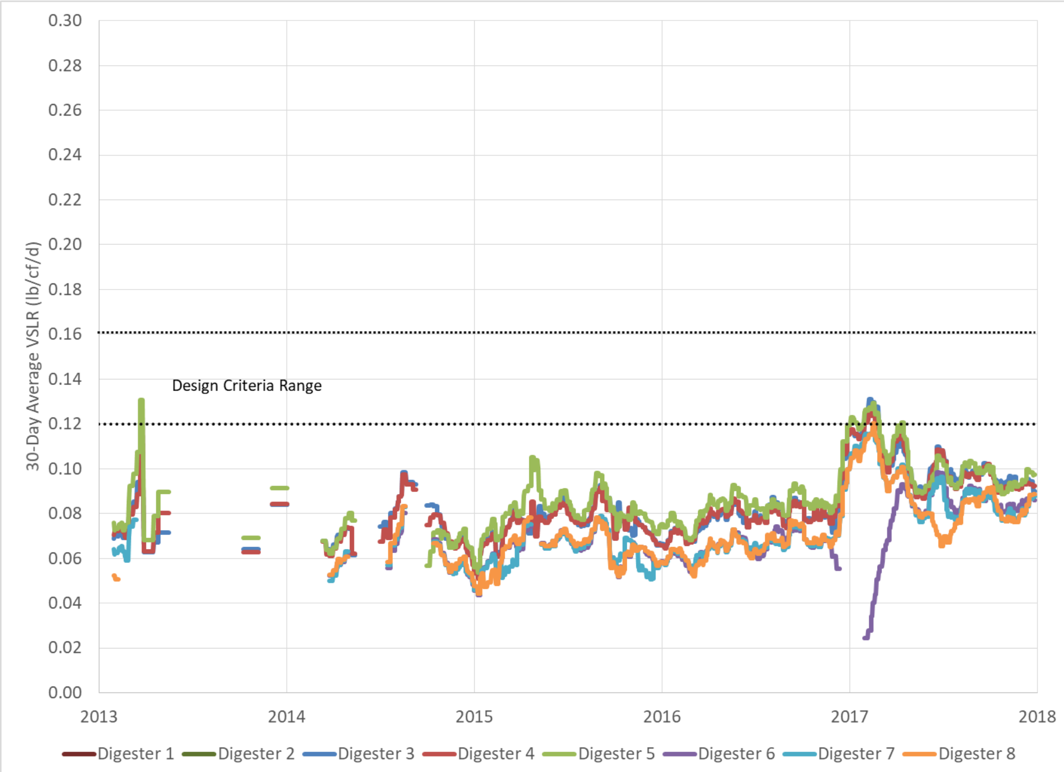

Figure 1.13 Volatile Solids Loading Rate (lb/cf/d) for Digesters without ADM Receiving (1-8)

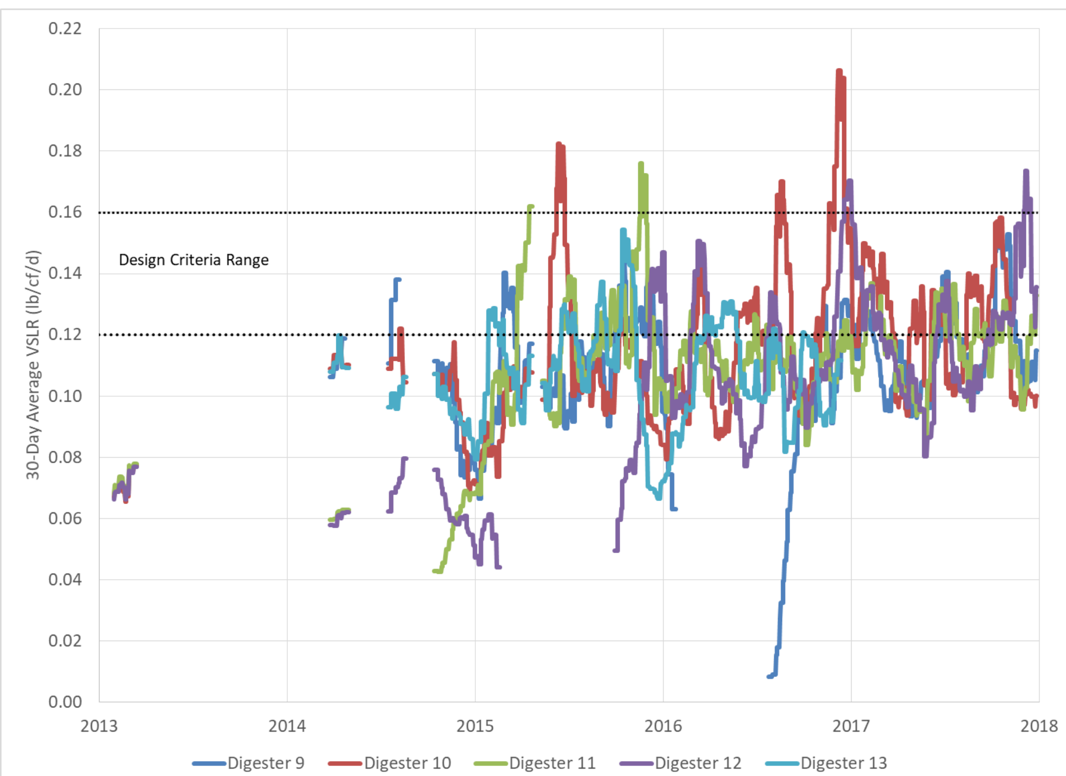

Figure 1.14 Volatile Solids Loading Rate (lb/cf/d) for Digesters with ADM Receiving (9-13)

In instances where the VSLR is above the design criteria, the volatile acids to alkalinity ratio (VA:Alk) should be considered. This ratio is a better indicator of digester performance and is shown in Figures 1.15 and 1.16 for all digesters. Organic matter in the feed is broken down into volatile fatty acids as digestion takes place. Methanogen bacteria consume volatile acids to convert it into methane gas. Methanogens are sensitive to pH changes. As alkalinity decreases, the pH becomes less stable and methanogens become limited in their ability to produce methane gas, resulting in a buildup of volatile acids. This becomes apparent as the VA:Alk increases, which can be due to overloading. Table 1.13 shows the maximum daily VA:Alk seen from 2013 through 2017 for each digester. Values below 0.1 typically indicate acceptable digester performance. The maximum VA:Alk ratio observed for all digesters is well below 0.1, which indicates stable operation, despite high VSLRs for some digesters at the plant. Average VA:Alk values for each digester can be found in Table A.1 in Appendix 1-A.

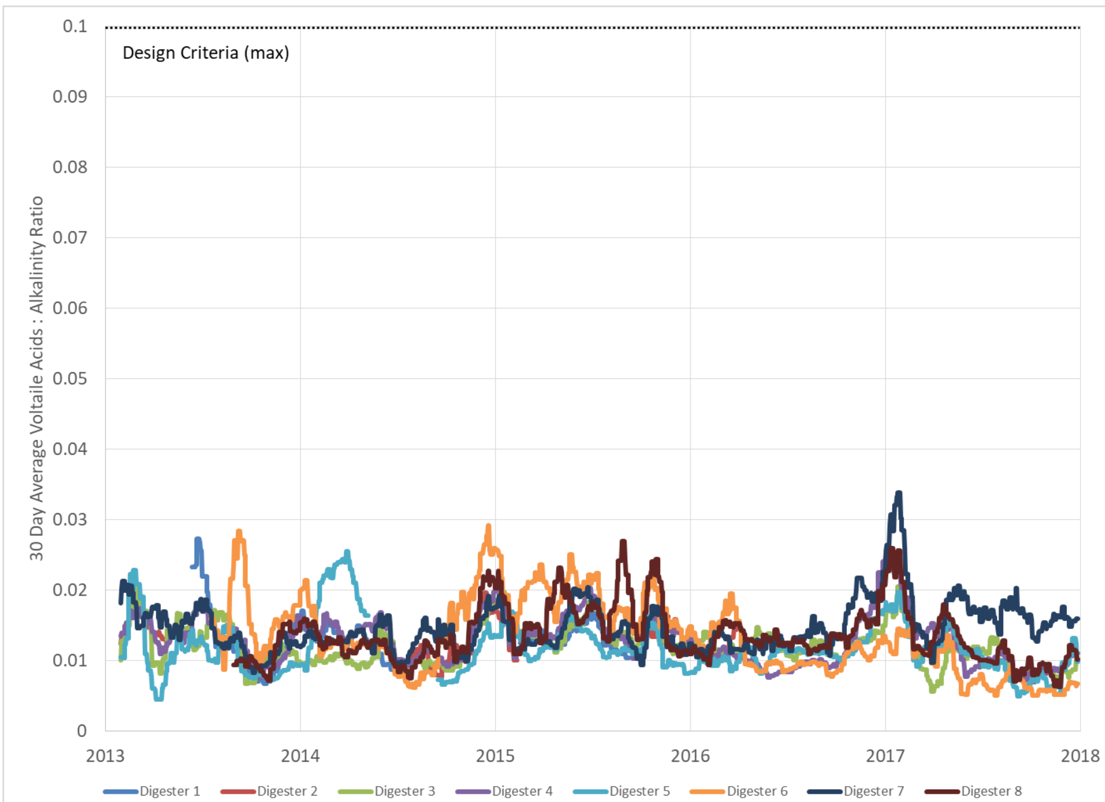

Figure 1.15 Volatile Acids to Alkalinity Ratio for Digesters without ADM Receiving (1-8)

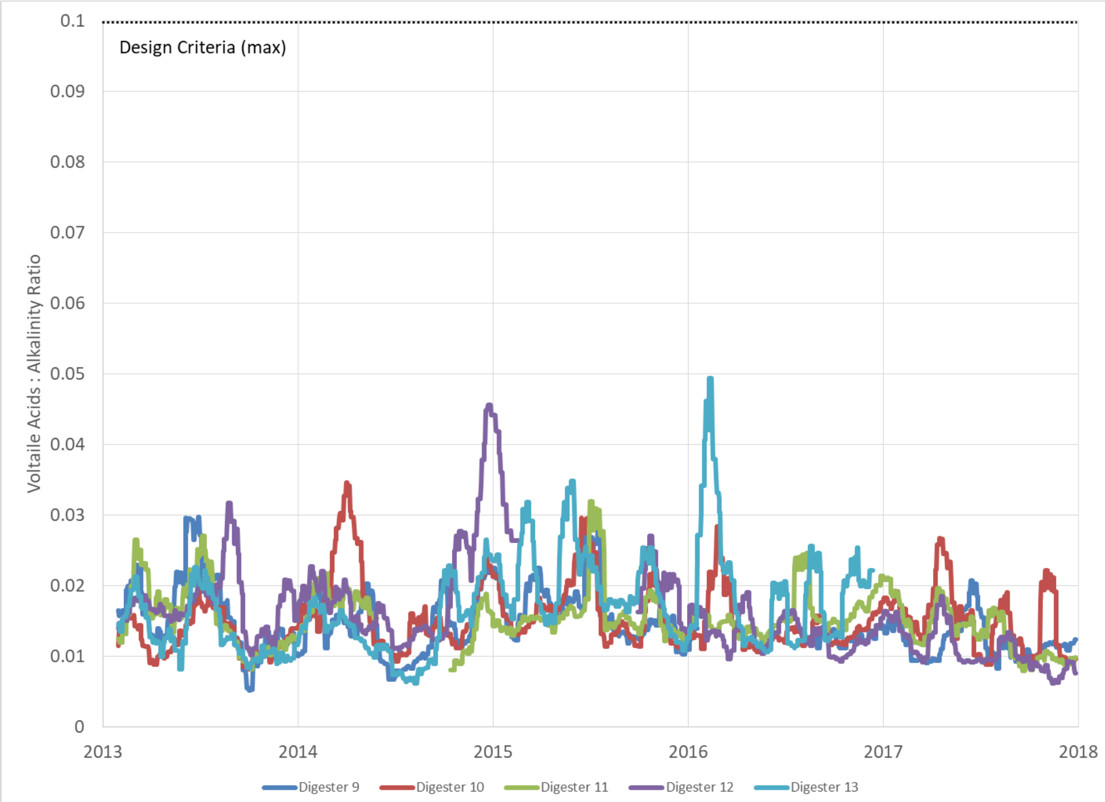

Figure 1.16 Volatile Acids to Alkalinity Ratio for Digesters with ADM Receiving (9-13)

The volatile solids reduction (VSR) performance was also analyzed from 2013 through 2017. Table 1.13 shows the minimum daily VSR, calculated as the 10th percentile of the daily data provided. This represents a worst case scenario for VSR. Average VSR values for each digester are included in Table A.1 in Appendix 1-A for reference. The VSR trend is similar for Digesters 1 through 8, as would be expected, since the composition of influent sludge is the same and the sludge is split evenly among them. However, while the VSR trend is similar for these digesters, some differences in VSR can be seen across them as shown in Figures 1.17 and 1.18. This could be due to minor variations in the way the mixing pumps operate.

Additionally, it is expected that the VSR for digesters with ADM is higher than the VSR for digesters without ADM. However, the data indicate similar VSR for digesters with and without ADM receiving on both an average and minimum daily basis. On average, the volatile solids in the PS and TWAS generally reduce by about 60 percent during digestion. ADM VSR is typically much higher, between 80 and 100 percent, because its composition is much higher in fatty acids and energy dense compounds, rather than inert solids typical in wastewater. However, the average VSR for digesters with and without ADM is approximately 60 percent (see Table A.1 in Appendix 1-A). There may be a discrepancy in the way the VSR is calculated for ADM digestion, as we would expect to see Digesters 9 through 13 to have noticeably higher VSR than other digesters. Plant staff calculates VSR using the Mass Balance Method.

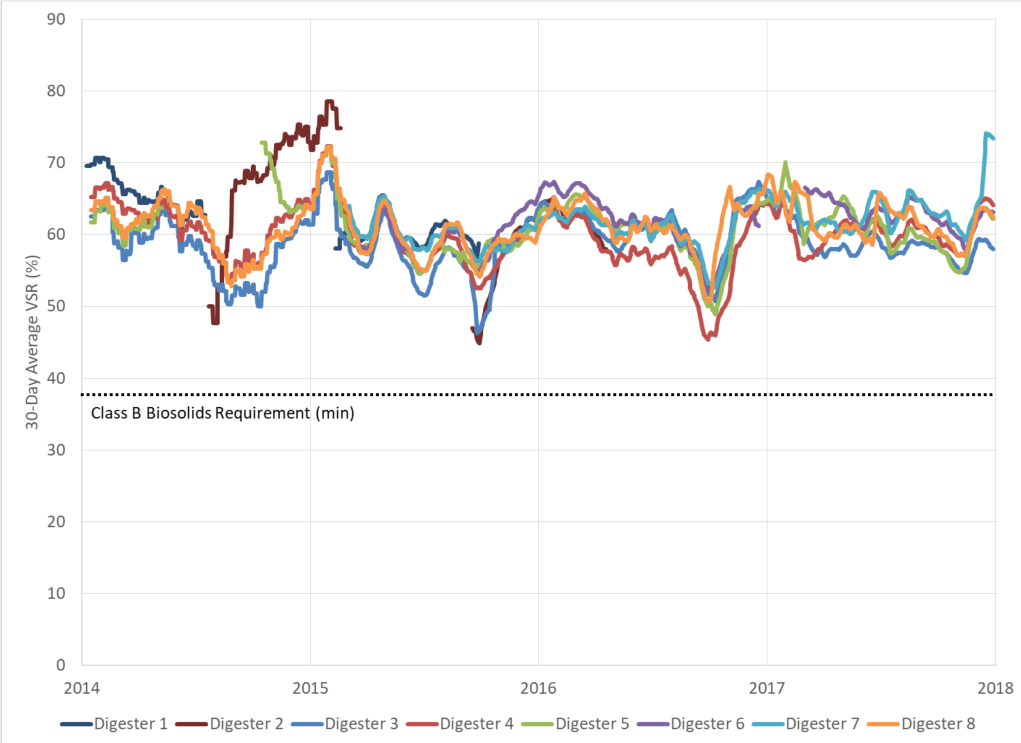

Figure 1.17 Volatile Solids Reduction (%) for Digesters without ADM Receiving (1-8)

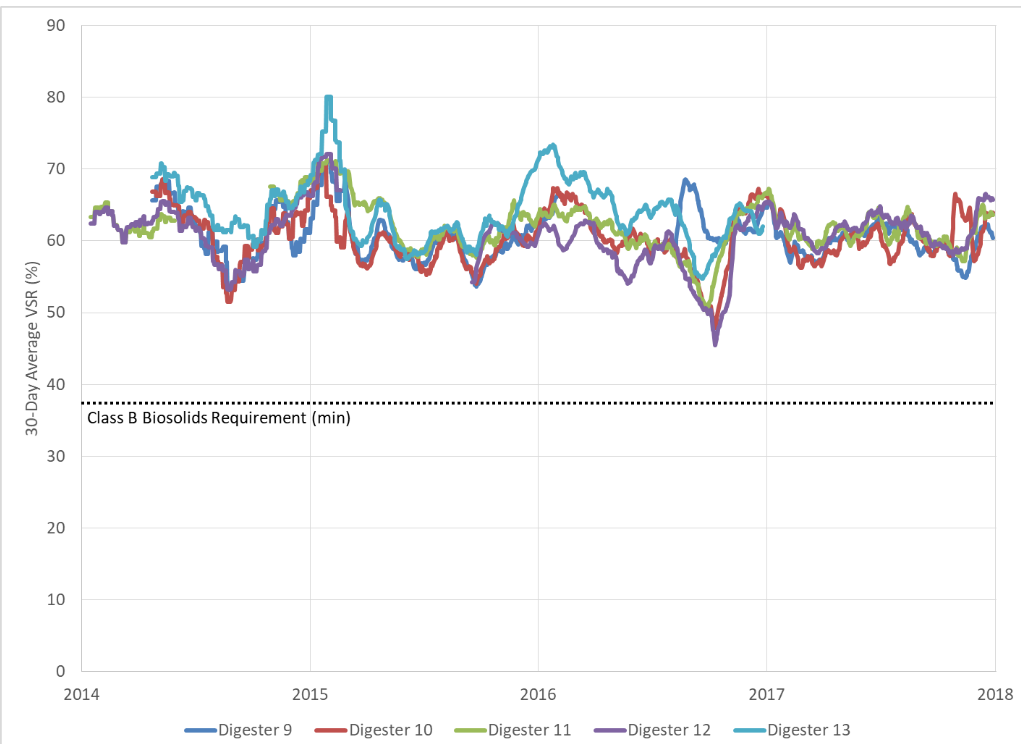

Figure 1.18 Volatile Solids Reduction (%) for Digesters with ADM Receiving (9-13)

Table 1.13 as well as Figures 1.19 and 1.20 show the minimum daily SRT in all digesters, calculated as the 10th percentile of the daily data provided. The minimum daily SRT for every digester is above the design criteria value of 15 days. Digesters 1 through 8 have minimum daily SRTs ranging from 19 to 23 days. The minimum daily SRTs for Digesters 9 through 13 are slightly lower, 16-18 days, since they operate similarly but receive additional solids from the ADM receiving station. As shown in Figures 1.19 and 1.20, the SRT across all digesters has decreased slightly over the five-year period analyzed (2013-2017). This indicates that the hydraulic loading to the digesters has increased. The 30-day average SRT for digesters not receiving ADM rarely drops below 20 days. However, for digesters with ADM receiving, the 30-day average SRT is frequently below 20 days. In order to produce Class B Biosolids, EPA Part 503 regulations require a minimum 15-day SRT at 95-degrees Fahrenheit, which all digesters consistently maintain on a 30-day average basis. The daily SRT values for the non ADM receiving digesters did drop below 15 days in 2017 when the plant was experiencing increased loading from outside sources. However, this issue has since been resolved. The daily SRT values for the ADM receiving digesters have rarely dropped below 15 days. However, the moving average SRT is consistently above 15 days. Therefore, the plant maintains compliance with the Class B Biosolids regulations. The City's contingency for abnormal situations where the SRT could drop below 15 day is to haul dewatered biosolids to a composting facility for further processing.

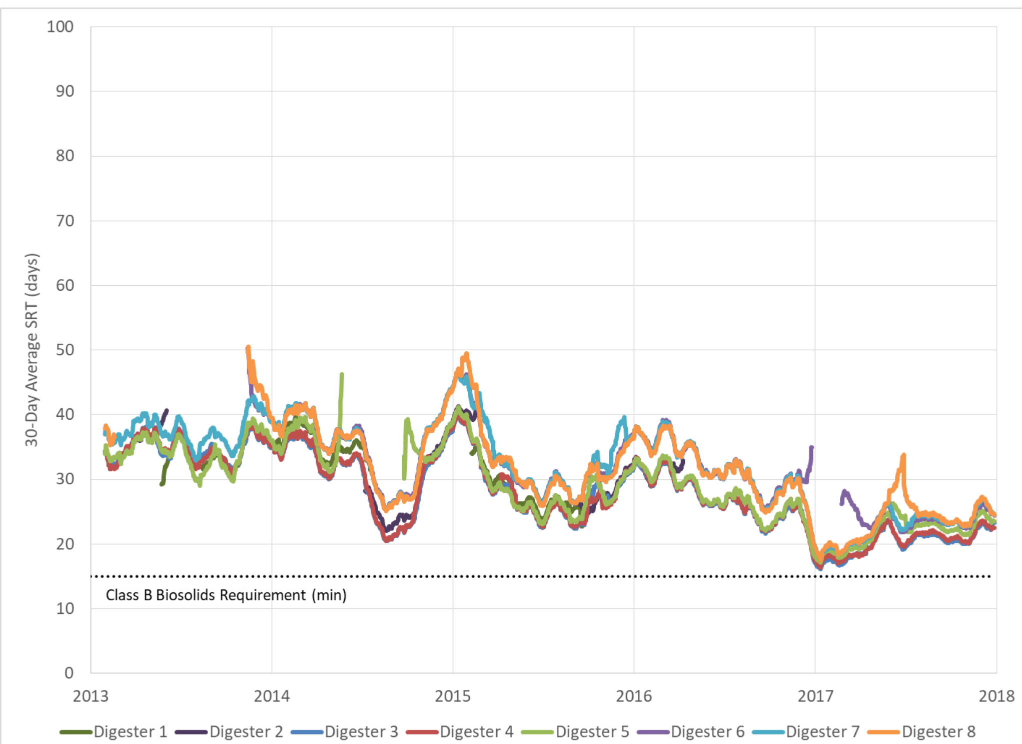

Figure 1.19 Solids Residence Time (days) for Digesters without ADM Receiving (1-8)

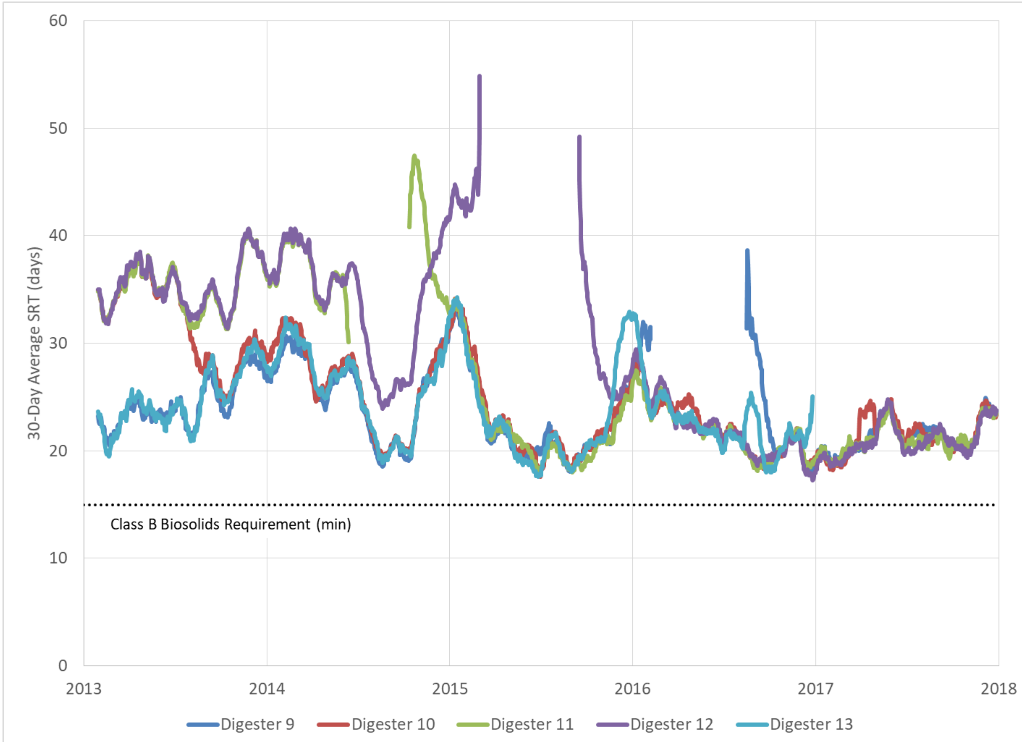

Figure 1.20 Solids Residence Time for Digesters with ADM Receiving (9-13)

Table 1.14 shows the portion of volatile solids loading by mass to the digesters from each source, PS, TWAS, and ADM. Primary Sludge is by far the largest contributor of volatile solids, making up over 50 percent of volatile solids plant-wide, and nearly 65 percent of all conventional sludge (PS and TWAS). Roughly 13 percent of volatile solids in the Digester 9 through 13 comes from ADM. Across all of the digesters, ADM makes up just under 10 percent of all volatile solids.

Table 1.14 Digester Feed Volatile Solids Loading by Source

Source	Current Volatile Solids Loading by Mass (Percent, %)		
	Digesters 1-8	Digesters 9-13	Plant-wide
ADM			
Average	NA	13%	10%
Maximum(1)	NA	25%	21%
TWAS			
Average	36%	31%	30%
Maximum(1)	56%	38%	44%
PS			
Average	64%	56%	60%
Maximum(1)	74%	65%	67%

Notes:
(1) Maximum values calculated as the 95th percentile.

Struvite

Plant staff has identified issues with struvite buildup in some of the digestion and dewatering process areas. Struvite is a mineral composed of magnesium, ammonium, and phosphate, which can be found in raw wastewater. Plant staff reported mineral formation in the booster pump suction piping that serves Digesters 3 through 8. The buildup in pipes reduces the effective pipe diameter and can eventually result in complete blockages. Per City staff, the ancillary equipment for Digester 9 through 13 has not experienced significant struvite buildup. This may be due to the age difference and configuration of the digesters. Digesters 1 through 8 were built in the 1970's and 1980's, whereas Digesters 9 through 13 were built between the 1990's and 2000's. The newer digesters have glass lined ductile iron digested sludge piping while the older digester interior piping is uncoated. This uncoated pipe interior likely allows the compounds to adhere to the surface of the pipe and encourages mineral formation.

One potential solution to mitigate the formation of struvite would be to replace the older uncoated piping with glass lined ductile iron pipe. Although the individual compounds of struvite would still be present in the water, the smooth pipe interior could discourage struvite mineral formation and prevent pipe blockages. However, struvite formation could still take place elsewhere in the plant.

To combat struvite formation, iron salts like ferric chloride could be used for struvite mitigation. However, the sulfide demand must be met before struvite formation is reduced. This is because the iron salts preferentially precipitate with sulfides before they precipitate with phosphorous.

Alternatively, there has been an increased focus on resource recovery over the last several years. Phosphorus is a non-renewable resource that has a demand in the agricultural sector. There may be opportunities for the RWRF to pilot technologies that would remove phosphorus in the form of struvite and produce a revenue-generating product.

1.4.4.4 Future Capacity and Performance Assessment

The methods described in Section 1.3.2, Future Conditions, were used to project solids production in the year 2040. The projected solids loading from PS, TWAS, and ADM are sent to the anaerobic digesters. A capacity analysis using maximum daily projected loading values (95^{th} percentile) is provided to present feasibility of maintaining operation within design criteria ranges year-round.

Table 1.15 shows the capacity of the digested solids transfer pumps. Transfer pumps pump digested solids from solids storage to the dewatering building. The transfer pumps have sufficient capacity to handle anticipated future digested solids flows. However, there are no standby transfer pumps. Installing a common standby transfer pump would allow for easier operation during maintenance.

Table 1.15 Capacity Assessment – Sludge Transfer Pump

Parameter	Units	Current Capacity	Current		Future	
			Flows	Sufficient Processing Capacity?	Flows	Sufficient Processing Capacity?
Sludge Transfer Pump Capacity, each(1)	gpm	1,300				
Average Daily			455	Yes	695	Yes
Maximum Daily(2)			572	Yes	925	Yes

Notes:
(1) There are two duty pumps.
(2) Performance values calculated as 90th percentile, which represent maximum flows.

Table 1.16 shows the projected digester feed volatile solids loading and flows from each source. With the projections provided in Table 1.16, two digester feed configurations were analyzed. The first analysis ("existing feed configuration") assumed that the digester feed configuration does not change so that Digesters 1 through 13 received PS and TWAS and Digesters 9 through 13 additionally receive ADM. The second analysis looks at capacity if PS, TWAS, and ADM is split evenly among Digesters 1 through 13 based on active volume. Assumptions for both analyses are that Digester 1 is used for solids storage (not in service), one larger digester (Digester 13) is out of service for cleaning and maintenance, and the capacity analysis is determined at maximum day projected loading conditions (95th percentile). The total active volume for Digesters 2 through 12 is 14.4 MG, while the active volume for the current ADM digesters (9 through 12) is 7.5 MG. These two digester feed configurations and their associated VSLR and SRT are shown in Table 1.17.

As shown in the table, under the existing feed configuration, Digesters 9 through 13 have limited capacity by 2024, at which point the SRT drops below 15 days. For Digesters 1 through 8, the SRT drops below 15 days in the year 2029. Assuming the feed configuration and digester feed solids concentration does not change, one new large digester, capable of receiving ADM, would be needed in 2024, 2032, and 2038, for a total of three new digesters, increasing active digestion capacity by 5.6 MG by 2040.

As a way to delay capital improvements and increase digestion capacity, the feed configuration could be changed so that ADM is fed to every digester. This is also shown in Table 1.17. Feeding ADM to every digester would delay the capacity limitations from 2024 until 2026, when the SRT in every digester would drop below 15 days if feed solids concentration remain the same. In this feed configuration, one new large digester would be needed in 2026, 2033, and 2039, for a total of three new digesters, increasing active digestion capacity by 5.6 MG by 2040.

Under all conditions considered, the SRT limits capacity, rather than VSLR. Increasing digester feed solids concentration would reduce the hydraulic load and increase SRT. Operating with thicker digester feed solids could allow further deferment of digester construction. Without this operational change, the digester SRT governs capacity limits rather than VSLR. The VSLR becomes limiting to digester capacity (above 0.16 lb/cf/d) one to six years after SRT drops below 15 days. However, as was stated previously, VA:Alk is a better way to indicate digester performance, particularly in digesters with ADM receiving. VSLR up to 0.2 may be acceptable if the digesters are capable of maintaining acceptable VSR and VA:Alk values. However, SRT should always be above 15 days in order to produce Class B biosolids. Additionally, if the digesters are operated below the design side water depth, capital improvements may be needed several years earlier than what is indicated above.

It is recommended that current feed configurations be altered to allow all digesters to receive ADM. This will evenly split loading, which will improve performance and reduce the burden on the larger digesters. Additionally, capital improvements can be delayed by sending ADM to all digesters.

Table 1.16 Future Flow and Volatile Solids Load Projections – Anaerobic Digestion

Year	Population	PS Loading (lb-VS/d)(1)	PS Flow (mgd)(1)	TWAS Loading (lb-VS/d)(1)	TWAS Flow (mgd)(1)	ADM Loading (lb-VS/d)(1)	ADM Flow (mgd)(1)	Total Loading (lb-VS/d)(1)	Total Flow (mgd)(1)
2017	559,186	139,000	0.50	85,000	0.29	23,700	0.040	247,700	0.83
2018	569,514	142,000	0.51	87,000	0.30	24,100	0.041	253,100	0.84
2019	580,038	144,000	0.52	88,000	0.30	24,600	0.041	256,600	0.86
2020	590,763	147,000	0.53	90,000	0.31	25,000	0.042	262,000	0.88
2021	601,495	150,000	0.53	92,000	0.31	25,500	0.043	267,500	0.89
2022	612,422	152,000	0.54	93,000	0.32	25,900	0.044	270,900	0.91
2023	623,549	155,000	0.55	95,000	0.33	26,400	0.044	276,400	0.92
2024	634,879	158,000	0.56	97,000	0.33	26,900	0.045	281,900	0.94
2025	646,415	161,000	0.57	98,000	0.34	27,400	0.046	286,400	0.96
2026	658,162	164,000	0.59	100,000	0.34	27,900	0.047	291,900	0.98
2027	670,123	167,000	0.60	102,000	0.35	28,400	0.048	297,400	0.99
2028	682,301	170,000	0.61	104,000	0.36	28,900	0.049	302,900	1.01
2029	694,703	173,000	0.62	106,000	0.36	29,400	0.050	308,400	1.03
2030	707,330	176,000	0.63	108,000	0.37	29,900	0.050	313,900	1.05
2031	720,188	179,000	0.64	110,000	0.38	30,500	0.051	319,500	1.07
2032	733,280	182,000	0.65	112,000	0.38	31,000	0.052	325,000	1.09
2033	746,611	186,000	0.66	114,000	0.39	31,600	0.053	331,600	1.11
2034	760,185	189,000	0.68	116,000	0.40	32,200	0.054	337,200	1.13
2035	773,928	193,000	0.69	118,000	0.40	32,800	0.055	343,800	1.15
2036	787,920	196,000	0.70	120,000	0.41	33,400	0.056	349,400	1.17
2037	802,164	200,000	0.71	122,000	0.42	34,000	0.057	356,000	1.19
2038	816,667	203,000	0.73	124,000	0.43	34,600	0.058	361,600	1.21
2039	831,431	207,000	0.74	127,000	0.43	35,200	0.059	369,200	1.23
2040	846,463	211,000	0.75	129,000	0.44	35,800	0.060	375,800	1.26

Notes:
(1) Maximum day values are shown in this table and were calculated as the 95th percentile. This percentile was used to exclude data outliers.

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Table 1.17 Future Capacity Assessment – Anaerobic Digestion

Year	Population	Existing Feed Configuration				ADM to Every Digester	
		Digesters 1 through 8		Digesters 9 through 13 (receives ADM)		Digesters 1 through 13	
		VSLR ($lb/ft^3/d$) (1)(2)	SRT (days) (1)(2)	VSLR ($lb/ft^3/d$) (1)(2)	SRT (days) (1)(2)	VSLR ($lb/ft^3/d$) (1)(2)	SRT (days) (1)(2)
2017	559,186	0.116	18.3	0.140	16.7	0.128	17.4
2018	569,514	0.118	18.0	0.142	16.4	0.131	17.1
2019	580,038	0.120	17.6	0.145	16.1	0.133	16.8
2020	590,763	0.123	17.3	0.147	15.9	0.136	16.5
2021	601,495	0.125	17.0	0.150	15.6	0.138	16.3
2022	612,422	0.127	16.7	0.153	15.4	0.141	16.0
2023	623,549	0.129	16.4	0.156	15.1	0.143	15.7
2024	634,879	0.132	16.1	0.158	14.9	0.146	15.4
2025	646,415	0.134	15.8	0.161	14.6	0.148	15.2
2026	658,162	0.137	15.6	0.164	14.4	0.151	14.9
2027	670,123	0.139	15.3	0.167	14.1	0.154	14.7
2028	682,301	0.142	15.0	0.170	13.9	0.157	14.4
2029	694,703	0.144	14.7	0.173	13.7	0.159	14.2
2030	707,330	0.147	14.5	0.177	13.4	0.162	13.9
2031	720,188	0.150	14.2	0.180	13.2	0.165	13.7
2032	733,280	0.152	14.0	0.183	13.0	0.168	13.4
2033	746,611	0.155	13.7	0.186	12.8	0.171	13.2
2034	760,185	0.158	13.5	0.190	12.6	0.174	13.0
2035	773,928	0.161	13.2	0.193	12.4	0.178	12.8
2036	787,920	0.164	13.0	0.197	12.2	0.181	12.5
2037	802,164	0.167	12.8	0.200	12.0	0.184	12.3
2038	816,667	0.170	12.5	0.204	11.8	0.187	12.1
2039	831,431	0.173	12.3	0.208	11.6	0.191	11.9
2040	846,463	0.176	12.1	0.211	11.4	0.194	11.7

Notes:
(1) Values calculated as 95^{th} percentile. This percentile was used to exclude data outliers. Analysis assumes maximum daily loading conditions with Digesters 1 and 13 out of service (for solids storage and maintenance, respectively)
(2) Values in red are outside of the design criteria – either falling below the minimum 15 days for SRT and or exceeding 0.16 $lb/ft^3/d$ for VSLR.

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1.4.5 Biogas Management & Utilization

1.4.5.1 Description

All thirteen digesters at the RWRF produce biogas. Digesters 1,2, and 5 have flat concrete covers, Digesters 3, 4, 6, and 8 have fixed steel covers, and Digesters 9 through 13 have fixed concrete dome covers. Digester 7 has a flexible membrane gas holding cover with a gas storage volume of 142,000 cubic feet. The cover on Digester 7 maintains a gas storage system pressure around 7 inches water column, just above the operating pressure of 6.5 inches water column at the flare.

The sections below provide information on the boiler, flare, components of the power generation facility (that was in operation within the last five years) and the remaining biogas conditioning system.

Boiler

The boiler was installed as one of the original components of the RWRF as an end use for biogas. The boiler is used for heating the digester feed sludge to maintain the digester temperature. To satisfy air emissions limits for the San Joaquin Valley Air Pollution Control District (Air District), hydrogen sulfide is removed from the biogas through a dedicated SulfaTreat system. The majority of the boiler production is automatic, other than manual usage for cleaning and maintenance purposes. An operator is required to be present in case of any operational alarms or maintenance issues that need immediate attention. The boiler is located in the High Pressure Air (HPA)/Boiler building just north of Digester 10.

In the second half of 2017, a temporary 49 horsepower (hp) water heater was installed to meet the digester heating demand. This boiler ran entirely on natural gas but is no longer operating.

Flare

Excess biogas is currently combusted in two waste gas flares (one permanent and one temporary). The permanent flare was installed in 1992 and has the capacity to process 39.6 million British thermal units per hour (MMBtu/hr) of biogas. The flare is fed raw biogas via a 16-inch pipeline.

In 2017, a temporary flare was added to augment the permanent flare due to the reduction in system capacity by removing the turbines from the power generation facility. This temporary flare has the capacity to process 36.2 MMBtu/hr of raw biogas. Both flares are located just north of Digester 9.

Power Generation Facility

The original intent of the Power Generation Facility (PGF) was to beneficially use biogas to generate renewable electricity onsite using gas turbines. However, the PGF has not been operational since December 2016 as both turbines were decommissioned and removed due to operational issues.

Biogas Conditioning System

In 2013, the biogas conditioning system became operational. The purpose of the biogas conditioning system is to “clean” the biogas to pipeline quality gas level, so it can be utilized for multiple purposes (renewable energy generation or low carbon fuel production). The process increases the methane concentration of the biogas and allows for the:

- Reduction of carbon dioxide and oxygen content
- Reduction of volatile organic compounds
- Removal of moisture
- Reduction of hydrogen sulfide and other compounds, such as siloxanes

Hydrogen sulfide is removed from biogas through a SulfaTreat process that uses a proprietary media to convert hydrogen sulfide to iron pyrite. The system requires minimal maintenance and produces biogas with hydrogen sulfide concentrations less than 5 ppmv.

A chiller uses a gas heat exchanger to remove moisture from the biogas. Removed moisture is collected in a condensate line that feeds a drainage pump.

Carbon dioxide is removed through the use of a Membrane Processing Unit skid, provided by Air Liquide. Biogas is routed through filters, activated carbon, and membranes to remove carbon dioxide, residual moisture, volatile organic compound (VOCs), and other undesirable compounds.

Waste gas from the Membrane Processing Unit, mostly carbon dioxide, is sent to a thermal oxidizer for destruction. Raw biogas is used to run the thermal oxidizer and can be sent directly to the thermal oxidizer for destruction, when needed.

After conditioning, the biogas is sent to a flooded screw-type compression system, capable of increasing biogas pressures to 190 psig. As biogas is compressed, the temperature significantly increases, so an after-cooler is used to lower the temperature of compressed biogas.

1.4.5.2 Original Design Criteria

Table 1.18 below summarizes the original design criteria for the biogas management and utilization facilities. Capacity listed for the thermal oxidizer is the combined energy throughput of raw biogas to power the unit and capacity to process waste gas.

Table 1.18 Biogas Management & Utilization Design Criteria

Parameter	Unit	Design Criteria
Boiler		
Number	--	1
Capacity, each	MMBtu/hr	16.8
Flare		
Number	--	1(1)
Capacity, each	MMBtu/hr	39.6(1)
Thermal Oxidizer		
Number	--	1
Capacity, each	MMBtu/hr	7.46

Notes:
(1) A temporary flare has been in use at the RWRF since 2017. The capacity of this temporary flare is 36.2 MMBtu/hr.

1.4.5.3 Capacity and Performance Assessment

Figure 1.21 shows the historical biogas production and the portion of biogas sent to each end use: flare, temporary flare, boiler, gas conditioning system, or thermal oxidizer (to power the pilot light). Table 1.19 summarizes the historical quality of the biogas. Dividing the average raw biogas higher heating value by the higher heating value of methane shows that the average methane concentration of biogas is 62 percent. As shown in Figure 1.21, the permanent flare does not have sufficient capacity to handle all of the biogas produced in the event that all other equipment is not operational, a requirement by the Air District. Thus, as described above, the RWRF installed a temporary flare to ensure sufficient capacity for all biogas to be flared if needed. As mentioned, the City is beginning a project that will address the need for additional flare capacity.

Table 1.19 Biogas Management & Utilization Design Criteria: Higher Heating Value of Raw and Conditioned Biogas

Date	Raw Biogas (dry BTU/cf)	Conditioned Biogas (dry BTU/cf)
Mar-13	--(1)	988
May-13	--(1)	968
Aug-13	--(1)	985
Nov-13	--(1)	984
Feb-14	--(1)	983
May-14	643	--(1)
Aug-14	636	988
Nov-14	614	960
Feb-15	615	966
May-15	609	972
Aug-15	612	975
Nov-15	621	980
Mar-16	576	982
Jun-16	632	--(1)
Aug-16	643	--(1)
Dec-16	643	978
Mar-17	646	--(1)
May-17	619	--(1)
Sep-17	652	--(1)
Nov-17	623	--(1)
Mar-13	--(1)	988
Average	**626**	**978**

Notes:
(1) No data available for this month.

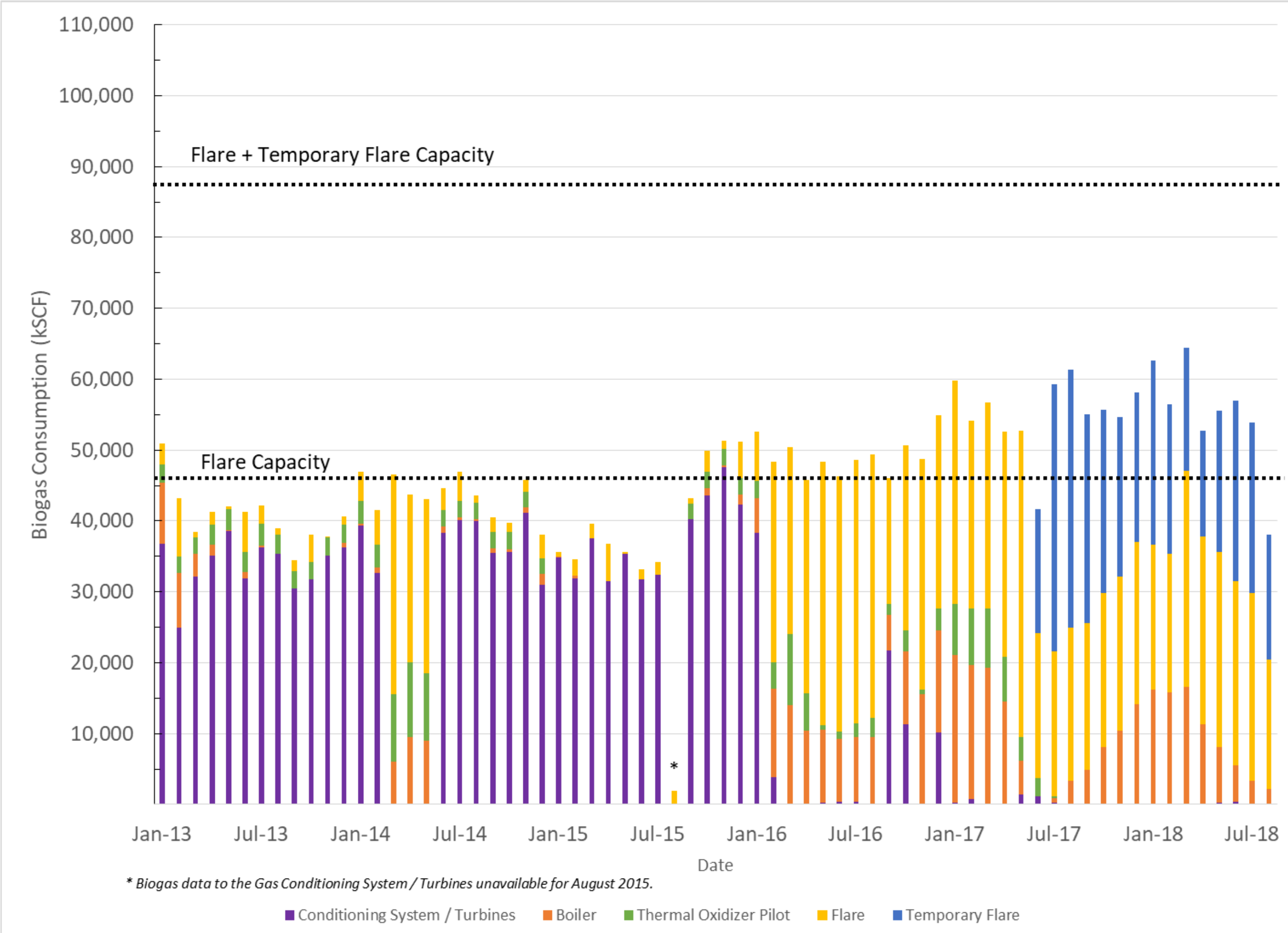

Figure 1.21 Biogas Consumption (kscf)

Figures 1.22 and 1.23 show the digester temperature since 2013. Decreases in digester operating temperature may indicate that the boiler used to heat the digesters does not have sufficient capacity. As shown in the figures, there have been several instances when the temperature drops in the winter. RWRF staff has stated that the boiler limitations occur when nighttime temperatures drop into the 40's (F) for consecutive days. The City is currently developing a Request for Qualifications (RFQ) to install new boilers.

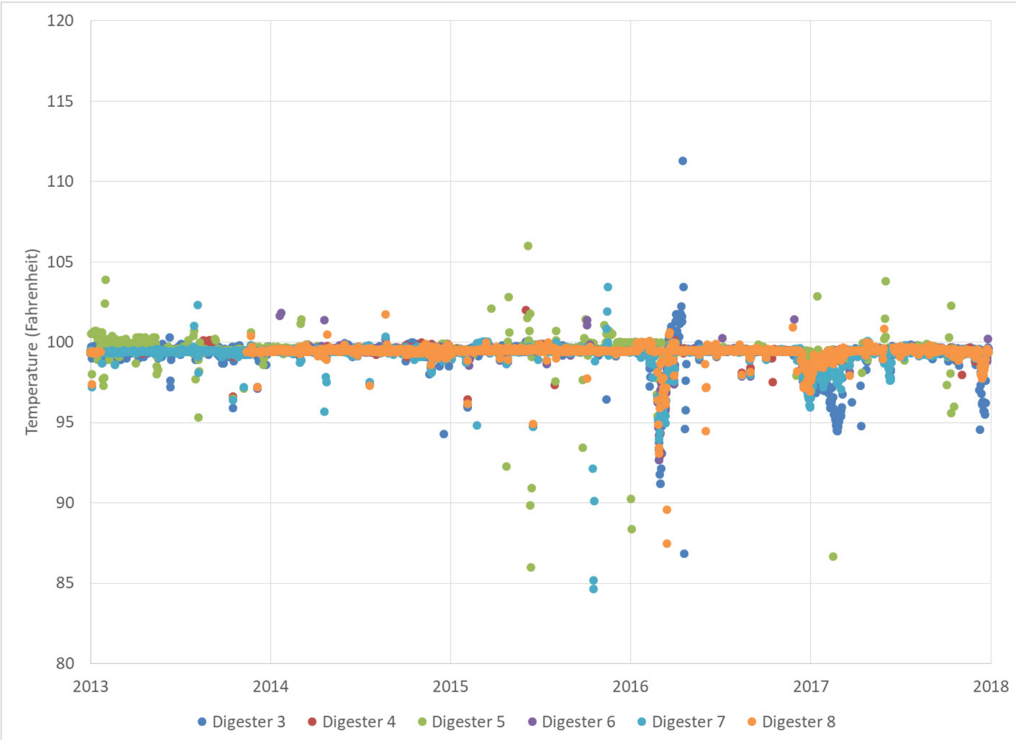

Figure 1.22 Digester Operating Temperature (F) for Digesters without ADM Receiving (3-8)

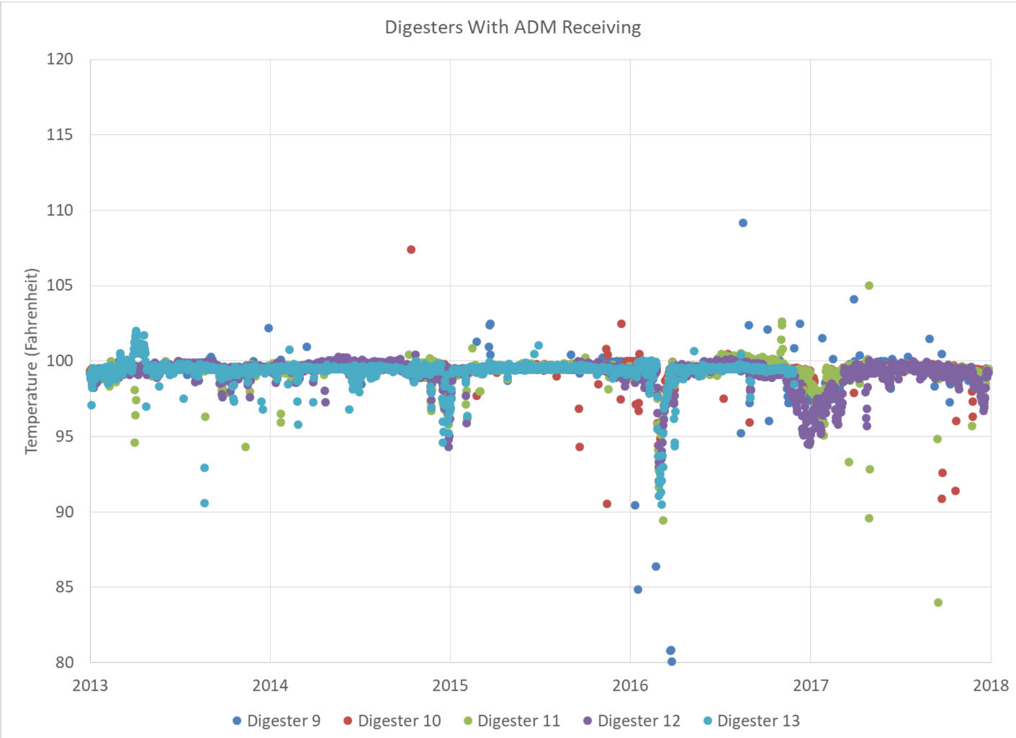

Figure 1.23 Digester Operating Temperature (F) for Digesters with ADM Receiving (9-13)

Using the biogas quality and production data presented in Table 1.19 and Figure 1.21, Table 1.20 summarizes the current biogas utilization performance. Since major changes were made to the biogas utilization system in 2016, Table 1.18 summarizes the performance starting in 2016. The gas turbines were not operational for most of 2016 and were offline starting in 2017. As shown in the table, both the flare and boiler have operated above their designed capacity on a maximum daily basis. This makes sense as both of these units are running near capacity to manage the biogas.

For both current and future capacity analyses, it is assumed that biogas utilization equipment operates continuously.

Data used to determine capacity analyses are daily averages, which does not account for fluctuations throughout the day. However, biogas consumption equipment, such as flares, need to be able to handle instantaneous demands. Capacity analyses provided for biogas utilization equipment is only approximate since instantaneous data is not available.

Table 1.20 Biogas Management & Utilization Capacity

Parameter	Unit	Design Criteria	Current Capacity Needs[1]	Sufficient Processing Capacity?
Boiler (SulfaTreated Biogas)[2]				
Boiler Capacity	MMBtu/hr	16.8		
Average Daily, Year-Round			8.9	Yes
Average Daily, Winter			12.1	Yes
Maximum Daily, Year-Round[3]			17.3	No[4]
Flare (Raw Biogas)				
Flare Capacity	MMBtu/hr	39.6		
Average Daily			23.2	Yes
Maximum Daily[3]			49.5[5]	No[4]
Thermal Oxidizer (Raw Biogas)				
Thermal Oxidizer Capacity	MMBtu/hr	7.46		
Average Daily			3.3	Yes
Maximum Daily[3]			14.6[6]	No[4]

Notes:
(1) Performance was calculated using biogas production data from 1/1/16 through 8/24/18 and assuming the average raw biogas quality of 626 dry BTU/cf shown in Table 1.18.
(2) Energy content of raw biogas and SulfaTreated biogas, which is sent to the boiler, is assumed to be the same as a conservative estimate.
(3) Maximum Daily value was calculated using the 90th percentile of the dataset. This percentile was used to exclude data outliers.
(4) Project is under way to address capacity limitations.
(5) Only daily data was available for this analysis. However, the flare needs to be able to handle instantaneous demands.
(6) Based on typical recovery rates of the Membrane Processing Unit, waste gas has an energy content of 8 percent of raw biogas.

Table 1.21 shows the amount of biogas produced in 2040 and the capacity of the existing system to process biogas. Future biogas production is based on volatile solids loading to the digesters and historic average VSR, as provided in Table A.1 of Appendix 1-A. Historic energy content was used to convert from projected methane volumes to biogas production rates. Flare capacity needs to be able to handle all of the biogas production in case other equipment is not operational. The existing permanent flare lacks capacity to be able to handle future biogas production. The City has issued an RFQ for a waste gas flare improvement project to expand flare capacity. Additional capacity is needed in all aspects of the biogas utilization system to be able to handle projected average daily biogas production as well as instantaneous peak demands.

Table 1.21 Future Biogas Production

Parameter	Unit	Design Criteria	Future Capacity Needs(1)	Sufficient Processing Capacity?
Biogas Production	MMBtu/hr			
Average Daily			82.1	
Maximum Daily			114.8	
Boiler Capacity	MMBtu/hr	16.8		No
Flare Capacity	MMBtu/hr	39.6		No
Thermal Oxidizer Capacity	MMBtu/hr	7.46		No
Total Capacity	**MMBtu/hr**	**63.9**		**No**

Notes:
(1) Calculated based on the projected digester feed values and average VSR and assuming biogas quality values for raw biogas as shown in Table 1.19.

1.4.6 Biosolids Dewatering

1.4.6.1 Description

The purpose of the dewatering process is to reduce the moisture content of the biosolids. This significantly reduces the volume and weight, therefore, decreasing required storage volume and hauling and disposal costs. Biosolids are routed from the holding tanks, either Digester 1 or 2, to the dewatering facility by two variable speed vertical centrifugal transfer pumps, located in the solids transfer pump station. Utilizing one of the digesters as a solids holding and dewatering process feed tank allows for some on site solids storage, which provides a buffer for the operation of the digestion and dewatering processes. After the transfer pumps, two macerators grind any debris to prevent damage to the biosolids feed pumps downstream.

The biosolids dewatering facility contains five belt filter presses and three centrifuges each fed by a separate progressive cavity feed pump. Each dewatering unit operates independently based on the discretion of the operator. Determining the operation of individual units is complex because of the need to balance hauler schedules with silo fill capacity and dewatering equipment run time.

Polymer undergoes three stages before being dosed into the dewatering units. There are two bulk polymer tanks, two polymer mix tanks, and two polymer feed tanks, each with dedicated mixers and pumps. Each stage is equipped with duty and standby equipment. Every month the standby equipment changes operation to become the duty equipment. Both polymer trains can dose to all dewatering units. The polymer stages dose and dilute bulk polymer, providing the right feed concentration. Then, a mixing sequence occurs that activates the polymer to extend the polymer chains. This encourages floc formation through charge neutralization, which enhances the solid/liquid separation, and in turn produces a drier biosolids cake and cleaner filtrate/centrate.

Belt Filter Press

The biosolids dewatering facility contains five belt filter presses. Each press has its own dedicated polymer and biosolids feed pump, which allows each of the presses to operate independently. The belt filter presses are continuous belt type with four distinct dewatering zones preceded by a gravity drainage section. The presses operate by entraining the biosolids between two continuous, porous, open-meshed belts with a system of perforated and solid rollers. A belt tensioning system acts on these rollers to provide increasing pressures. The biosolids are pumped onto the upper belt in the gravity section and is evenly distributed onto the belt through an inlet distribution assembly. Here, initial dewatering takes place by the water draining through the biosolids mass and porous belt. The remaining partially dewatered biosolids pass through the vertical dewatering zone, pressure zone, shear zone, and drive rollers.

In the vertical dewatering zone, biosolids pass around a large perforated drum. The roller has internal scoops to carry the filtrate that passes from the inner surface of the belt/biosolids sandwich to discharge ports on one end of the drum.

In the pressure zone of the dewatering process, biosolids are pressed between the two belts to remove excess water. The biosolids are then carried between the belt's S-shaped loops in the shear zone. This zone consists of a system of plain rollers of decreasing diameter that increase the pressurization of the cake, and also function as shear rollers. The shearing action rearranges the biosolids mass, exposing the wet inner cake to the belt, allowing more water to drain.

The last set of rollers are the dried rollers. These rollers provide the last pressurization of the cake. After passing over these rollers, the belts separate and spring loaded scraper blades separate the cake from the belts at the point of cake discharge.

Dewatered liquid, known as filtrate, and the belt filter press wash water are collected in stainless steel troughs that are piped to the drainage pump station and routed back to the headworks.

Centrifuge

The three centrifuges have dedicated biosolids feed and polymer pumps, allowing them to operate independently. Biosolids are fed into the centrifuge through the central feed pipe. The centrifuge spins at nearly 3,000 rotations per minute (rpm). This allows the denser solids to settle against the bowl wall under the influence of centrifugal force. Each centrifuge allows for adjustments based on feed solids characteristics. For example, the finer the solids, the higher the bowl speed necessary for satisfactory separation results. The liquid or lighter material is clarified, flows to the liquid discharge and leaves the bowl by way of an adjustable weir, which determines the pool depth. The solids deposited on the bowl wall are transported towards the conical end of the bowl by the conveyor scroll, further compressing and dewatering the biosolids. The biosolids move to the discharge ports where it leaves the centrifuge and feeds a screw conveyor. Each centrifuge discharges into a dedicated screw conveyor.

1.4.6.2 Original Design Criteria

Table 1.22 outlines the design criteria for the belt filter presses and centrifuges. Although the hydraulic capacity for both processes stated in the table is based on information provided by the manufacturers, the units are incapable of operating at the upper limit of the range. The BFPs have a maximum operating setpoint of 125 gpm, while the hydraulic throughput of the centrifuges is around 240 gpm based on limitations of the downstream conveyance system.

Table 1.22 Dewatering Design Criteria

Parameter	Unit	Design Criteria	
		Belt Filter Press	Centrifuge
Number	--	5	3
Hydraulic Capacity, each	gpm	125-150	200-400
Solids Capacity, each	lb-solids/hr	2400	5300
Feed Solids Concentration	%	2 – 3	1 – 3
Cake Solids Concentration	%	18 – 20	20-22
Polymer Usage	lb/ton dry solids	10 – 15	15 – 30

Table 1.23 presents the design criteria for the dewatering polymer system. The same polymer type is used for the dewatering system as is used for DAFTs. The current polymer type utilized at RWRF was selected in the 1990s and optimized for the BFPs. The City has plans to negotiate a new polymer contract that will be optimized around the centrifuges due to their increased consumption compared to BFPs.

Table 1.23 Dewatering Polymer Design Criteria

Parameter	Unit	Design Criteria
Polymer Type	-	Emulsion
Polymer Activity	%	41
Bulk Polymer Storage Tanks		
Number	-	1 duty + 1 standby
Size, each	gallons	6400
Bulk Polymer Transfer Pumps		
Number	-	2 duty + 2 standby
Capacity, each	gpm	25
Polymer Mix Tanks		
Number	-	1 duty + 1 standby
Size, each	gallons	6400
Polymer Mix Transfer Pumps		
Number	-	1 duty + 1 standby(1)
Capacity, each	gpm	50
Polymer Feed Tanks		
Number	-	1 duty + 1 standby
Size, each	gallons	6400
Parameter	Unit	Design Criteria
Polymer Day Tank		
Number	-	1 duty + 1 standby
Size, each	gallons	3000
Polymer Feed Pumps to BFPs(2)		

Parameter	Unit	Design Criteria
Number	-	5
Capacity, each	gpm	50
Polymer Feed Pumps to Centrifuges(2)		
Number	-	3
Capacity, each	gpm	50
Slip Injection Polymer Feed Pumps to Dewatered Biosolids Pipeline(3)		
Number	-	5
Capacity, each	gpm	1.6

Notes:
(1) One per tank.
(2) Fed from Polymer Feed Tanks.
(3) Fed from Polymer Day Tank

1.4.6.3 Capacity and Performance Assessment

The City does not monitor equipment run time, which is needed to accurately analyze capacity and performance of dewatering equipment. Therefore, in order to assess capacity it is assumed that every dewatering unit operates continuously. Results are relative to maximum capacity. It is understood that the dewatering equipment does not run continually and the capacity values are not representative of actual operation, rather a representative comparison to the maximum. Plant staff chooses to operate dewatering equipment based on several factors. Some units may not operate for weeks at a time while others may operate more constantly. Based on an average of historical data from 2013 through 2017, it was calculated that roughly 30 percent of all dewatering feed flow is sent to the BFPs while 70 percent is sent to the centrifuges.

Appendix 1-A includes Figures A-1 through A-4, which show the hydraulic and solids loading to the BFPs and centrifuges assuming continuous operation. The figures intend to represent that the loading to all dewatering equipment on a daily basis is well below the design ranges. Therefore, the plant staff is able to operate equipment as needed to balance biosolids feed with silo storage availability. Figure 1.24 shows dewatering feed solids concentration, which has decreased slightly over the last several years. However, the concentration of roughly 2 percent is within the design range of 1-3 percent.

Figure 1.25 shows the performance of biosolids cake from each equipment type. Centrifuge cake is drier than the design range. However, the BFP cake solids is below the design range. It is advised that the new polymer type be tested with BFPs to confirm suitable dose and cake performance.

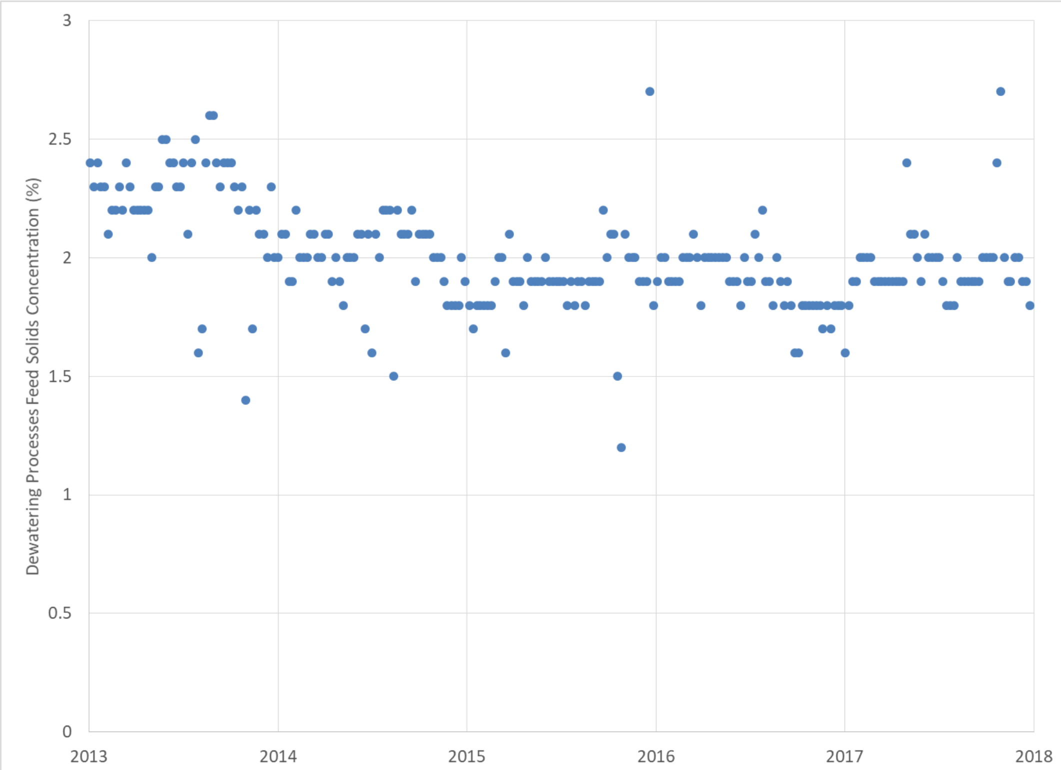

Figure 1.24 Dewatering Feed Solids Concentration (%)

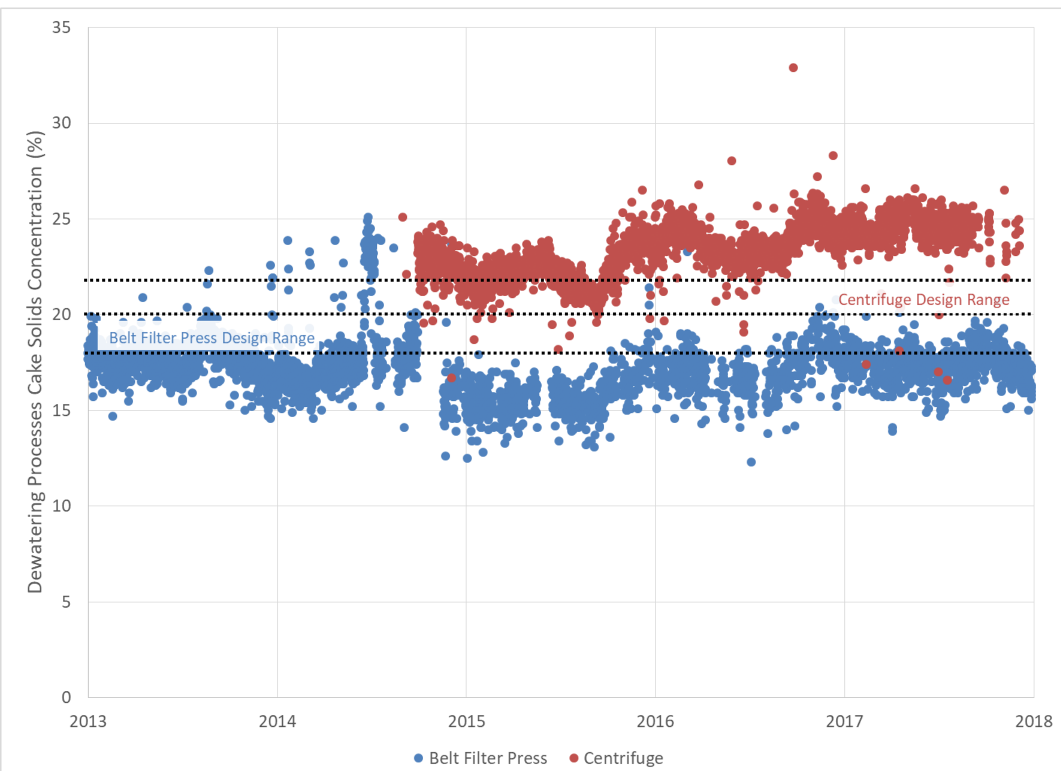

Figure 1.25 Dewatered Cake Percent Solids Concentration

Tables 1.24 and 1.25 outline the capacity and performance of all dewatering equipment. BFP solids capture is not monitored. As has been discussed previously, the current polymer type is optimized based on BFPs. Also, the centrifuge solids capture, shown in Figure 1.26, is often below the design range of 95 percent. The polymer consumption for the centrifuges is above the design criteria, as shown in Figure 1.27. The new polymer contract optimized for centrifuge operation should help decrease centrifuge polymer consumption and increase percent solids capture.

Table 1.24 Performance Assessment – Dewatering Equipment

Parameter	Units	Design Criteria	Current	
			Performance	Meeting Design Criteria?
Active Polymer Consumption(1)	lb/dry ton solids			
Belt Filter Press		10 – 15	14.7(1)	Yes
Centrifuge		15 – 30	33.9	No
Cake Solids(1)	%			
Belt Filter Press		18 – 20	17.2	No
Centrifuge		20 – 22	23.3	Yes
Centrifuge Solids Capture	%	95		
Centrifuge(2)			93	No

Notes:
(1) Calculated as the average.
(2) Calculated as the 10th percentile

Table 1.25 Capacity Assessment - Dewatering Equipment

Parameter	Units	Design Criteria	Current		Future	
			Capacity Needs	Sufficient Processing Capacity?	Capacity Needs	Sufficient Processing Capacity?
Hydraulic Loading	**gpm/unit**					
Belt Filter Press		120				
Daily Average			28	Yes	42	Yes
Daily Maximum(1)			55	Yes	74	Yes
Centrifuge		240				
Daily Average			106	Yes	159	Yes
Daily Maximum(1)			166	Yes	209	Yes
Solids Loading	**lb/hr/unit**					
Belt Filter Press		2,400				
Daily Average			337	Yes	440	Yes
Daily Maximum(1)			577	Yes	790	Yes
Centrifuge		5,300				
Daily Average			1,108	Yes	1,676	Yes
Daily Maximum(1)			1,729	Yes	2,200	Yes
Polymer Feed Pump	**gpm**	**50**				
Daily Average			11.7	Yes	18.1	Yes
Daily Maximum(1)			23.9	Yes	37.0	Yes

Notes:
(1) Maximum values calculated as the 90th percentile.

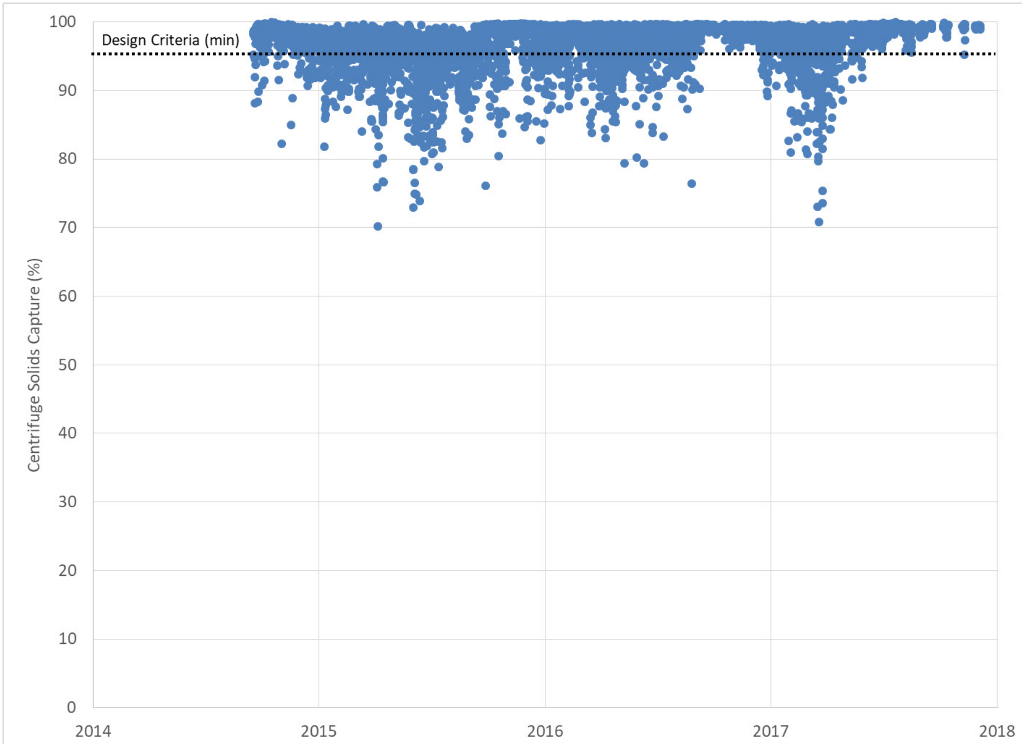

Figure 1.26 Centrifuge Percent Solids Capture

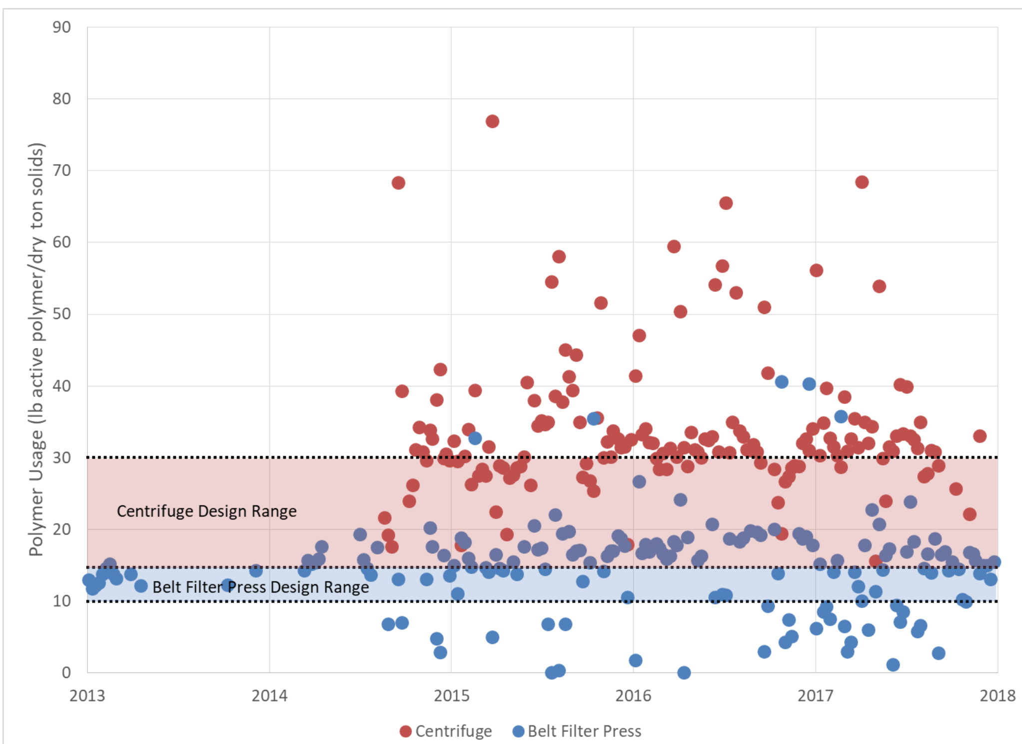

Figure 1.27 Dewatering Equipment Polymer Consumption

1.4.7 Biosolids (Cake) Conveyance and Storage

1.4.7.1 Description

Dewatered biosolids is transported to one of two storage silos where it is then transferred to trucks for beneficial use through compost or land application. Cake drops from each centrifuge into a screw conveyor that moves the cake into the inlet hopper of each cake pump. The inlet hopper includes a screw intended to prevent bridge formation as the cake drops into the cake pump suction housing. From there the centrifuge cake is pumped into either storage silo. The cake from all belt filter presses is collected on a common horizontal belt conveyor. Another inclined belt conveyor transports cake to Silo 2.

Biosolids (cake) from the BFPs can only be sent to Silo 2, whereas centrifuge cake can be sent to either silo. Centrifuge cake pumps feed cake into the top of the silos. The BFP belt conveyor offloads cake through the sidewall of Silo 2 near the top. If the operating level in Silo 2 becomes too high, the belt conveyor can pull solids through the opening on the undertow and torque out. Therefore, the operating capacity of Silo 2 is slightly less than that of Silo 1.

Roughly 10 loads of biosolids are collected from the silos daily. Whether haulers load from Silo 1 or 2 depends on the operation of the dewatering units and changes daily.

1.4.7.2 Original Design Criteria

Table 1.26 outlines the design criteria of the biosolids cake equipment and storage silos.

1.4.7.3 Capacity and Performance Assessment

Table 1.27 shows the operating capacity and performance of the biosolids cake equipment. Operating capacities assume continuous equipment operation. Based on this analysis, the conveying equipment and storage silos have sufficient capacity to handle the current and increased volume of cake produced in the future.

However, plant staff has had and continues to have repeated issues with the centrifuge cake pumps. The rated discharge capacity of the pumps is 440 psi. However, even when the operating discharge pressure is between 100 and 200 psi there are issues pumping cake to the silos. The pressures cause damage to the stators, requiring frequent and costly rebuilds. In addition, the cake pump inlet hopper and conveyor cannot keep up with the volumetric rate of cake fed from the centrifuge conveyors into the hoppers. The plant is testing the impacts of lubrication rings in different locations on the cake pump discharge piping. The intent is to reduce operating pressures that are causing pump damage. Polymer should be injected into the lubrication rings rather than water for maximum pressure reduction.

Table 1.26 Biosolids Conveyance and Storage Design Criteria

Parameter	Units	Design Criteria
Centrifuge Cake Pumps		
Number	-	3
Type	-	10-Stage Progressive Cavity
Capacity, each	gpm	40
Discharge pressure	psi	440
Horsepower, each	hp	60
Centrifuge Conveyors		
Number	-	3
Type	-	Screw
Horsepower	hp	7.5
Capacity	ft^3/hr	500
Belt Filter Press Conveyors		
Number	-	2
Type	-	Belt
Capacity, each	lb/hr	--(1)
	ft^3/hr	--(1)
Horsepower, each	hp	7.5, 15
Storage Silos		
Number	-	2
Volume, each	yd^3	430
Holding Time	hr	24

Notes:
(1) Missing information

Table 1 27 Capacity and Performance Assessment - Biosolids Conveyance and Storage

Parameter	Units	Design Criteria	Current		Future	
			Capacity Needs	Sufficient Processing Capacity?	Capacity Needs	Sufficient Processing Capacity?
Cake Pumps						
Centrifuge Cake Pump Capacity	gpm	40				
Average Daily			9	Yes	14	Yes
Maximum Daily			13	Yes	18	Yes
BFP Conveyor Capacity						
Mass Load	lb/hr	--(1)	10,250	--(1)	12,500	--(1)
Volume	ft^3/hr	--(1)	228	--(1)	275	--(1)
Storage Silos						
Biosolids Hauled	tons/day	N/A	245	N/A	400	N/A
Volume	yd^3	860	403(2)	Yes	658	Yes
Holding Time	hr	24	51(3)	Yes	31	Yes

Notes:
(1) Missing information.
(2) Average volume of biosolids hauled daily from 2013 to 2017. Calculated assuming a cake density of 45 pcf.
(3) Average holding time was calculated by dividing the design volume by the daily volume hauled.

1.5 Solids Handling Operating Costs

An extensive analysis of the operating costs associated with the solids handling processes was performed. The cost analysis included power, labor costs associated with operation and maintenance, equipment maintenance costs, polymer and biosolids hauling costs, and costs offset by ADM tipping fees. Table 1.28 summarizes the overall solids handling annual costs. Appendix 1-B provides a breakdown of all these costs.

Electricity consumption was estimated by determining number of duty units, motor horsepower, operating percent of nameplate power (if motor has a variable frequency drive), and operating hours per day. Because motors are often oversized in order to provide a factor of safety for operation, the power consumption was calculated as 85 percent of the nameplate horsepower. This is a conservative estimate because pumps often operate lower on their curve than what they are rated for. The 5-year average unit electricity cost (2013-2017) was used to calculate total electrical costs. The solids handling electrical cost is estimated to be $1.3M. This is 28 percent of the plant-wide electrical cost for 2017, which was $4.7M. Without metered power consumption information or consumption broken down by process area it is difficult to accurately discern solids handling costs from plant-wide costs.

Table 1.28 Annual Cost Summary of Solids Handling

Parameter	Unit Cost	Total Cost
Electricity	$0.12/kWh(1)	$1,259,000(4)
Labor – Operations	$40.58/hr(3)	$578,000(5)
Labor - Maintenance	$40.58/hr(3)	$353,000(5)
Equipment Maintenance	NA	$421,000(5)
Chemicals	$10.20/gallon bulk polymer(1)	$1,359,000
Tipping	$0.03/gallon(3)	-$318,000
Hauling	$34/ton(6)	$3,041,000
Total	NA	**$6,693,000**

Notes:
(1) Based on five years of historical data.
(2) Based on June 2018 unit cost.
(3) Provided by the City.
(4) Calculated by multiplying operational horsepower by equipment run time.
(5) Estimated from five years of maintenance logs
(6) Based on hauling contracts negotiated in 2018

Five years of maintenance logs (2014-2018) from each solids handling process were analyzed to determine approximate labor hours and equipment costs for maintenance. For processes strictly related to solids handling (thickening, digestion, and dewatering), 100 percent of maintenance costs were included. For processes not strictly solids handling (primary and secondary sludge processing), the costs associated with solids handling was assumed to be 50 percent of all associated maintenance costs. Additionally, the average annual maintenance costs include maintenance for ancillary equipment like structures, safety, and programmable logic controller (PLCs). Structural maintenance is assumed to last for 20 years. Therefore, only 25 percent of labor hours and maintenance costs with 'Building' or 'Structure' tags from the five year period were included in determining solids handling costs.

The burdened labor rate for a Wastewater Treatment Plant Specialist with full benefits was provided by the City. The dewatering building is staffed continuously, three shifts per day, year round. It is estimated that roughly half of A-side operations, which includes ADM, DAFT, and digestion, is related to solids handling, or 12 hours/day. Remaining solids handling operations for B and C side were estimated to be three hours per day. In total, approximately 39 labor hours per day are dedicated to the solids handling processes. This equates to five full time employees dedicated to solids handling operation.

The five year average polymer consumption and unit cost were used to calculate total polymer costs. A similar analysis was done for biosolids hauling costs. Figure 1.28 shows the costs associated with polymer for thickening and dewatering.

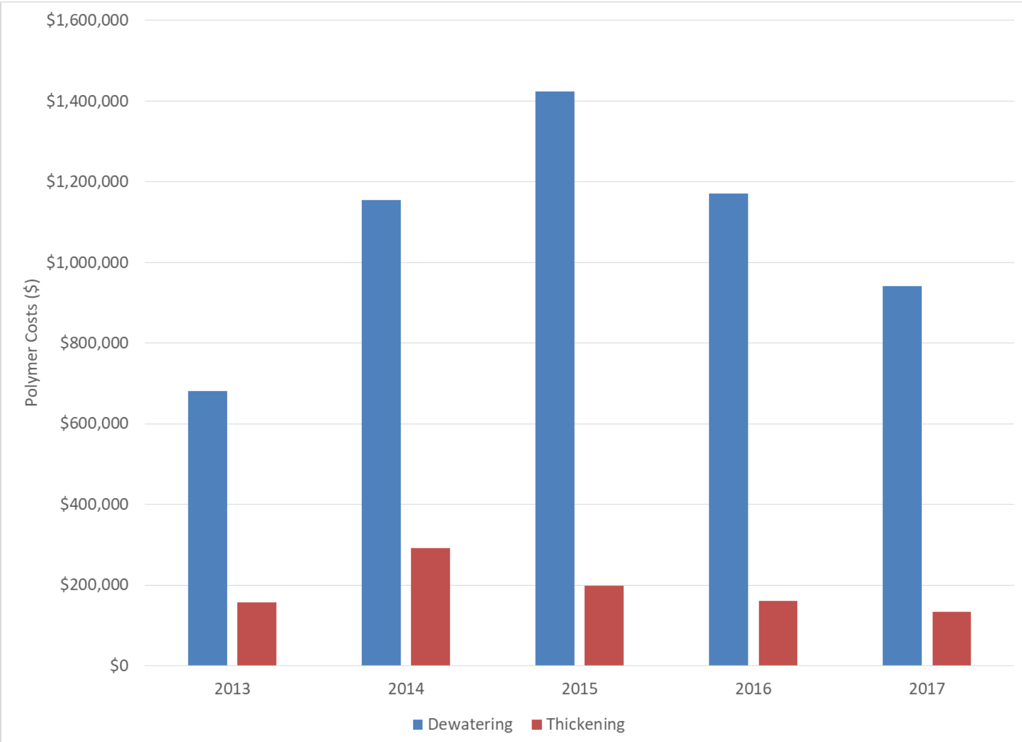

Figure 1.28 Polymer Costs

Dewatering and its associated maintenance, power, polymer, and hauling expenses account for more than half of all solids handling costs at RWRF. Thus dewatering expenses for belt filter presses and centrifuges were compared to identify potential cost savings. Table 1.29 compares the costs associated with dewatering 1 million gallons of digested sludge by both equipment types. Feed total solids concentration was assumed to be 2.1 percent based on historical values. Equipment costs and hydraulic throughput are typical of what is provided in the biosolids cost summary table. Because the City is planning to optimize its polymer, a 96 percent solids capture was assumed for both equipment types. Additional assumptions include a unit polymer cost of $10.20/gal and 41 percent active, and hauling costs of $34/ton.

Based on current hauling and polymer costs, the belt filter presses are cheaper to operate. Thus it is recommended that the plant run their belt filter presses frequently with centrifuges coming online to handle excess production when needed. However, if hauling costs increase and polymer consumption decreases, it is possible that centrifuges will become cheaper to operate. if polymer is optimized around centrifuge operation and centrifuge polymer consumption drops to just 28 lb/dry ton, then operating the centrifuges will have an equal cost as the BFPs. Furthermore, if hauling costs continue to increase as expected, centrifuges will become more economical to operate.

Table 1.29 Cost Comparison of Dewatering One Million Gallons of Sludge

Parameter (unit)	Belt Filter Press	Centrifuge
Assumed Flow (gpm)	120	240
Total Duty Equipment Motor Size (hp)	12	175
Power Cost ($0.12/kWh)	$ 147	$ 1,072
Percent of Total Cost	**1%**	**5%**
Polymer Consumption (lb active/dry ton)	14.7	33
Polymer Cost ($10.20/gal; 41% active)	$ 3,724	$ 8,360
Percent of Total Cost	**18%**	**39%**
% solids cake	17.2	23.3
Hauling Cost ($34/ton)	$ 16,618	$ 12,267
% of Total Cost	**81%**	**59%**
Dewatering Cost ($/MG)	**$ 20,488**	**$ 21,699**

Haulers that bring ADM to the receiving station are charged a tipping fee of three cents per gallon. Since the opening of the ADM facility, hauling volumes have increased steadily. Revenue generated was based on 2017 hauling volumes. Table 1.30 and Figure 1.29 translates the existing ADM receiving station usage to revenue generated for the RWRF facility. This revenue helps offset the cost of facility operation and maintenance described in Section 4 below. As a way to increase revenue and reduce receipt of low quality ADM, it is recommended that the City continue its efforts to identify and eliminate bad actors from the program and implement a sliding scale tipping fee based on projected biomethane production.

Figure 1.30 shows the annual cost of biosolids hauling. Hauling costs have ranged from just under $24/ton to $28/ton in 2017. A new biosolids contract is exploring alternative beneficial reuse options. Unit costs as a result of the new hauling contract will likely be greater than $30/ton.

Table 1.30 Anaerobically Digestible Material Revenue Generated

Year	Revenue(1)
2013	$145,866
2014	$163,515
2015	$212,444
2016	$239,944
2017	$317,723

Notes:
(1) Tipping fee of $0.03 per gallon used.

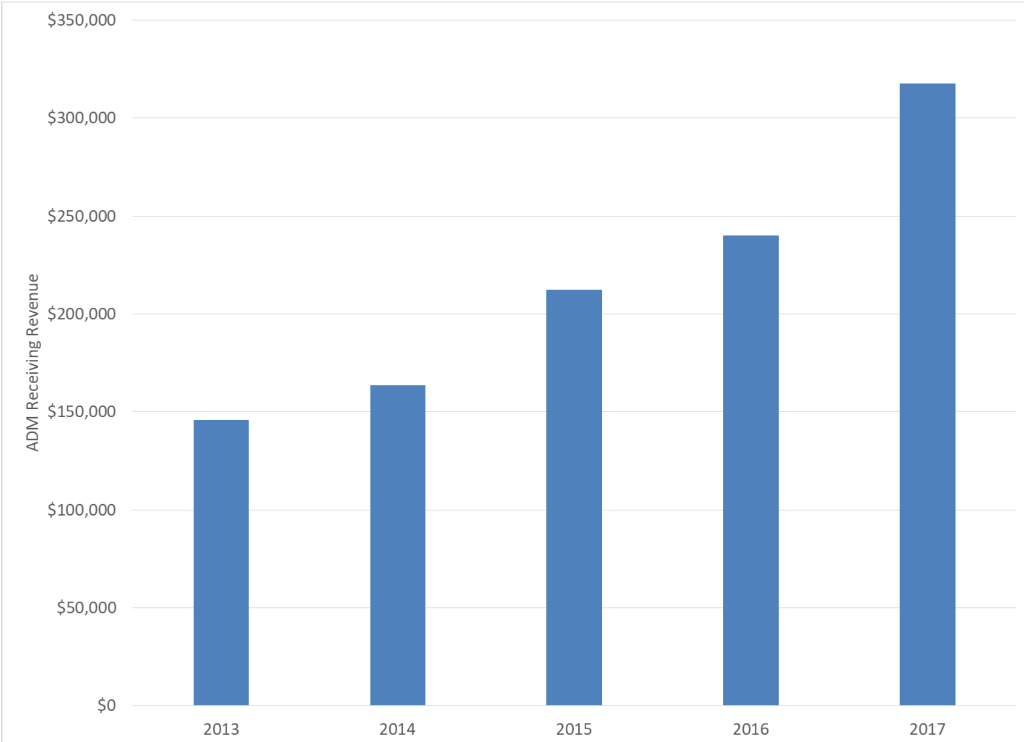

Figure 1.29 ADM Receiving Revenue

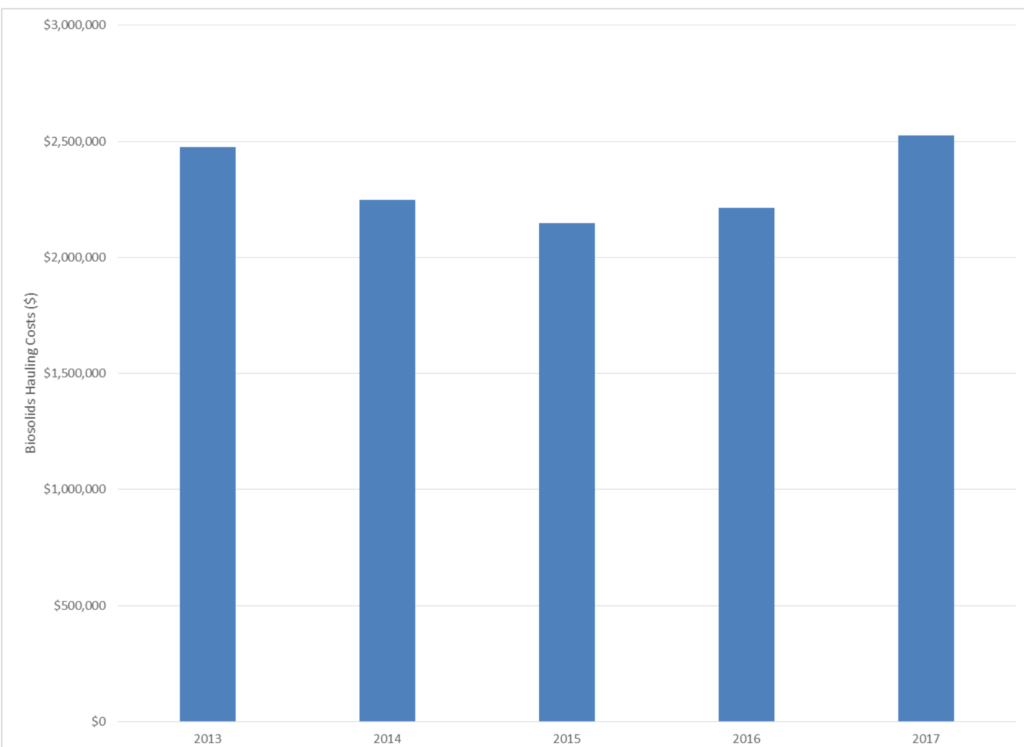

Figure 1.30 Biosolids Hauling Costs

1.6 Additions/Modifications to Address Capacity Constraints of Existing Solids Handling Facilities

1.6.1 Primary and Waste Activated Sludge

The City has not expressed significant limitations in the operation or performance of the primary and secondary solids handling facilities. Both primary sludge and WAS pump stations have plenty of standby pumps that should provide adequate backup during maintenance and sufficient capacity beyond the planning horizon of 2040. One standby B-side WAS pump may need to operate as a duty pump under future, peak conditions.

1.6.2 Sludge Thickening

The DAFT units have plenty of hydraulic capacity through the year 2040, but may be limited in the future based on solids loading. One DAFT unit in service should be able to handle the majority of loading conditions but the City may need to run both units in parallel during peak flows in the future. Additional polymer pumps may also need to operate during future peak flows in order to have sufficient capacity.

The solids capture for the thickening process could be improved by optimizing polymer selection. Currently the same polymer is used plant-wide and is optimized for the dewatering process. If the City determines that the solids capture for the DAFT units is unacceptable or considers multiple polymer types on site, a polymer selection should be made based on optimization for the thickening process. If polymer selection is optimized for the dewatering process, it is advised to run preliminary testing of that polymer for the thickening process to confirm suitability.

The City has expressed pumping issues with the TWAS float pumps when the TWAS is greater than five percent total solids. If this becomes a limitation to thickening the City may explore replacing the pumps, motors, or VFDs to increase pumping capacity. Increasing TWAS and PS concentration may be warranted to minimize hydraulic loads on the digesters in the future. If thicker solids can be produced and conveyed, the City could further defer digester construction.

1.6.3 Anaerobically Digestible Material Receiving Station

As described earlier, the City has expressed concern with some haulers disposing of ADM with low volatile solids loading. It would be in the City's interest to change the flat rate tipping fee to a sliding scale fee based on projected gas production. At that point the City can determine if preventing low loaded haulers from dumping outweighs the benefits of increased revenue. Alternatively, poor quality loads could be disposed of at the headworks structure to prevent dilution of the digester feed.

Given the stable performance of all digesters, the City has capacity to increase ADM receiving, in turn increasing biogas production. The City should refrain from significant increases in ADM receiving until additional capacity is available to handle biogas production (i.e. additional flares/boilers, operating power generation facility).

Uneven equipment usage among the three disposal sites has led to increased maintenance, particularly at Bay 1. One way to more evenly distribute loads across docking stations would be to implement a program change to the indicator lights that only shows availability to bays sequentially.

1.6.4 Anaerobic Digestion and Ancillary Processes

The volatile acids to alkalinity ratio (VA:Alk) was used to assess digester performance because VSLR can be misleading for ADM digesters. The VA:Alk ratio in every digester is around 0.01, with maximum values around 0.03. A stable digester should remain below 0.1. Although some digesters have VSLR above 0.12, the VA:Alk for every digester indicates that digesters are stable and capable of being loaded with more volatile solids.

Projected digester loading indicates digestion limitations by 2024 or 2026, depending on the feed configuration of ADM. It is recommended that the feed configuration be altered to allow all digesters to receive ADM. This will evenly split loading among digesters and increase performance in the larger digesters, which are currently burdened with the entire ADM load. Altering the feed configuration will allow capital improvements to be delayed by a couple years. However, even after changing ADM feed configuration, due to the projected increases in sludge production and ADM loads, it is estimated that one additional large digester will be needed in 2026, 2033, and 2039, for a total increase in active digestion volume of 5.6 million gallons by 2040. This timeline could be extended if the City were able to increase digester feed solids concentration from the primary clarifiers and DAFTs. It is suggested that as solids flows increase, the City start operating these systems to produce thicker solids streams and reduce hydraulic load on the digesters.

Additionally, there are struvite buildup issues in the booster pump suction line that serves Digesters 3 through 8. However, no struvite issues are experienced for the Digesters 9 through 13. It was mentioned that the newer pipe may be glass lined, which prevents struvite from adhering. It is recommended to inspect the lining of the pipe at issue and replace with glass lined ductile iron pipe if necessary to prevent struvite buildup. However, this would not eliminate struvite buildup in downstream process equipment. Alternatively, the City may be able to implement a phosphorus recovery system capable of producing high quality struvite. This would eliminate struvite related maintenance costs in the digestion and dewatering process areas and could also increase revenue by producing a marketable product if such a market exists in the local area.

1.6.5 Biogas Utilization and Management

The City has limited capacity in the biogas boiler and flare. There are plans for separate projects to add additional capacity for each. Another boiler would prevent digester heating deficiencies experienced during winter months and reduce biogas sent to the flare. Another permanent flare is needed to be able to handle peak biogas production.

After future projects to increase capacity in the boiler and flare, the City may want to explore the feasibility of utilizing the biogas conditioning system to generate pipeline grade biomethane or low carbon transportation fuel.

1.6.6 Biosolids Dewatering

Solids capture rates for the centrifuges are below the design criteria value of 95 percent. The City has plans to change their polymer type to be optimized for the centrifuges. Currently, polymer consumption for the centrifuges is above the recommended range of 15 to 30 lb active polymer per ton of dry solids. Optimizing polymer selection for the centrifuge should decrease polymer consumption and increase solids capture, in turn reducing operating costs. Additionally, centrifuges produce a dryer cake than the belt filter presses. Although the BFPs may be easier to operate, if the centrifuges are run more often, particularly after the polymer consumption is brought down and biosolids unit hauling costs increase, cost savings may be realized from reduced biosolids hauling costs.

It is recommended that the City begin monitoring equipment run times for each of the dewatering units. This will make future analyses more accurate by eliminating required assumptions. We also suggest that the City try to monitor the solids capture efficiency of the belt filter presses. This will help determine actual performance and provide a basis for optimization.

1.6.7 Biosolids (Cake) Storage

There are issues pumping centrifuge cake from the screw conveyor into the silos due to the discharge pressure. The plant is testing the impacts of lubrication rings in different locations on the cake pump discharge piping. Polymer should be injected into the lubrication rings rather than water for maximum pressure reduction.

There are some limitations in the biosolids dewatering operations due to the operational complexity of balancing biosolids feeds, unit operation run times, silo storage, and haulers schedules. One option the City could consider to simplify dewatering operations is to impose a fixed hauling schedule that preliminarily sets a time schedule for the number of loads per silo per day. Then, operators can better understand expected silo capacities throughout the day and operate dewatering units accordingly.

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Chapter 2

CURRENT AND FUTURE REGULATIONS

2.1 Introduction

Assessment of both current and anticipated future regulatory requirements is critical for the development of effective long-term biosolids management alternatives. This chapter summarizes current regulatory requirements and considerations that impact the operation of the City of Fresno (City) Fresno-Clovis Regional Wastewater Reclamation Facility's (RWRF) solids processing facilities today, as well as proposed regulations that will impact the facility operations within the planning horizon of the Biosolids Master Plan (i.e., through 2040). The regulatory summary includes a comprehensive review of the current regulations governing solids treatment and end use, as well as air emissions (local and global pollutants). Potential impacts of future regulations are also considered.

2.2 Wastewater Solids Regulations

To determine the appropriate types of regulations the RWRF must consider, the types of solids/biosolids streams the RWRF manages must be understood. Influent solids processed at the RWRF consist of screenings, grit, raw or primary sludge (PS), thickened secondary or waste activated sludge (TWAS), and imported anaerobically digestible material (ADM), consisting of fats, oils, and grease (FOG) and other wastes. The screenings and grit are predominantly comprised of inert and/or non-organic material and are disposed of in American Avenue landfill. The PS and TWAS are mixed with ADM, and pumped to anaerobic digesters for stabilization to create a stabilized product defined by the United States Environmental Protection Agency (EPA) as biosolids. Anaerobic digestion is one of the many processes that meet the stabilization standards set by the EPA[1] that define a biosolids product suitable for beneficial use. Biosolids contain many properties that promote beneficial use including macronutrients (nitrogen, phosphorus, and potassium), secondary and micronutrients (calcium, magnesium, zinc, and copper), and organic matter.

Federal, state, and local regulations determine whether biosolids from municipal water reclamation facilities (WRFs) can be beneficially used or must be disposed. At the federal level, biosolids regulations are well established, with few changes anticipated in the planning horizon. In contrast, at the state level, anticipated changes to California's biosolids regulations will influence biosolids management options, making the development and execution of a flexible management program essential.

[1] EPA's Title 40 Code of Federal Regulations Part 503 *Standards for the Use and Disposal of Sewage Sludge* ("40 CFR 503"),

A summary of relevant federal, state, and local regulations is provided in the following sections. The specific relevance of regulations depends on the intended end use or disposal method, which dictates the level of treatment required and the resulting product classification (unclassified, Class B, Class A, Class A Exceptional Quality (EQ), biochar, or a licensed fertilizer as LysteGro).

2.2.1 Federal

Federal, state, and local agencies are responsible for regulating beneficial use/disposal of biosolids. Each agency's required level of treatment varies based on the beneficial use/disposal methods employed. However, key minimum guidelines are established by EPA that must be implemented by state and local governments. In California, state and local agencies have developed additional rules, guidelines, and criteria for biosolids management.

In order to implement a long-term biosolids program required by the Water Quality Act of 1987, EPA initiated two rule-makings resulting in the promulgation of 40 CFR 503 (the Rule or Regulation), *Standards for the Use or Disposal of Sewage Sludge*. The regulation establishes requirements, procedures, operational standards, and management practices for:

- Biosolids management in National Pollutant Discharge Elimination System (NPDES) permits;
- Implementing federal biosolids permit programs, if a state so chooses;
- Granting state biosolids management programs primacy over federal programs;
- Land application of sewage sludge (which is biosolids in this context) for beneficial use;
- Surface disposal in a monofill, surface impoundment, or other dedicated site; and
- Incineration of sewage sludge with or without auxiliary fuel.

2.2.1.1 40 CFR 503 Regulations

40 CFR 503 establishes biosolids quality standards based on three parameters: pathogen reduction (PR), vector attraction reduction (VAR), and pollutant (metals) concentration.

Pathogen reduction alternatives are designed to reduce the concentration of pathogens (organisms capable of causing diseases pathogens) in biosolids and are categorized into two major categories: Class A and Class B. Class A technologies reduce pathogens to undetectable levels[2], allowing products to be used in markets with both low public contact (e.g., agricultural land and land reclamation sites) and high public contact (e.g., public parks, plant nurseries, roadsides, golf course, and home gardens). In contrast, Class B PR technologies significantly reduce pathogens, but requires additional "processing" through environmental exposure, so these products may only be used in low-public access areas. The 40 CFR 503 Class A and Class B PR requirements for land applied biosolids are summarized in Table 2.1. For a product to be classified as Class A or Class B, it must meet each of the major bullets outlined in Table 2.1.

[2] Based on 1992 testing standards

Table 2.1 EPA 40 CFR 503 Pathogen Reduction Requirements for Class A and Class B

Class A	Class B
Either fecal coliform density in the sewage sludge is less than 1,000 MPN/gram of total solids (dry weight basis), or the density of Salmonella species bacteria in the sewage sludge is less than 3 MPN/4 grams of total solids (dry weight basis). Sewage sludge must be treated and/or meet one of the following alternatives before use or disposal. For more details on each treatment alternative, refer to 40 CFR 503.32(a): • Thermally treated. • High pH-high temperature treatment. • Treatment to reduce enteric virus to less than 1 PFU per 4 grams of total dry solids and viable helminth ova to less than one per four grams of total dry solids. • Processes to further reduce pathogens (PFRP) include treatment by composting, heat drying, heat treatment, thermophilic aerobic digestion, beta ray irradiation, gamma ray irradiation, or pasteurization. Specific operating conditions for each process has been specified in 40 CFR 503.32(a). • Use of processes equivalent to the above (subject to authority approval).	Comply with site restrictions of land application as specified in 40 CFR 503.32(b)(2), (b)(3), or (b)(4). In summary, these restrictions limit access to animals and the public on sites where Class B material was applied. Sewage sludge must be treated and/or meet one of the following alternatives before use or disposal. For more details on each treatment alternative, refer to 40 CFR 503.32(b): • Geometric mean of seven samples of treated sewage sludge collected at the time of use or disposal shall meet a fecal coliform density of 2 million CFU or MPN/gram of total solids (dry weight basis). • Processes that significantly reduce pathogens (PSRP) which include aerobic digestion, air drying, anaerobic digestion, composting, or lime stabilization. Specific operating conditions for each process has been specified in 40 CFR 503.32(b). • Use of processes equivalent to the above (subject to authority approval).

Abbreviations:
(1) MPN = Most Probable Number.
(2) CFU = Colony Forming Unit.
(3) PFU = Plaque Forming Unit.

Vector attraction reduction options are designed to reduce the transport of pathogens by vectors (i.e., flies, mosquitoes, fleas, rodents, and birds) from biosolids to other animals or humans. Vector attraction reduction includes process methods (i.e., chemical or biological reduction [Options 1-8]) or barrier methods (i.e., physically blocking biosolids from vectors [Options 9-10]). Vector attraction reduction requirements are summarized in Table 2.2.

Table 2.2 EPA 40 CFR 503 Vector Attraction Reduction Requirements

Alternative No. in 40 CFR 503.33(b)	Description
1	Meet 38 percent reduction in volatile solids content.
2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit.
3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit.
4	Meet a specific oxygen uptake rate for aerobically digested biosolids.
5	Use aerobic processes at greater than 40 degrees C for 14 days or longer.
6	Alkali addition under specified conditions.
7	Dry biosolids (with no unstabilized solids) to at least 75 percent solids.
8	Dry biosolids (with unstabilized solids) to at least 90 percent solids.
9	Inject biosolids beneath the soil surface.
10	Incorporate biosolids into the soil within six hours of application to or placement on the land.
11	Cover biosolids placed on a surface disposal site with soil or other material at the end of each operating day. (Note: only for surface disposal.)
12	Alkaline treatment of domestic septage to pH 12 or above for 30 minutes without adding more alkaline material.

Biosolids must, at a minimum, meet metal concentration limits in order to be beneficially used, referred to as Ceiling Concentration Limits. If land applying, the biosolids must meet either the pollutant concentration limits or cumulative pollutant loading rate limits[3]. Table 2.3 summarizes the pollutant limits required by 40 CFR 503 to beneficially use biosolids.

In addition to the requirements above, 40 CFR 503 provides guidance on best practices for land application of biosolids, provides site restrictions for each type of biosolids, and sets the requirements for monitoring, recordkeeping, and reporting. These apply to both the supplier and application of biosolids (which could be a third party).

[3] Per Section 503.11 of 40 CFR 503, it is maximum amount of an inorganic pollutant that can be applied to an area of land.

Table 2.3 EPA 40 CFR 503 Metal Concentration Limits

Pollutant	EPA(3) CCL(1), mg/kg dry weight basis	EPA(3) PCL(4), mg/kg dry weight basis	EPA(3) CPLR(2) Limit, kg per hectare
Arsenic	75	41	41
Cadmium	85	39	39
Chromium	3,000	1,200	3,000
Copper	4,300	1,500	1,500
Lead	840	300	300
Mercury	57	17	17
Molybdenum	75	-	-
Nickel	420	420	420
Selenium	100	36	36
Zinc	7,500	2,800	2,800
Applicable to:	Land applied material	Bulk and bagged material	Bulk material

Notes:
(1) CCL: Ceiling Concentration Limit.
(2) CPLR: Cumulative Pollutant Loading Rate.
(3) EPA: Environmental Protection Agency.
(4) PCL: Pollutant Concentration Limit.

Class B Biosolids

Class B biosolids are treated with processes intended to significantly reduce, but not eliminate pathogens. As such, biosolids may be land applied, but land appliers must also follow application and pollutant load restrictions for Class B biosolids with regard to public contact, animal forage, and production of crops for human consumption. For example:

- Class B biosolids may only be applied to sites where there is no possibility of contact with the general public. These sites include specific types of agriculture, land reclamation, landfills, etc.
- Crop harvesting, animal grazing, and public access are restricted for a defined period of time until environmental conditions have further reduced pathogens.

Class B biosolids can be produced through three Alternatives defined in Table 2.2, and must also meet VAR and pollutant standards previously defined. The alternatives considered in the RWRF's Biosolids Master Plan include two technologies classified under Alternative 2 (treatment with a defined PSRP): mesophilic anaerobic digestion and static aerated pile composting. In mesophilic anaerobic digestion, the process must be operated between 15 days at 35 to 55 degrees Celsius (°C) and 60 days at 20°C to meet Class B standards. Mesophilic anaerobic digestion to meet Class B standards is the City's current practice. Class B composting operations are required to raise the temperature of biosolids to 40°C or higher for five days. The temperature in the compost pile must also exceed 55°C for at least four hours during the five-day period. For both technologies, the quantity and quality of the processed sewage sludge and resulting biosolids must be monitored and recorded by each producer.

Class A Biosolids

Class A biosolids are produced with technologies designed to reduce pathogens to nearly undetectable levels and, therefore, may be beneficially used where contact with the general public is possible (i.e., nurseries, gardens, golf courses, etc.). Class A biosolids can be produced through any of the six defined Alternatives in 40 CFR 503 (Table 2.1). The alternatives considered within the RWRF's Biosolids Master Plan include four technologies classified under the Alternative 5 (treatment with a defined PFRP): thermophilic anaerobic digestion, aerated static pile composting, heat drying, and pasteurization. To meet Class A standards, the thermophilic anaerobic digestion process must be operated at 50°C or higher for 30 minutes or longer. Composting operations are required to operate at 55°C or higher for three consecutive days. Heat drying must reduce the moisture content of the biosolids to 10 percent or lower. Pasteurization processes must maintain the temperature of the biosolids at 70°C for 30 minutes or longer.

Exceptional Quality Biosolids

Biosolids that meet the pollutant concentrations limits of Table 2.3, one of the Class A PR requirements of Table 2.1, and one of options 1 through 8 of the VAR alternatives in Table 2.2, may be identified as EQ biosolids. EQ biosolids may be used and distributed in bulk or bag form and are not subject to general requirements and management practices with the exception of monitoring, recordkeeping, and reporting to substantiate the quality criteria have been met.

2.2.1.2 40 CFR 258 Regulations

In addition to the regulations set forth to govern sewage sludge use and disposal, 40 CFR Part 258 *Solid Waste Disposal Facility Criteria* was promulgated October 1991 to control the disposal of sewage sludge classified as solid waste. Sewage sludge is exempt from the definition of solid waste unless the sludge is co-disposed with household solid waste. 40 CFR Part 258 sets forth criteria for landfills with respect to: location, design, operation, groundwater monitoring, and closure with the intent of protection of ground and surface water from contamination. The main requirement of co-disposed sludge is that it must meet the Paint Filter Liquids Test (EPA Method 9095A). This method determines the presence of free liquids in a sample. Well-dewatered unstabilized wastewater solids and biosolids, such as in the case of the RWRF's biosolids, typically pass this test.

2.2.1.3 Non-Hazardous Waste

Biosolids must be tested at a frequency that is based on the amount generated to demonstrate they are non-hazardous. The RWRF has tested the biosolids for parameters found in the TCLP test and has demonstrated their biosolids are non-hazardous.

2.2.2 State

The beneficial use or disposal of biosolids is primarily regulated by California's State Water Resources Control Board (SWRCB), the Division of Water Quality (DWQ), and the nine Regional Water Boards. As required under the Porter-Cologne Act, the SWRCB, along with its nine Regional Water Boards (RWQCBs), is principally concerned with protecting existing and future beneficial uses of water, but also addresses the use or disposal of sewage sludge (and biosolids). The RWRF is regulated under the Central Valley Regional Water Board.

The SWRCB's General Waste Discharge Requirements (WDRs) for the *Discharge of Biosolids to Land for Use as a Soil Amendment in Agriculture, Silviculture, Horticulture, and Land Reclamation Activities (General Order)* covers the use of biosolids as a soil amendment. The General Order applies to Class B land application sites and sites where Class A Exceptional Quality biosolids will be applied at rates greater than 10 dry tons per acre per year to a field that is larger than 20 acres in size. The General Order goes beyond the requirements of 40 CFR 503 by requiring additional biosolids testing, soil testing, and groundwater sampling. In order for such a discharge to be allowed, the biosolids must meet these treatment and testing requirements, and must demonstrate capability to be beneficially used as a soil amendment as specified under 40 CFR 503. The Central Valley RWQCB adopted the State's General Order, which provides additional management requirements. The General Order is intended to help streamline the regulatory process for such discharges, but may not be appropriate for all sites using biosolids due to site-specific conditions or locations. Such sites are not precluded from being issued individual WDRs.

The SWRCB and the RWQCBs generally recognize that Class A, Exceptional Quality biosolids products such as heat dried pellets, properly prepared composts, and liquid product from thermo-chemical hydrolysis are commercial products and their use is not regulated by the SWRCB. This is also the case for biochar, which is excluded by 40 CFR Part 503[4]. In these cases, the California Department of Food and Agriculture (CDFA) is in charge of licensing these products as fertilizers and regulates nutrient guarantees of fertilizer materials and agricultural minerals.

The California Department of Resources Recycling and Recovery (CalRecycle) oversees and regulates California's solid waste disposal. Specific to biosolids, CalRecycle oversees disposal of biosolids with MSW (i.e., land discharge) and biosolids use as an alternative daily covering material at landfills. The main regulation dealing with land discharge of biosolids (and incineration ash) is the California Code of Regulations (CCR) Title 23, Division 3, Chapter 15. Other regulations and guidelines include Title 22, Division 4.5, Chapter 11; California Water Environment Association's (CWEA) Manual of Good Practice for Agricultural Land Application of Biosolids; and the California Environmental Quality Act (CEQA). Additionally, a summary of recently adopted legislation that will impact management and beneficial use of biosolids is provided in Table 2.4.

Traditionally, CalRecycle's role in biosolids beneficial use has been to define biosolids management practices that are considered landfill diversion for municipalities attempting to meet the 50 percent landfill diversion target set by Assembly Bill (AB) 939. Historically, both landfill alternative daily cover (ADC) and land application have qualified as landfill diversion. However, when proposed Organic Waste Reduction Regulations under Senate Bill (SB) 1383 become effective in 2022, landfill ADC will be considered disposal and no longer qualify as diversion (see Table 2.4 for a summary of SB 1383). With these new regulations in place, land application will continue to qualify as landfill diversion. Currently, incineration is not considered landfill diversion; however, the proposed regulations under SB 1383 tentatively provide an opportunity to go through a process to verify whether other biosolids treatment options (such as

[4] US EPA (2019). Biennial Review of 40 CFR Part 503 As Required Under the Clean Water Act Section 405(d)(2)(C): *Reporting Period 2016-2017.* EPA-822R18003.

incineration) qualify as diversion, depending on their greenhouse gas reducing potential relative to composting operations.

2.2.3 Local (County)

At a local level, counties across California have developed, or are developing or amending, ordinances governing biosolids land application. The stringency of these county regulations ranges from requiring high minimum insurance to banning biosolids land application (e.g., Fresno County has a ban on Class B biosolids land application).

Figure 2.1 summarizes the current status of County ordinances affecting the use (specifically, land application) of biosolids. However, the future viability of these ordinances is uncertain given the language in the proposed Organic Waste Reduction Regulations under Senate Bill (SB) 1383 (see Section 2.2.4).

To comply with current restrictions, the Biosolids Master Plan considers alternative biosolids use and/or disposal scenarios that are cost effective and can operate within the existing RWRF facilities.

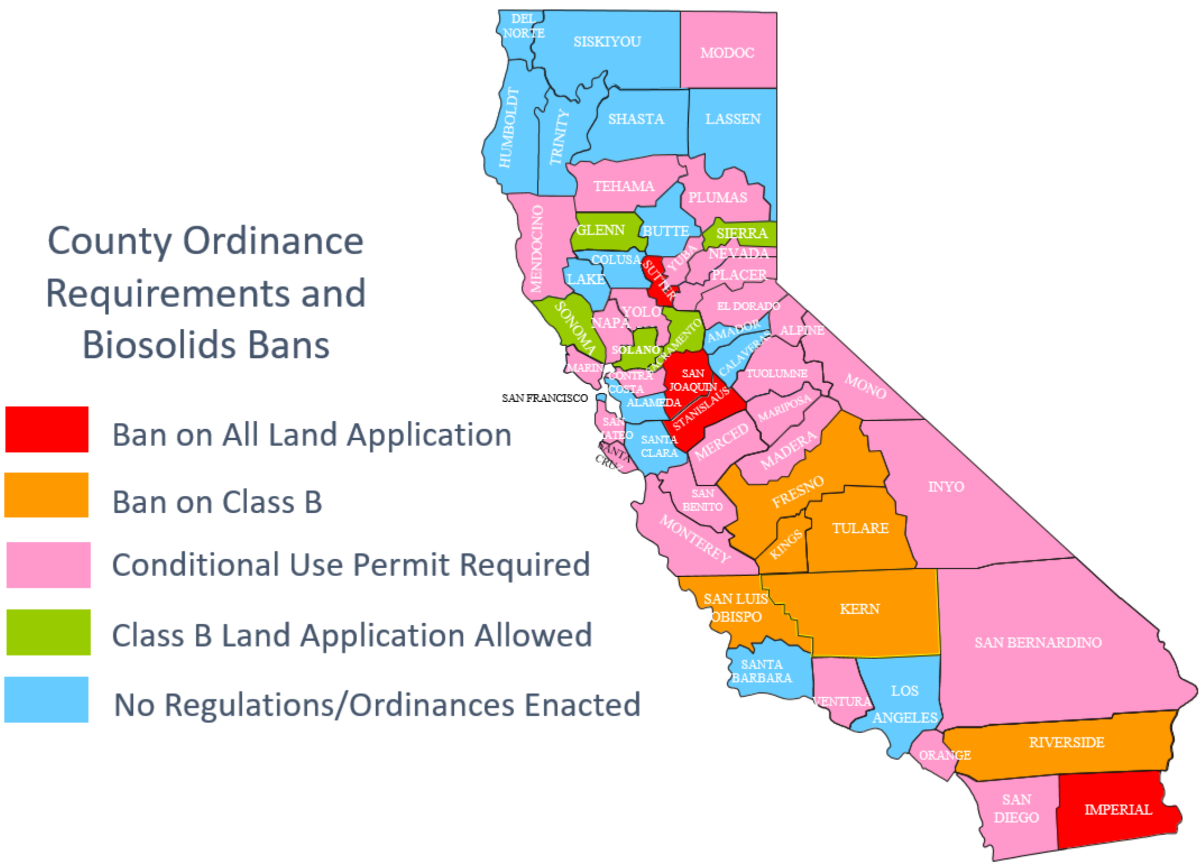

Figure 2.1 County Ordinance Requirements for Biosolids Land Application

2.2.4 Future Regulatory Considerations

This section summarizes the potential for changes to existing regulations, development of new regulations already underway, and the potential for newly introduced regulations that may impact biosolids management. Additionally, there are various California Senate Bills and Assembly Bills that have recently been adopted that will shape the future of biosolids management and use. These bills and their potential impact are described below and summarized in Table 2.4.

2.2.4.1 Biannual Reviews of 40 CFR Part 503

The Clean Water Act requires biannual review of 40 CFR Part 503. Since promulgation of the regulation in 1993, there have been no major changes or new pollutants added. However, as part of the 2009 Targeted National Sewage Sludge Survey, the EPA found nine pollutants of potential concern. These nine chemicals are barium, beryllium, manganese, silver, 4- chloroaniline, fluoranthene, pyrene, nitrate, and nitrite. Limits for these compounds could be included in Part 503 in the future. In addition, molybdenum limits could be introduced for EQ and CPLR conditions.

2.2.4.2 2019 EPA Office of Inspector General Review of Biosolids Program

In November of 2018, the EPA's Office of Inspector General (OIG) released a report on their audit of the EPA's biosolids program[5]. The goal of this audit was to assess whether EPA's biosolids land application program adequately protects human health and the environment. The OIG made 13 recommendations to improve the EPA's biosolids land application program, eight of which have been accepted by the EPA. Of the five contested recommendations, most are in regards to language used on EPA's website regarding the safety of biosolids. Resolution on the five contested recommendations was achieved in May 2019[6]. The main concern from the OIG is that chemical risk assessments have not been conducted for 352 pollutants found in biosolids and thus more research is needed to determine the safety of biosolids. In response to this, the EPA stated that *"the presence of a pollutant in biosolids alone does not equate to scientific risk, but EPA's Biosolids Program is working hard to prioritize its risk assessment work for known but not yet regulated pollutants"*[6]. As a result of the OIG audit, the EPA plans to complete a probabilistic risk assessment and screening tool for biosolids land application scenarios by the end of 2021. With this tool, the EPA will develop and implement a plan to obtain additional data needed to complete risk assessments for the 352 pollutants identified and promulgate regulations as needed. This action is planned for completion by the end of 2022.

2.2.4.3 Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)

PFOS and PFOA are manmade, fluorinated, organic chemicals that are part of a larger family of compounds referred to as perfluoroalkyl substances (PFAS). These substances are synthetic compounds that are heat, water, and lipid-resistant. Because they deter water, grease and oil, they are useful in a variety of manufacturing processes and industrial applications, ranging from

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[5] EPA OIG (2018). *EPA Unable to Assess the Impact of Hundreds of Unregulated Pollutants in Land-Applied Biosolids on Human Health and the Environment*. 19-P-0002. https://www.epa.gov/sites/production/files/2018-11/documents/_epaoig_20181115-19-p-0002.pdf

[6] US EPA (2019). *Response to November 15, 2018, Office of Inspector General's Final Report, "EPA Unable to Assess the impact of Hundreds of Unregulated Pollutants in the Land-Applied Biosolids on Human Health and the Environment".* https://www.epa.gov/sites/production/files/2019-07/documents/_epaoig_19-p-0002_agency_response.pdf

flame retardants to stain-resistant carpets to Teflon® pans. Due to wide use of these products, PFOS and PFOA have been detected in the soil, air, water, household dust, etc. In fact, in several studies, the mean and median concentration of PFOA in American households was found to be between 10,000 and 50,000 parts per trillion (ppt), respectively. Elevated exposure to PFAS compounds (primarily by way of ingestion of drinking water) have been associated with developmental effects during pregnancy such as low infant birth weights and skeletal variations, effects on the immune system such as changes in antibody production and immunity, liver effects including tissue damage, cancer, and thyroid hormone disruption[7].

PFAS compounds are not used in the wastewater treatment process; however, because they are widely used in commercial and residential applications, they end up in wastewater, and, in turn, wastewater solids. The largest source of PFAS compounds at WWTPs is from industrial dischargers. Thus, source control of industrial facilities using significant volumes of PFAS compounds is important because WWTP solids treatment process do not destroy PFAS compounds.

PFOA and PFOS levels in biosolids are typically well below standards for dermal contact and ingestion, so the exposure pathway of concern for PFAS compounds in biosolids is not handling or accidental ingestion[8]. Instead, exposure pathway of greatest interest is through contamination of drinking water if land applied products (such as biosolids, paper mill sludge, or other residuals) leach PFAS compounds into the ground- and surface waters.

On a national level, the EPA has set a health advisory (HA) for PFOA and PFOS in drinking water at 70 ppt and is currently evaluating the need for maximum contaminant levels (MCL). A health advisory limit provides information on contaminants that can cause human health effects and are set to offer a margin of protection for all humans (including the most vulnerable populations) throughout their life. The HA limits are non-regulatory and non-enforceable. In August of 2019, California's State Water Resources Control Board (SWRCB) lowered the notification levels for PFOA and PFOS to 5.1 ppt and 6.5 ppt respectively[9]. Notification level exceedance requires consumer and local government notification; however only at HA levels (response level) does the CA Division of Drinking Water recommend the drinking water source be taken out of service[9].

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[7] US EPA (2019). *EPA's Per- and Polyfluoroalkyl Substances (PFAS) Action Plan*. EPA-823R18004. https://www.epa.gov/sites/production/files/2019-02/documents/pfas_action_plan_021319_508compliant_1.pdf

[8] NEBRA (2019). *Interim Best Practices – PFAS and Biosolids / Residuals*. https://static1.squarespace.com/static/54806478e4b0dc44e1698e88/t/5c38a1cf4fa51a28ba9e2555/1547215312689/PFAS%26Biosolids-InterimBestPractices-10Jan2019-V1.2.pdf

[9] CA SWRCB (2019). *Drinking Water Notification Levels and Response Levels: An Overview.* https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notification_levels_response_levels_overview.pdf

Table 2.4 Recently Adopted Legislation Impacting Biosolids Management Operations and/or Use

Legislative Bill	Summary	Impact to RWRF	Status
AB 876 (2015)	Requires entity to track and annually report the amount of organic waste in cubic yards it will generate over the next 15 years, the additional organic waste recycling facility capacity that will be needed to process that waste, and identify new or expanded organic waste recycling facilities (such as WRF anaerobic digesters) capable of reliably meeting that additional need.	RWRF may be identified as a recycling facility for accepting additional organic waste.	First report was due: August 2017
AB 1826 (2014)	As of April 1, 2016, requires a business (commercial or public entity) or residential dwelling of five (5) or more units, generating a certain amount (starts at eight [8] CY and over time decreases to two [2] CY) of organic waste per week to arrange for recycling services. This bill requires phased implementation for the reduction of organic waste production and creates market certainty for the diversion of organic waste from businesses and multifamily dwellings to a recycling service (e.g., anaerobic digesters at WRFs).	May experience entities that produce organic waste seeking to send their organic waste to the RWRF.	Phased Implementation 2016 - 2020
SB 1383 (2016)	Requires the reduction of short-lived climate pollutants (including methane) to achieve *statewide* GHG reduction targets by 2030. Requires a regulation be developed and adopted by end of 2018, to accomplish 50 percent diversion of organics (including WRF solids and biosolids) from landfills by 2020 relative to 2014 levels and 75 percent diversion by 2025. May require WRFs to identify new options for biosolids management where land application and ADC is not an option.	May see increased competition for land application and composting as other agencies' biosolids are diverted from landfills.	Final regulation: January 2020 50% statewide diversion: 2020 75% statewide diversion: 2025
AB 1594 (2014)	States green waste will no longer qualify for diversion credit when used as ADC at a landfill. Green waste that is mixed with biosolids for use as ADC currently receives diversion credit under AB 939, but will no longer be able to do so for the green waste portion beginning in 2020. As a result, it is expected that landfills will not accept biosolids (if not mixed with green waste) for ADC since they need the combination to achieve a workable moisture content.	With green waste no longer receiving diversion credit for use as ADC, may limit the amount of biosolids used as ADC.	Effective: 2020
AB 341 (2011)	Sets a goal that 75 percent of solid waste generated (including organics) be source reduced, recycled, or composted by the year 2020. Provides a platform for state agencies to consider WRFs as part of the solution to achieve this goal.	May see increased competition for land application and composting as other agencies' biosolids are diverted from landfills.	Deadline: 2020
SB 970 (2016)	Requires CalRecycle, when awarding a grant for organics composting or anaerobic digestion, to consider the amount of GHG emissions reductions that may result from the project and the amount of organic material that is diverted from landfills as a result of the project. This bill allows for larger grant awards to be given to large-scale regional integrated projects that provide cost-effective organic waste diversion and maximize environmental benefits.	More funding may be available for regional projects that provide cost-effective organic waste diversion that maximize environmental benefits.	Determined Per Project
AB 901 (2015)	Changes disposal and recycling reporting to CalRecycle. Waste, recycling (including WRFs), and compost facilities, as well as exporters, brokers, and transporters of recyclables or compost will be required to submit information directly to CalRecycle on the types, quantities, and destinations of materials that are disposed of, sold, or transferred inside or outside of the state. CalRecycle is given enforcement authority to collect this information.	The RWRF will be required to report the types, quantities, and destinations of their biosolids to CalRecycle starting in Q3 of 2019. The regulation will outline how to comply with the reporting requirement.	Regulation Adoption: Spring 2019 First Reports: Q3 2019
Healthy Soils Initiative (2015)	Collaboration of state agencies and departments, led by CDFA, to promote the development of healthy soils on California's farm and ranchlands (e.g., through land application of biosolids) building adequate soil organic matter that can increase carbon sequestration and reduce overall GHG emissions.	The RWRF may see additional incentive for land application of biosolids through the Healthy Soils Initiative.	Developing Key Actions

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The science surrounding PFAS compounds is in its infancy and EPA is still investigating the need for MCLs. However, some states have set lower, enforceable MCLs in drinking water; the lowest limit is in New Hampshire where the limit for PFOA and PFOS in drinking water is 12 and 25 ppt, respectively[10]. While these limits have been established, municipalities and the farming community have pushed back, filing a lawsuit against the New Hampshire Department of Environmental Services, noting that the established standards failed to provide adequate scientific justification for such low MCLs and groundwater standards.

To date, most biosolids land application sites where groundwater monitoring is conducted have not found levels of PFOA and PFOS above 70 ppt; however, there have been a few cases (e.g. in Alabama[11] and Michigan[12]) where biosolids land application resulted in PFAS levels above the EPA drinking water HA in the groundwater tested. These cases were the result of high levels of PFAS discharged to WWTPs by a PFAS-using industry. In March of 2019, in reaction to public outcry of a farm that received paper mill sludge and biosolids, Maine initiated a testing requirement for all land applied biosolids. While this farm did receive biosolids, after further investigation, the source of the PFOS contamination (biosolids or other residuals) was inconclusive. As a precautionary measure, Maine established a limit for PFOA and PFOS in beneficially used biosolids. These limits are 2.5 ppb and 5.2 ppb, respectively[13]. Notably, these levels are lower than the concentration levels detected in most biosolids products tested to date[8]. Maine's Department of Environmental Protection (DEP) states materials will have to meet the screening limits for PFOA and PFOS or additional loading rate calculations and determinations of acceptable risk will need to be demonstrated by the biosolids generator.

The EPA released Method 8327 for testing PFAS in non-potable waters, including wastewater, in June of 2019[14]. The EPA's Action Plan also noted that the EPA is in the early scoping stages of a

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[10] Vermont Department of Health (2016). *Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid (PFOS) Vermont Drinking Water Health Advisory*. https://anrweb.vt.gov/PubDocs/DEC/PFOA/PFOA%20-%20PFOS%20Health%20Advisories/Vermont/PFOA_PFOS_HealthAdvisory_June_22_2016.pdf

[11] US EPA (2009). *Results of the Analyses of Surface Soil Samples from Near Decatur, Alabama for Fluorinated Organic Compounds.* https://archive.epa.gov/pesticides/region4/water/documents/web/pdf/final_report_results_7_13_09.pdf

Andrew B. Lindstrom, Mark J. Strynar, Amy D. Delinsky, Shoji F. Nakayama, Larry McMillan, E. Laurence Libelo, Michael Neill, and Lee Thomas (2011). *Application of WWTP Biosolids and Resulting Perfluorinated Compound Contamination of Surface and Well Water in Decatur, Alabama, USA.* Environmental Science & Technology 2011 45 (19), 8015-8021, DOI: 10.1021/es1039425

[12] AECOM (2018). *Evaluation of Lapeer WWTP Biosolids Site 08n10e33-CL01.* Prepared for the Michigan Department of Environmental Quality. https://www.michigan.gov/documents/pfasresponse/Evaluation_of_Lapeer_WWTP_Biosolids_Site_08n10e33-CL01_655039_7.pdf

[13] Maine Department of Environmental Protection (2019). *Requirement to analyze for PFAS compounds*. Memorandum to licensed facilities that land apply, compost, or process sludge in Maine. https://pierceatwoodwhatsup.com/31/632/uploads/2019-03-22-memo-from-dep-to-licensed-facilities-re-pfas-(w7187464x7ac2e).PDF

[14] US EPA (2019). *Method 8327 Per-and Polyfluoroalkyl Substances (PFAS) Using External Standard Calibration and Multiple Reaction Monitoring (MRM) Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS).* https://www.epa.gov/sites/production/files/2019-06/documents/proposed_method_8327_procedure.pdf

risk assessment for PFAS in biosolids. It is expected that California's SWRCB will require testing of groundwater at sites amended with biosolids in the near future[15].

2.2.4.4 Land Application

As previously noted, regulation governing treatment of biosolids products is primarily the role of EPA (via 40 CFR 503) and the SWRCB (via the General Order). However, in California, local regulations (generally at the county level) have significantly squandered beneficial use of biosolids (particularly land application of Class B and non-compost products). For example, Fresno County, as well as the adjacent Kings County and Tulare County, have banned Class B biosolids land application.

However, recent legislation and litigation may modify local limitations.

- In 2012, California adopted AB 845 stating that counties cannot pass ordinances banning importation of biosolids or any other solid waste based on its origin.
- Measure E in Kern County (banning importation and land application of Class B biosolids) was overturned in 2017 and a settlement was reached in 2018. Development of an environmental impact report is underway to determine the minimum treatment level required for biosolids products to be land applied in Kern County.
- In the summer of 2018, Measure X in Imperial County was overturned. This measure, like Measure E, sought to ban the importation of biosolids from other counties.
- The rulings to overturn Measures E and X are consistent with state regulations under development (specifically, SB 1383 anticipated to be adopted by January 2020) to disallow prohibitive or restrictive local ordinances and are leading to other county ordinances being reviewed.

As a result of these important changes in biosolids regulations and ordinances, the main pressure on biosolids land application may no longer be the prevalence of local restrictions. For the City of Fresno, which is located in a predominantly agricultural area, elimination of local ordinances will have the potential to open up additional beneficial use opportunities, assuming the biosolids product produced will be preferred by the local markets.

2.2.4.5 Landfill Alternative Daily Cover

The following adopted and developing legislation is changing the future viability of biosolids used as ADC:

- In 2014, AB 1594 was adopted and requires that green waste no longer qualify for diversion credit when used as ADC at a landfill. This bill may *indirectly* affect an agency's biosolids use/disposal program when it is fully implemented on January 1, 2020. Agencies that mix green waste with biosolids for use as ADC at landfills currently receive diversion credit under AB 939, but will no longer be able to do so for the green waste portion. It is expected that landfills will not accept biosolids (if not mixed with green waste) for ADC since they need the mixture for achieving a workable moisture content.
- In 2016, SB 1383 was adopted and requires the reduction of short-lived climate pollutants (specifically, methane) to achieve statewide greenhouse gas (GHG) emission reduction targets for 2030. Since landfills represent ~20 percent of the state's total

[15] NEBRA (2019). *A PFAS and Biosolids/Residuals Update*. https://www.nebiosolids.org/pfas-a-crisis-point-update

methane emissions (a potent GHG) as a result of anaerobic degradation of organics, regulations are being developed requiring 75 percent diversion of organic waste sent to landfills by 2025. The definition of organic waste includes sludges, biosolids, and digestate, and ADC of biosolids will be considered disposal once the regulation becomes effective. These regulations are expected to be adopted by January 18, 2020, become effective in 2022, and enforceable in 2024. CalRecycle, the State Water Board, and the California Air Resources Board (CARB) see co-digestion of food waste and fats, oils, and grease with sewage sludge at municipal WRFs as a key strategy for achieving reductions in methane emissions across the state more cost-effectively.

CalRecycle is expected to incorporate language in the regulations being developed under SB 1383 specific to biosolids to help develop alternative routes (such as more extensive land application) for biosolids end-uses. Termination of landfill ADC will place capacity and price pressure on existing biosolids markets, such as compost and land application, increasing competition among utilities for available biosolids outlets. Fresno would retain flexibility in addressing forthcoming regulations and responding to market drivers if they pursue projects that allow them to maintain control of the biosolids handling process and product end-use.

2.2.4.6 End Use/Disposal Reporting Requirements

The state is also encouraging an increase in tracking and reporting of organic waste disposal (including sludge, biosolids, and digestate) and recycling (reduction in organic waste disposal and production). Legislation pertaining to reporting includes the following:

- AB 1826 requires businesses and residential dwellings (of 5 units or more) generating 8 cubic yards (CY) or more of organic waste per week to arrange for recycling services. This phased implementation bill decreases the 8 CY diversion cap in 2016 to 2 CY through 2020. This bill will reduce organic waste production and create market certainty for the diversion of organic waste from businesses and multifamily dwellings to a recycling service, such as municipal WRF anaerobic digesters.
- AB 876 requires a county or regional agency to track and annually report the amount of organic waste it will generate over a 15-year period, the additional organic waste recycling facility capacity that will be needed to process that organic waste, and identify new or expanded organic waste recycling facilities (such as municipal WRF anaerobic digesters) capable of safely meeting that additional need. The first annual reports required by this legislation were due in August 2017.

The final regulation developed under AB 901 was formally adopted March 5, 2019. The legislation and regulation changes how disposal and recycling is reported to CalRecycle. Waste, recycling, and compost facilities, as well as exporters, brokers, and transporters of recyclables or compost will be required to submit information directly to CalRecycle on the types, quantities, and destinations (i.e., county) of materials that are disposed of, sold, or transferred inside or outside of the state. CalRecycle also gains enforcement authority to collect this information. Facilities producing biosolids and transporting them offsite were expected to report and register in the Recycling and Disposal Reporting System (RDRS) by May 31, 2019. Recordkeeping began the third quarter of 2019 (July 1 – September 30), with the first reporting due no later than December 31, 2019.

2.2.5 Other Considerations: Regional Facilities

When planning for future biosolids management and diversification, it is important to consider potential regional options. Two regional options are described below: the Bay Area Biosolids Coalition (Coalition) as well as the potential regional Organic Material Recovery Center (OMRC) to be located at the Selma–Kingsburg-Fowler County Sanitation District's (SKFCSD) WRF in Kingsburg, CA.

2.2.5.1 Bay Area Biosolids Coalition

The Coalition is comprised of 17 Bay Area agencies and was formed to create a local sustainable solution compliant with SB 1383 and to diversify biosolids management options with the development of a regional facility or facilities. While the Coalition's focus is on the Bay Area, the work they are doing to examine biosolids management options and biosolids product marketability is applicable throughout California.

Most of the participating agencies presently use a combination of transporting Class B biosolids for direct land application, composting, and/or ADC at landfills and would like to see these beneficial uses preserved. However, upcoming regulations (Section 2.2.4) may reduce the availability of these options within the next 5 to 10 years. Understanding the need to adapt biosolids management programs, the BABC has identified the need for identifying additional long term sustainable beneficial use alternatives.

The Coalition is examining regional opportunities to diversify biosolids management options and make use of renewable byproducts. The Coalition is developing options that provide beneficial use of biosolids generated by Coalition member agencies that are currently sent to landfills (roughly 60,000 dry tons per year (TPY) of biosolids). These options include regional wet weather storage, composting, dryer, and thermal hydrolysis facilities. In addition, the Coalition continues to track other emerging technology solutions. Such tracking of emerging technologies and development of near-term regional biosolids solutions would keep the City in the loop on the state of biosolids innovation and end use. Over the Coalition's recent history, there have been six projects that have either been considered for hosting a demonstration facility or have been developed to various levels. These projects and their status are described below:

- Delta Diablo:
  - In partnership with Mt. Diablo Resource Recovery (MDRR), Delta Diablo evaluated Anaergia's OREX and pyrolysis technology to determine sizing, phasing, and needed support infrastructure to convert a portion of their post-anaerobically digested biosolids and imported food waste into electricity, a high-nutrient biochar soil amendment, and an ammonium sulfate fertilizer product. This project has since been pared down to consideration of Anaergia's OREX at MDRR and co-digestion at Delta Diablo to maximize production of biogas to supply enough energy to Delta Diablo to become a net energy producer and continue producing Class B biosolids for land application. This project is currently in 30 percent design.
  - Also in partnership with MDRR, Delta Diablo evaluated Aries Clean Energy's down-draft gasification technology to determine project size, phasing, optimal feedstock ratios, and needed support infrastructure to convert green waste from MDRR and Delta Diablo biosolids into electricity and biochar. This project is no longer being pursued in partnership, rather MDRR is carrying forward the project to process its wood waste.

- Dublin San Ramon Services District: In partnership with Synagro and SCFI Group evaluated the SCFI AquaCritox® technology to determine project viability. The technology is aiming to break down the volatile solids in biosolids using super critical water oxidation to result in water and a small fraction of inert material. The heat generated can be used to power the process by producing steam and hot water to heat their anaerobic digesters and offset the use of fossil-fuel based energy and the associated greenhouse gas emissions. Since SCFI was unable to meet the terms of its contract with Synagro, the project was discontinued in 2018.
- West County Wastewater District: In partnership with Synagro and SCFI Group, also evaluated the SCFI AquaCritox® technology to determine project viability and needed support infrastructure to treat WAS, in lieu of treating it in anaerobic digestion. This project was aiming to free up 40 percent of the digester capacity for alternative bio-sources/organic waste. Since SCFI was unable to meet the terms of its contract with Synagro, the project was discontinued in 2018.
- Silicon Valley Clean Water: In partnership with BioForceTech (BFT) Corporation, has installed a BioDryer™ process followed by a pyrolysis unit that processes approximately half of the biosolids generated at Silicon Valley Clean Water. The byproducts of the process are syngas and biochar, both of which may have a high beneficial use value. The facility has been in operation since June 2017 and staff are working to obtain the permit to operate from the Bay Area Air Quality Management District.
- Fairfield-Suisun Sewer District: In partnership with Lystek International, Ltd., has constructed a full-scale merchant project with a capacity to process 150,000 wet tons of biosolids (at 15 to 17 percent solids) per year. The facility aims to optimize the operation of the anaerobic digesters, produce a federally registered biofertilizer, enhance biogas production, and process organic waste streams. The facility began operation in August 2016, is at 40 percent capacity, and the LysteGro product has been licensed as a bulk fertilizer by the California Department of Food and Agriculture (CDFA), as well as in Solano County. This regional biosolids management facility receives third-party material from numerous communities surrounding the San Francisco Bay area.

2.2.5.2 Organic Material Recovery Center at Selma–Kingsburg-Fowler County Sanitation District's WRF

In addition to the Coalition projects (listed above), the nearby Selma–Kingsburg-Fowler County Sanitation District (SKFCSD) is exploring the installation of a regional Organic Material Recovery Center (OMRC) in Kingsburg, CA, similar to the installation in Fairfield-Suisun Sewer District (FSSD). SKFCSD wants to improve their biosolids management practices and transition towards a resource recovery facility, as well as offer a regional management solution for neighboring utilities to obtain recycling credits, recover resources, and produce a value-added product for the local agricultural market. A regional facility at SKFCSD would provide the City with a biosolids end use option that is 35 miles closer than the current biosolids end use through Synagro (CVC Compost Facility).

SKFCSD is considering partnering with Lystek International Ltd. to leverage their proven thermo-chemical hydrolysis technology that is capable of processing digested (biosolids) and undigested solids and organic waste feedstock materials. The process produces a Class A biosolids fertilizer product that has received state registration as a bulk fertilizer from the CDFA.

SKFCSD produces less than 10,000 tons of biosolids annually. The viability of a regional facility at SKFCSD may depend on the City's willingness to participate, by contributing at least a portion of their roughly 100,000 tons of biosolids produced annually.

Such a regional facility may provide diversification for the RWRF's solids, which is increasingly important as the regulatory environment shifts towards resource recovery.

2.3 Air Quality Regulations

The federal Clean Air Act (CAA) creates a comprehensive national framework designed to protect ambient air quality by limiting air emissions for both stationary and mobile sources. While the CAA deals primarily with "conventional" air pollutants, it also addresses emissions of 188 toxic materials defined as "hazardous air pollutants".

The CAA requires EPA to set national ambient air quality standards to protect human health and welfare. Agencies at the federal, state, and local levels have jurisdiction over air pollution and odor control at WRFs. At the federal level, the major agencies are EPA and the Occupational Safety and Health Administration (OSHA). At the state level, the California Air Resources Board (CARB) is the applicable agency. In addition, Cal-OSHA requirements for indoor air quality may apply. At the local level, it is the San Joaquin Valley Air Pollution Control District (SJVAPCD). These agencies establish ambient air quality criteria and levels of treatment necessary to protect the public health and environment both on-site and off-site of a potential source.

At the RWRF, stationary sources of air contaminants are predominantly derived from diesel engines (three emergency and two transportable), digester gas flares, and boilers. Permits identify these stationary sources and a number of other RWRF sources. Other sources of air contaminants are derived from wastewater treatment processes and associated fugitive emissions.

The majority of federal, state, and local air quality requirements are currently enforced through the RWRF's Title V operating permit. Air regulations are fairly dynamic and need to be monitored with the renewal of each permit (i.e., every five years for the Title V operating permit). The SJVAPCD also has a permit program and issues a new Permit-to-Operate (PTO) every five years. Changes in the PTO are usually rolled into the Title V permit. Therefore, the RWRF needs to comply with both the local 5-year PTO renewal and the federal 5-year Title V permit renewal.

The following sections provide summaries of the federal, state and local air quality standards applicable to RWRF operations.

2.3.1 Federal

The RWRF is subject to EPA's federally enforceable operating permit program, also known as Title V Permit Program, because it contains units that are determined to be a major source of criteria and hazardous air pollutant emissions. The initial Title V permit was issued in January 2011, and the first 5-year renewal permit was issued in 2016, with the second renewal anticipated by 2021 (submission of renewal application due by July 31, 2020).

Title V operating permits differ from Air District issued operating permits in that they explicitly include the requirements of all regulations that apply to RWRF operations. The important features of Title V operating permits include the following:

- All federally enforceable requirements that apply to RWRF operations.
- Public notice of proposed permits.
- Authority given to EPA to terminate, modify or revoke and re-issue a permit if cause exists.
- Federally enforceable and may be enforced via citizen lawsuits.
- Renewal every five years with the full public notice and EPA review process.
- Modification procedures dictated by EPA regulations.
- Since the RWRF has decommissioned the turbines, it is necessary to inform EPA and undergo the process to renew the Title V permit to determine if the RWRF will remain in the Title V program.

2.3.2 State

The RWRF currently operates three stationary diesel engines that range in size from 140 to 2518 horsepower. Any new or replacement engines would need to comply with the Airborne Toxic Control Measure (ATCM) for Stationary Compression-Ignition (CI) Engines. CARB originally approved the ATCM in 2004. Subsequent to the adoption of the original ATCM in 2004, the EPA promulgated new federal "Standards of Performance for Stationary Compression-Ignition Internal Combustion Engines" (NSPS). In October 2010, CARB approved amendments to the ATCM to closely align California's requirements with those in the federal NSPS. The amended ATCM became effective May 19, 2011.

The ATCM requires a 0.15 gram per brake horsepower-hour (g/bhp-hr) particulate matter (PM) emission limit for all new emergency standby stationary compression ignition engines greater than or equal to 50 hp. Annual maintenance and testing hours are limited to no more than 50 hours per calendar year. Local air districts may impose more limited hours. New emergency standby engines are required to meet the applicable non-methane hydrocarbon plus nitrogen oxides (NMHC+NOx), hydrocarbon (HC), and carbon monoxide (CO) Tier 2 or Tier 3 non-road CI engine emission standards, and Tier 4 standards that do not require add-on controls. Table 2.5 shows emission limits for engine sizes comparable to those currently in use at the RWRF.

The RWRF also operates two portable diesel engines that are 74 and 125 horsepower. These engines need to comply with the ATCM for Portable CI Engines. CARB originally approved the ATCM in 2004. An amended ATCM became effective February 19, 2011. The ATCM for Portable CI Engines requires progressively more stringent PM requirements for portable CI engine fleets. These PM requirements are shown on Table 2.6.

Table 2.5 Emission Standards for New Stationary Emergency Standby Diesel-Fueled CI Engines

Maximum Engine Power	Particulate Matter g/bhp-hr (g/kW-hr)	Non-Methane Hydrocarbon plus Nitrogen Oxides g/bhp-hr (g/kW-hr)	Carbon Monoxide g/bhp-hr (g/kW-hr)
100 ≤ HP < 175 (75 ≤ kW < 130)	0.15 (0.20)	3.0 (4.0)	3.7 (5.0)
175 ≤ HP < 750 (130 ≤ kW < 560)	0.15 (0.20)	3.0 (4.0)	2.6 (3.5)
HP > 750 (kW > 560)	0.15 (0.20)	4.8 (6.4)	2.6 (3.5)

Note:
(1) May be subject to additional emission limitations as specified in current applicable rules, regulations, or policies.

Table 2.6 Emission Standards for Portable Diesel-Fueled CI Engines

Fleet Standard Compliance Date	Engines < 175 HP (g/bhp-hr)	Engines < 175 HP (g/bhp-hr)	Engines < 175 HP (g/bhp-hr)
1/1/13	0.3	0.15	0.25
1/1/17	0.18	0.08	0.08
1/1/20	0.04	0.02	0.02

2.3.3 Local Air District

The RWRF is also subject to local SJVAPCD regulations. The SJVAPCD activities include rule development and enforcement, monitoring of air quality, a permit system for stationary sources, air quality planning, protection of the public from adverse effects of toxic air contaminants (TACs), and responses to public requests for information regarding air quality issues.

The SJVAPCD administers rules and regulations that apply to stationary sources that emit air contaminants in the San Joaquin Valley. Generally, new and existing stationary sources are governed by requirements in the following Regulation Sections: 2 (Permits), 4 (Prohibitions), and 8 (Fugitive PM 10 Prohibition).

2.3.3.1 Current SJVAPCD Permit

The RWRF currently holds a permit to operate from the SJVAPCD. The existing permit allows operation of numerous stationary sources, including two standby diesel engines, two emergency diesel engines, one portable diesel engine, two turbine generators (decommissioned as of 2016), one digester gas treatment system, one hot water boiler, one odor control scrubbing system, and one waste gas flare. The City's SJVAPCD permits are included as Appendix 2-A.

Unit Specific SJVAPCD Regulations

This section summarizes specific SJVAPCD regulations (as shown in the attached permits in Appendix 2-A) for units the City currently operates or are included in the current permits:

- Stationary Diesel Engines:
  - Sulfur dioxide (SO_2) emissions must be below 2000 ppmv.
  - Particulate Matter (PM) emissions must be below 0.1 grains/dscf.

  - Nitrogen Oxide (NO_x) emissions as follows:
    - 140 HP unit: 6.0 g/hp-hr.
    - 455 HP unit: 5.61 g/hp-hr.
- Portable Diesel Engines:
  - NOx emissions shall not exceed 4.10 g/bhp-hr.
  - Carbon Monoxide (CO) emissions shall not exceed 0.75 g/bhp-hr.
  - VOC emissions shall not exceed 0.30 g/bhp-hr.
  - PM 10 emissions shall not exceed 0.19 g/bhp-hr.
- Turbine Generators (decommissioned in 2016)
  - NOx emissions shall not exceed 0.95 lb/hr. Excludes start-up and shutdown.
  - SOx emissions shall not exceed 2.07 lb/hr. Excludes start-up and shutdown.
  - PM 10 emissions shall not exceed 1.34 lb/hr. Excludes start-up and shutdown.
  - CO emissions shall not exceed 27.95 lb/hr. Excludes start-up and shutdown.
  - VOC emissions shall not exceed 0.02 lb/hr. Excludes start-up and shutdown.
  - Additional daily and yearly limits including start-up and shutdown are shown on the attached permit.
- Digester Gas Treatment System:
  - PM emissions must be below 0.1 grains/dscf.
  - Hydrogen sulfide (H_2S) emissions must be below 200 ppmv.
  - NOx emissions shall not exceed 0.06 lb/MMBtu.
  - CO emissions shall not exceed 0.20 lb/MMBtu.
  - VOC emissions shall not exceed 0.084 lb/MMBtu.
  - PM 10 emissions shall not exceed 0.016 lb/MMBtu.
- Boilers:
  - NOx emissions shall not exceed 0.011 lb/MMBtu.
  - SOx emissions shall not exceed 0.026 lb/MMBtu.
  - CO emissions shall not exceed 0.061 lb/MMBtu.
  - VOC emissions shall not exceed 0.004 lb/MMBtu.
  - PM 10 emissions shall not exceed 0.0048 lb/MMBtu.
- Odor Control Scrubbing System:
  - VOC emissions shall not exceed 0.075 lb/MGD.
- Waste Gas Flare:
  - NOx emissions shall not exceed 2.2 lb/hr.
  - SOx emissions shall not exceed 1.8 lb/hr.
  - PM 10 emissions shall not exceed 0.18 lb/hr.
  - CO emissions shall not exceed 10.5 lb/hr.
  - VOC emissions shall not exceed 0.0027 lb/MMBtu.
  - The total volume of flared gas cannot exceed 1,584,000 scf per day.

2.3.3.2 Requirements for New and Modified Sources

Rule 2201 implements Federal New Source Review (NSR) requirements and Rule 2410 implements Prevention of Significant Deterioration (PSD) requirements. SJVAPCD plans to update the NSR regulations to satisfy requirements related to the air district's reclassification from Moderate to Serious nonattainment for PM 2.5.

The District Governing Board adopted the 2018 PM2.5 Plan on November 15, 2018, and forwarded the Plan to CARB. In turn, the CARB Board considered the Plan on January 24, 2019, adopted it, and has forwarded it to the U.S. EPA as a revision to the California State Implementation Plan (SIP). The 2018 PM2.5 Plan sets forth a comprehensive strategy to meet four National Ambient Air Quality Standards (NAAQS) for fine particulate matter (PM2.5) for which the San Joaquin Valley is in nonattainment: the 1997 24-hour standard of 65 micrograms per cubic meter (µg/m3), the 1997 annual standard of 15 µg/m3, the 2006 24-hour standard of 35 µg/m3, and the 2012 annual standard of 12 µg/m3. Attainment deadlines for the 1997, 2006, and 2012 PM2.5 standards are 2020, 2024, and 2025, respectively.

The SJVAPCD strategy to reduce emissions from stationary and area sources includes commitments to strengthen existing rules and to provide incentive funding to accelerate emissions reductions. New reductions of direct PM2.5 will come from tightened controls on residential wood-burning fireplaces and heaters and enhanced incentives to install control technology on commercial underfired charbroilers. Additionally, the District is pursuing strengthening a suite of measures to reduce emissions of NOx from flares, internal combustion engines, and boilers, among other sources. The Valley State SIP Strategy also builds on existing mobile source controls described in CARB's earlier 2016 State Strategy for the State Implementation Plan (2016 State SIP Strategy) and includes new measures, both regulatory and incentive, to reduce emissions of NOx and directly emitted PM2.5. Regulatory measures achieving new emissions reductions include lower opacity limits and amended warranty requirements for heavy-duty vehicles, a heavy-duty vehicle inspection and maintenance program, a California low-NOx engine standard, and a low emission diesel fuel requirement. Incentive measures achieving new emissions reductions include accelerated turnover of trucks, buses, agricultural equipment, and off-road equipment.

This permitting process governs the construction, replacement, operation, or alteration of any source that emits or may emit contaminants. The process involves an Authority to Construct, followed by a Permit to Operate. Any new or modified source is required to comply with new source review requirements, including application of Best Available Control Technology (BACT), and emission offsets.

BACT is the level of emission control or reduction for new and modified sources of emissions that have the potential to emit any pollutant for which an ambient air quality standard has been established by EPA or by CARB. BACT is intended to reduce emissions to the maximum extent possible considering technological and economic feasibility. The SJVAPCD maintains a BACT clearinghouse, and the California Air Pollution Control Officers Association (CAPCOA) also maintains a clearinghouse for statewide BACT determinations. CARB is in the process of developing a state-wide clearinghouse per requirements under AB 617 (see Section 2.3.5.1).

Emission Offsets, or Emission Reduction Credits (ERCs), are generated by reducing emissions beyond what is required by regulation, or by curtailing or shutting down a source. ERCs may be used to provide offsets for emission increases from a new or modified source, as required by NSR. The ERCs may be banked and the banking certificates may be traded or sold to another facility for use as offsets for that facility. These credits can be very valuable and consideration should be given to retaining them for future projects, as needed.

2.3.4 Greenhouse Gas Emissions

2.3.4.1 State and Federal Mandatory Reporting Programs

CARB adopted the Global Warming Solutions Act (also referred to as AB 32) in September 2006. This Act requires public and private agencies statewide to reduce GHG emissions to 1990 levels by year 2020. During Governor Brown's inauguration in January 2015, he declared the need for a 2030 emissions reduction target to set the state on track for achieving the 2050 goal of 80 percent below 1990 levels. As a result, Senate Bill 32 was adopted in 2016 requiring the state implement a 2030 target of reducing emissions by 40 percent below 1990 levels and developing programs to meet that target. The GHGs regulated under both AB 32 and SB 32 that are relevant to WRFs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The legislation does not target wastewater treatment process emissions specifically, but it does cover electricity generating units and onsite general stationary combustion sources.

California is reportedly on track to meet or exceed the AB 32 target of reducing GHG emissions to 1990 levels by 2020. Building on this success, Governor Brown identified key climate change strategy pillars in his January 2015 inaugural address. The pillars include (1) reducing today's petroleum use in cars and trucks by up to 50 percent; (2) increasing electricity derived from renewable sources from one-third to 50 percent; (3) doubling the energy efficiency savings achieved at existing buildings and making heating fuels cleaner; (4) reducing the release of methane, black carbon, and other short-lived climate pollutants; (5) managing farm and rangelands, forests, and wetlands so they can store carbon. In addition, Governor Brown issued an Executive Order B-55-18 in 2018 to establish statewide carbon neutrality by 2045.

Wastewater treatment plants and landfills may play an important role in implementing the pillars and Executive Order. CARB identified diverting organics from landfills to anaerobic digestion and composting as key strategies to reduce methane emissions from landfills by generating more renewable energy at wastewater treatment plants and using composted biosolids to sequester carbon and promote healthy soils.

CARB lists two thresholds against which wastewater treatment facilities must check if they are required to report. The reporting thresholds shown in Table 2.7 include emissions from both fossil fuel (i.e., natural gas and diesel) and non-fossil fuel or biogenic (i.e., biogas) sources.

Table 2.7 Greenhouse Gas Emissions Thresholds for Reporting Years 2011 and Beyond

Unit Type	Threshold
Electricity Generating Unit	≥ 10,000 mt(1) CO_2e(2) per year
General Stationary Combustion	≥ 10,000 mt(1) CO_2e(2) per year

Notes:
(1) mt: metric tons.
(2) CO_2e: carbon dioxide equivalent emissions.

In addition, EPA's Mandatory GHG Reporting Rule (Reporting Rule) was adopted October 30, 2009. The Reporting Rule explicitly states that centralized domestic wastewater treatment systems are not required to report emissions; however, any stationary combustion of fossil fuels taking place at a wastewater treatment facility may be considered a 'large' source of GHGs if they emit a total of 25,000 metric tons or more of CO_2 equivalent (CO_2e) emissions per year.

Pursuant to AB 32, GHG estimates are based on CARB's Regulation for the Mandatory Reporting of GHG Emissions (title 17, California Code of Regulations (CCR), sections 95100-95157). To align itself with EPA's GHG Reporting Rule, CARB's regulation incorporated by reference certain requirements in EPA's Final Rule on Mandatory Reporting of GHGs (Title 40, Code of Federal Regulations (CFR), Part 98). Specifically, section 95100(c) of CARB's regulation incorporated those requirements promulgated by EPA as published in the Federal Register.

Carollo has estimated and reported the RWRF's GHG emissions since 2009. Since decommissioning the turbines in 2016, the total metric tons of CO_2e per year has fallen below the reporting threshold for CARB for the years 2017 and 2018 and has not exceeded the EPA reporting threshold to date. Because the RWRF had exceeded CARB's reporting threshold in the past, it will continue to report its emissions and request cessation of reporting in accordance with the requirements (i.e., falling below the reporting threshold for three consecutive years). The RWRF GHG emissions are not expected to exceed the thresholds in the near future. Therefore, it is expected that the RWRF will be able to cease reporting GHG emissions to CARB following the 2019 reporting year.

2.3.4.2 State Cap-and-Trade Program

In addition to mandatory reporting of GHGs, CARB adopted a GHG cap-and-trade program that became effective in January 2012. This program states that agencies emitting 25,000 metric tons or more of fossil fuel-based (i.e., natural gas and diesel) CO_2e emissions per year beginning in 2011 or any subsequent year will be capped and required to pay for allowances and eventually reduce their emissions over time. As long as the RWRF maximizes its use of renewable fuels and stays below this threshold, the current regulations may only require it to report GHG emissions and will not subject it to being a "capped" (or "covered") entity. The RWRF GHG emissions are estimated to be well below 10,000 metric tons of CO_2e per year, which is far below the cap-and-trade threshold. Therefore, the RWRF is not expected to exceed the threshold in the near future.

2.3.5 Future Regulatory Considerations

There are various potential future regulations that need to be considered as part of the Biosolids Master Plan.

2.3.5.1 AB 617: Criteria Air Pollutants and Toxic Air Contaminants

Assembly Bill 617 (AB 617) was adopted in 2017 and requires CARB to lead the standardization of and statewide reporting of (via an online database available for public query) for air emissions reporting of criteria air pollutants (CAPs) and toxic air contaminants (TACs). There is already a CAP and TAC emissions reporting process in place at local air districts; however, CARB is required to change the reporting process to be uniformly implemented across the state by local air districts.

Facilities that meet the applicability criteria of the proposed "Regulations for the Reporting of Criteria Pollutants and Toxic Air Contaminants" (i.e., CTR Regulation) listed below are expected to be subject to reporting air emissions annually.

1. Emit >250 tons per year of criteria pollutants or their precursors;
2. Subject to mandatory GHG reporting under AB 32;
3. Have an elevated prioritization score for toxic air contaminants; and/or
4. Any facility having permitted criteria air pollutant emissions >4 tons per year or is part of a listed sector that meets the sector's TAC reporting thresholds. Municipal WRFs

receiving >10 MGD are considered one sector (>5 MGD if uncovered). Combustion of crude, residual, distillate, or diesel oil is another sector, which includes stationary diesel engines. The only exemption is for Tier IV engines using less than 100 gallons diesel per year or Tier III or older engines using less than 30 gallons per year.

Air emissions reporting is intended to be done through the local air district (as it is now), but all air districts will need to meet the same standards laid out in the CTR Regulation. However, if a local air district decides not to submit on an entity's behalf, the covered entity would be responsible for reporting directly to CARB. If the proposed changes to reporting are accepted, some RWRF equipment may require more detailed emissions data reporting to the local air district and/or CARB on an annual basis.

The 2019 data submittals will be unchanged by this rulemaking. Beginning in 2020 (i.e., data that is submitted in 2021), the additional sectors for TACs and other facilities pulled into the reporting program will be expected to start reporting on a phased-in schedule to be announced.

2.3.5.2 Potential Flare Rule 4311 Amendments: Nitrogen Oxides and Volatile Organic Compounds

The purpose of the upcoming anticipated amendments to Rule 4311 is to: 1) further reduce nitrogen oxide (NOx) and volatile organic compound (VOC) emissions when flaring produced gas (including digester gas, landfill gas, and other combustible gases or vapors) and 2) encourage overall reduction of or alternatives to flaring. The rule is expected to apply to owners and operators of flares that require a permit including wastewater treatment facilities, landfills, and organic liquid handling facilities.

The South Coast Air Quality Management District (SCAQMD) recently adopted a non-refinery flare rule (Rule 1118.1) with requirements that the SJVAPCD is seeking. However, as part of the adoption of that rule, the Governing Board directed staff to work with the California Air Pollution Control Officers Association (CAPCOA), California Department of Resources Recycling and Recovery (CalRecycle), California Association of Sanitation Agencies (CASA), and Southern California Alliance of Publicly Owned Treatment Works (SCAP) aiming to balance air quality requirements with the state-wide effort to divert organics from landfills as required under Senate Bill 1383. The group will report back to the Stationary Source Committee within 12 months of rule adoption (by January 2020) on findings and potential recommendations after conducting a BACT technical assessment on flares receiving biogas derived from advanced digestion and/or organic waste digestion or co-digestion. The assessment must consider costs and review the current scientific literature, existing measurement methods, technology achieved in-practice, reliability issues, and (if necessary) perform field testing. SCAQMD staff will then determine if amending the BACT Guidelines and Rule 1118.1 is necessary.

The SJVAPCD is anticipated to re-open amendments to Flare Rule 4311 in summer of 2019.

2.3.5.3 Thermal Conversion Technologies (Other than Incineration)

Thermal conversion technologies other than multiple hearth furnaces (MHFs) and fluidized bed incinerators (FBIs) may also be subject to EPA's 40 CFR 503 regulations. Regulations and emission limits for wastewater solids (or biosolids) gasification, pyrolysis, hydrothermal liquefaction, and other thermal conversion technologies have not been formerly established. EPA has suggested that application of regulatory requirements for such technologies be considered on a case-by-case basis. For example, in December 2014 EPA ruled that the MaxWest gasifier that operated in Sanford, Florida was not a sewage sludge incinerator (SSI), and thus SSI regulatory criteria did not apply. The MaxWest gasification facility at Sanford shut down in 2015 and thus information regarding the applicable regulations is not known at this time. Additionally, the EPA ruled that the BioForceTech pyrolysis unit in operation at Silicon Valley Clean Water was also not a SSI, and thus SSI regulatory criteria do not apply.

Other thermal conversion technologies are under development and are just beginning to be implemented on a demonstration and commercial scale. As these systems are put into operation, the applicable air, water, and solids regulations will develop and be better understood. Growing interest in bioenergy and biofuel in California has led multiple utilities to investigate the feasibility of such technologies and will continue to do so in order to achieve state mandates and goals aiming to decarbonize the energy and transportation sectors. Additionally, the implementation of such technologies may qualify for state or federal incentives making them even more affordable to implement. It is possible that technologies such as pyrolysis and gasification will require air pollution control technologies similar to BACT and TBACT used for incineration regardless of whether or not they are considered an SSI by EPA.

2.4 Cross-Media Impacts

The interconnection of regulations to the various areas impacted by wastewater treatment is an important consideration. Representatives from various air districts, Regional Water Boards, Caltrans, and the EPA came to an agreement to develop a cross-media checklist for use during the development of regulations. CASA had originally been coordinating the efforts to develop the checklist. The components of the cross-media checklist include: biosolids, compost processing, recycled water, AB 32 (regulating GHG emissions), the California Environmental Quality Act (CEQA), regulatory processes, development of Water Quality Control Plans (referred to as Basin Plans) and water quality standards/ regulations, and impact assessments to air, water, and solids/land media.

An example of a cross-media impact relevant to the City is the increased demand for food waste co-digestion due to the statewide organic waste diversion requirement under SB 1383 set by CalRecycle. The potential increased loading if the RWRF were to accept additional food waste results in increased biogas production leading to increased GHG, CAP, and TAC emissions if combusted onsite and increased biosolids production, which could trigger additional air quality reporting requirements to the local air district and Air Resources Board, as well as reporting requirements to CalRecycle for managing additional biosolids product.

2.5 Summary

Through the planning horizon of 2040, the RWRF will consider strategies to comply with current and developing (future) regulations. In general, the future regulations that have the greatest impact on the RWRF biosolids management planning are those requiring major process changes or additions.

Figure 2.2 summarizes the primary regulations that will affect the RWRF alternatives development. The anticipated timing of future regulatory development/adoption are shown. Actual implementation dates for future regulations are unknown.

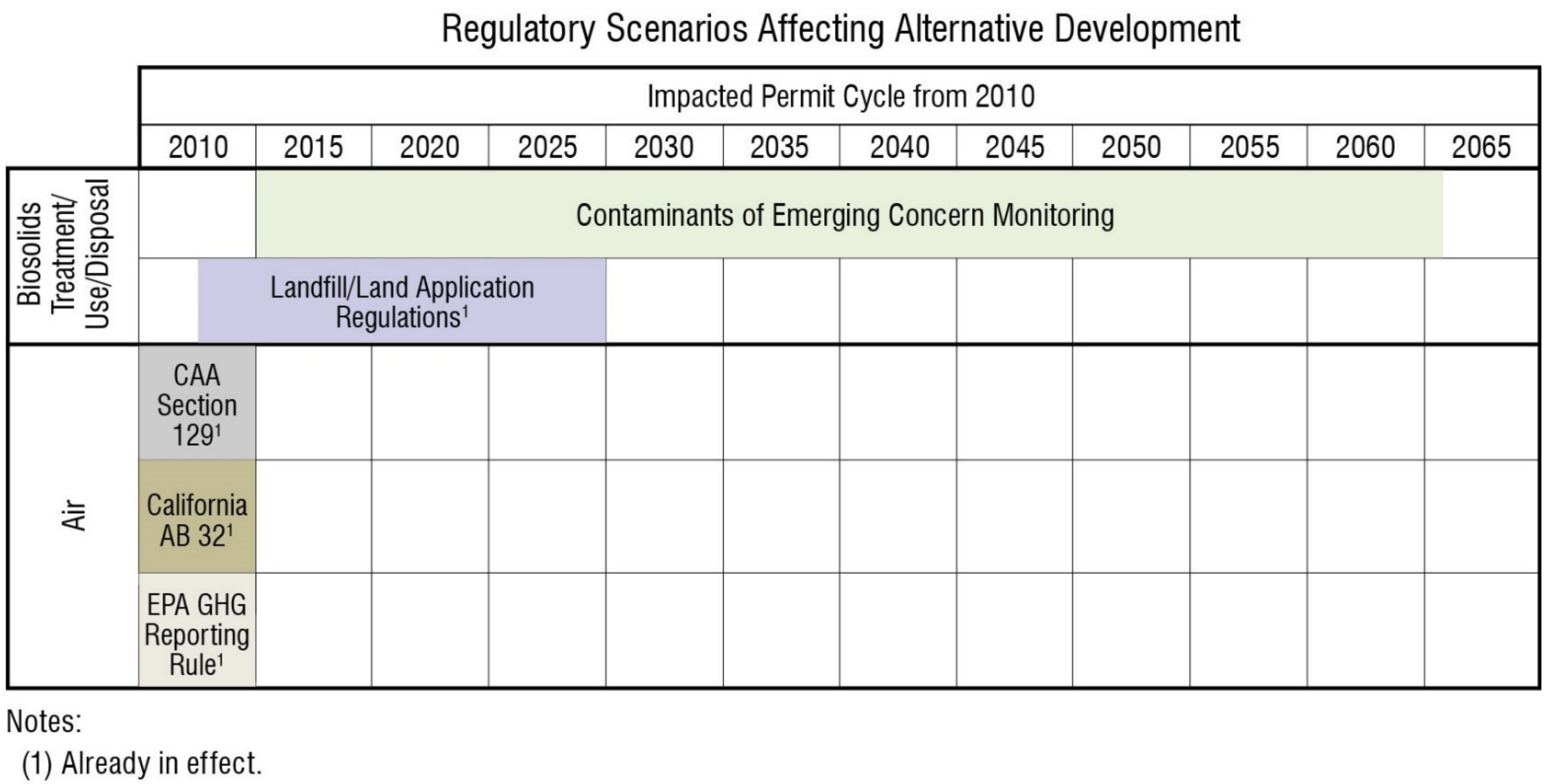

Figure 2.2 Regional Water Board Future Regulatory Scenarios

Table 2.8 summarizes solutions that can be implemented at the RWRF to comply with current and future potential regulatory issues.

Table 2.8 Summary of Potential Regulatory Issues and Solutions

Topic	Issue	Potential Solution
Biosolids	Landfilling of biosolids is becoming increasingly restricted and land application of Class B biosolids may become less restrictive (i.e., the County Ordinance banning land application may be lifted if the regulations under SB 1383 require it).	Diversify biosolids management to decrease risk and increase reliability of RWRF's biosolids management.
Air Emissions	New emissions monitoring and more restrictive emissions limits for CAPs and TACs may limit onsite biogas management options, which is closely linked to the anaerobic digestion process.	Plan for increasingly stringent emissions requirements and need for emissions control equipment for the digesters and stationary combustion units.
Greenhouse Gases (GHG)	While the RWRF is not seeking to expand its organic feedstocks it receives, WRFs are being looked at as part of the solution to managing organic waste diverted from landfills statewide (to reduce methane emissions at landfills). This may result in pressure being applied to the RWRF to accept diverted food waste, which could lead to additional GHG emissions reporting and management.	Monitor GHG emissions regulations and continue to track and weigh the costs and benefits related to accepting diverted food waste and/or contributing to other GHG related state mandates and goals.

Chapter 3

BIOSOLIDS QUALITY AND MARKET ASSESSMENT

3.1 Purpose

This report presents the findings of the Biosolids Quality and Market Assessments conducted as a part of the City of Fresno's Biosolids Master Plan (BMP) for the Fresno-Clovis Regional Wastewater Reclamation Facility (RWRF). Fresno initiated these assessments to assist in identifying appropriate alternative(s) for the management and beneficial use of the City's biosolids.

3.2 Background

The City of Fresno (City) initiated the evaluation to understand the demand for various types of biosolids products in California.

The RWRF serves the City, a portion of Clovis, and surrounding areas, and treats current average daily flows of 57 million gallons per day (mgd). The RWRF employs anaerobic digestion for solids stabilization and produces Class B biosolids. Five (5) belt filter presses and three (3) centrifuges are used for dewatering, achieving an average of 17 percent and 24 percent total solids (TS), respectively. A third-party contractor transports the biosolids either to direct land application or to off-site compost facilities for further processing and beneficial use. All current biosolids management sites are located more than 80 miles from the RWRF.

Local and state biosolids related regulations are evolving, as is the management of biosolids and other organic materials throughout California. Recognizing that the future of biosolids management in California is progressing, Fresno embarked on a 20-year biosolids master plan that seeks reliable and cost-effective biosolids management option(s) moving into the future.

3.2.1 Project Objective and Approach

The Biosolids Market Assessment creates a connection between potential biosolids products and local market preferences to aid the RWRF in selecting appropriate, cost-effective biosolids management alternative(s). Material Matters conducted three major tasks to achieve the project objective. In the first task, Material Matters evaluated the RWRF's baseline biosolids quality data to understand trends and to characterize biosolids products under consideration by the RWRF. In the second task, Material Matters conducted a preliminary market assessment to understand current biosolids management practices by Fresno and other California utilities, and to identify potential beneficial use markets in the region. In the final task, Material Matters completed a final market assessment to define preferences of local businesses, including product qualities, quantities, seasonal demand, and potential outside-the-gate expenses and revenues. Figure 3.1 summarizes the steps taken to complete the market assessment.

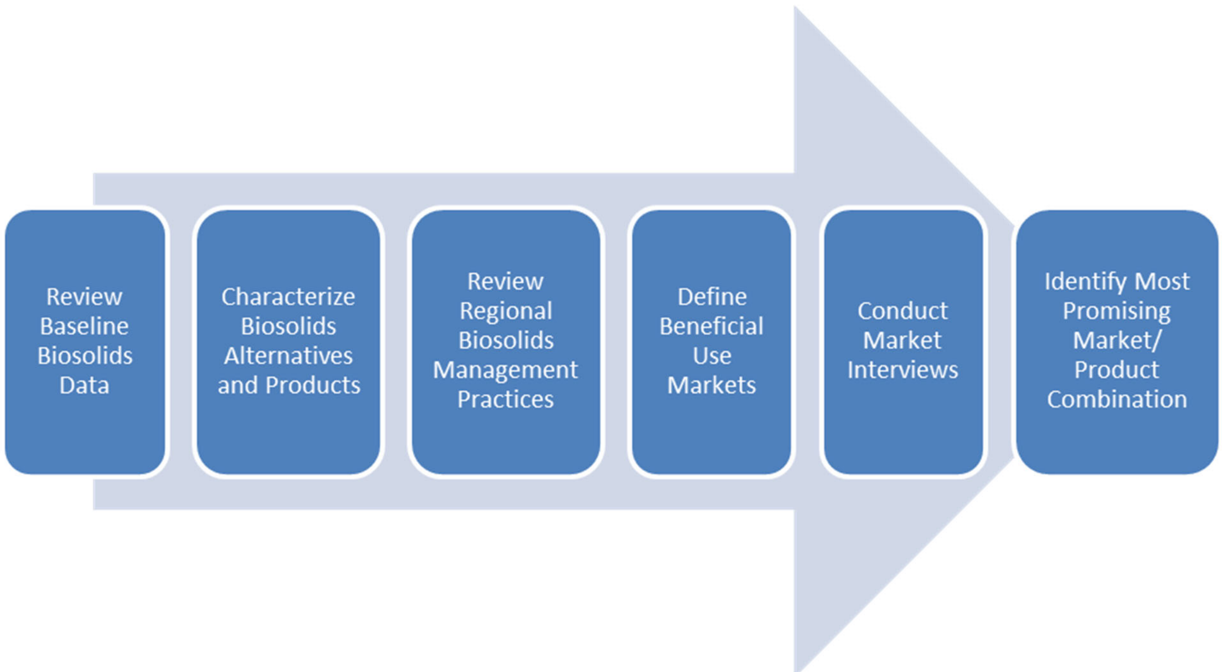

Figure 3.1 Market Assessment Process

3.3 Biosolids Quality Assessment

The RWRF is considering many technologies as part of the Biosolids Master Plan, including mesophilic anaerobic digestion (baseline), thermal hydrolysis, post-digestion thermo-chemical hydrolysis, pyrolysis, gasification, thermal drying, and composting, and each technology generates a unique product. Each product and its corresponding characteristics are preferred by different markets. Therefore, to complete the biosolids quality assessment, Material Matters first characterized Fresno's biosolids including compliance with pathogen reduction (PR), vector attraction reduction (VAR), and pollutant standards, as well as nutrient data, and, in turn, used this information to characterize the remaining products under consideration.

3.3.1 Existing Biosolids Quality

The RWRF employs mesophilic anaerobic digestion (MAD) for solids stabilization. Material Matters reviewed and evaluated RWRF's MAD biosolids data for 2016 through 2018 to ensure compliance with PR, VAR, and pollutant standards, and to assess nutrient quality and potential for malodors, as is summarized below.

3.3.1.1 Pathogen Reduction

Mesophilic anaerobic digestion meets PR through Class B - Alternative 2 Process to Significantly Reduce Pathogens (PSRP), anaerobic digestion. In the anaerobic digestion PSRP, biosolids are treated in the absence of air for a specific mean cell residence time (MCRT) at a specific temperature; values for the MCRT and temperature must be between 15 days at 95 to 131 degrees Fahrenheit (°F) and 60 days at 68°F.

Material Matters reviewed and summarized the digester temperature data for the RWRF (Figure 3.2). Generally, the digesters meet minimum average monthly temperatures of 95°F, as is indicated by the orange line. On a few occasions, daily temperatures dropped below 95°F indicating there is not sufficient boiler capacity. As discussed in Chapter 1, RWRF staff have stated that the boiler limitations occur when nighttime temperatures drop in the 40s (F) for consecutive days, and the City is in the process of developing a Request for Qualifications (RFQ) to install new boilers. Note, however, that while digester temperature may fall below 95 F on a single day, average monthly temperatures have always exceeded the 95 F minimum requirement.

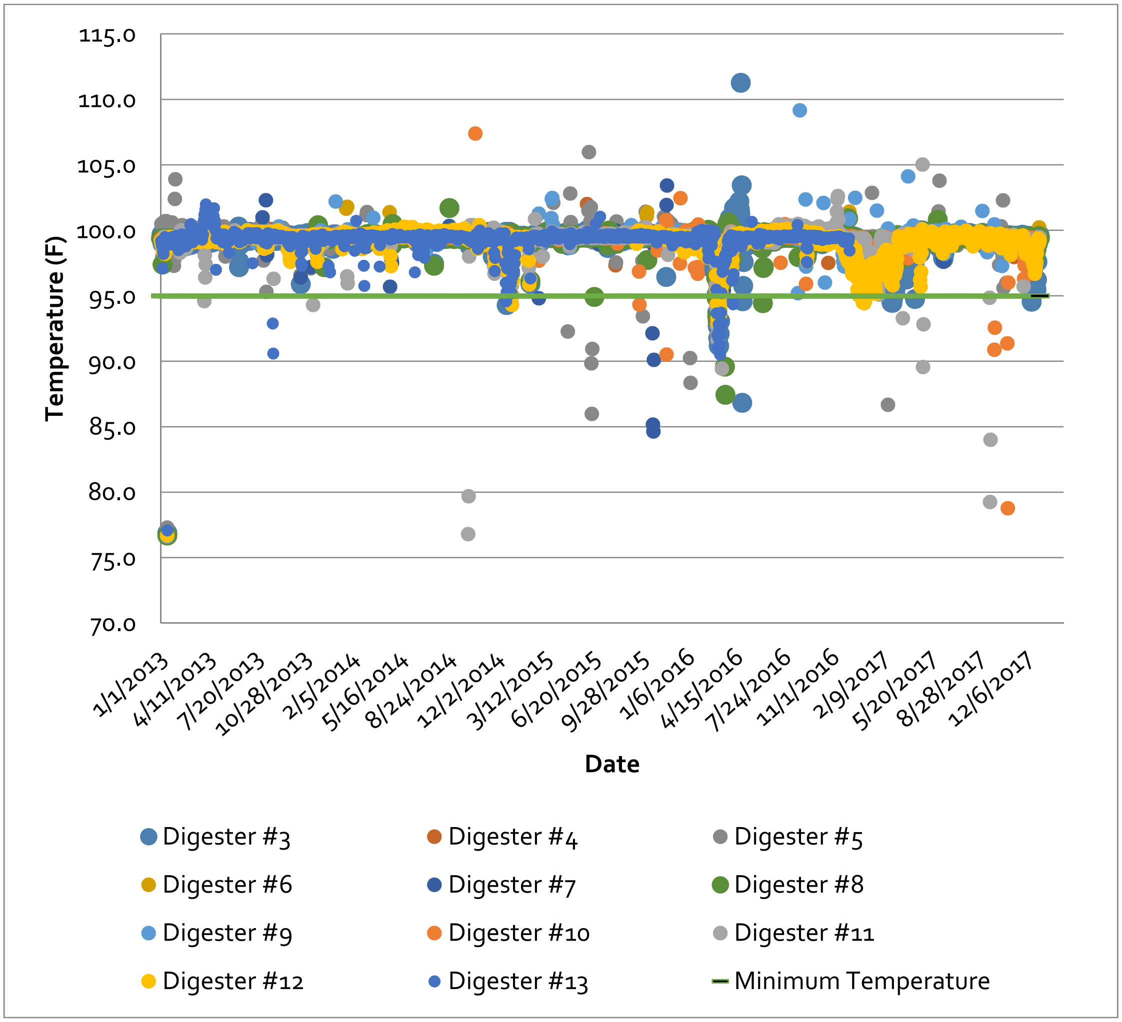

Figure 3.2 2013 to 2017 Anaerobic Digester Temperature Data

Material Matters also reviewed solids retention time (SRT) data to ensure minimum 15-day hold time is met. Data was reviewed using both a rolling 30-day average and a monthly average (Figure 3.3). Excluding data outliers, the SRT for the digesters ranged from 16 to 50 days. Data supports that each of the digesters individually met the 15-day SRT minimum.

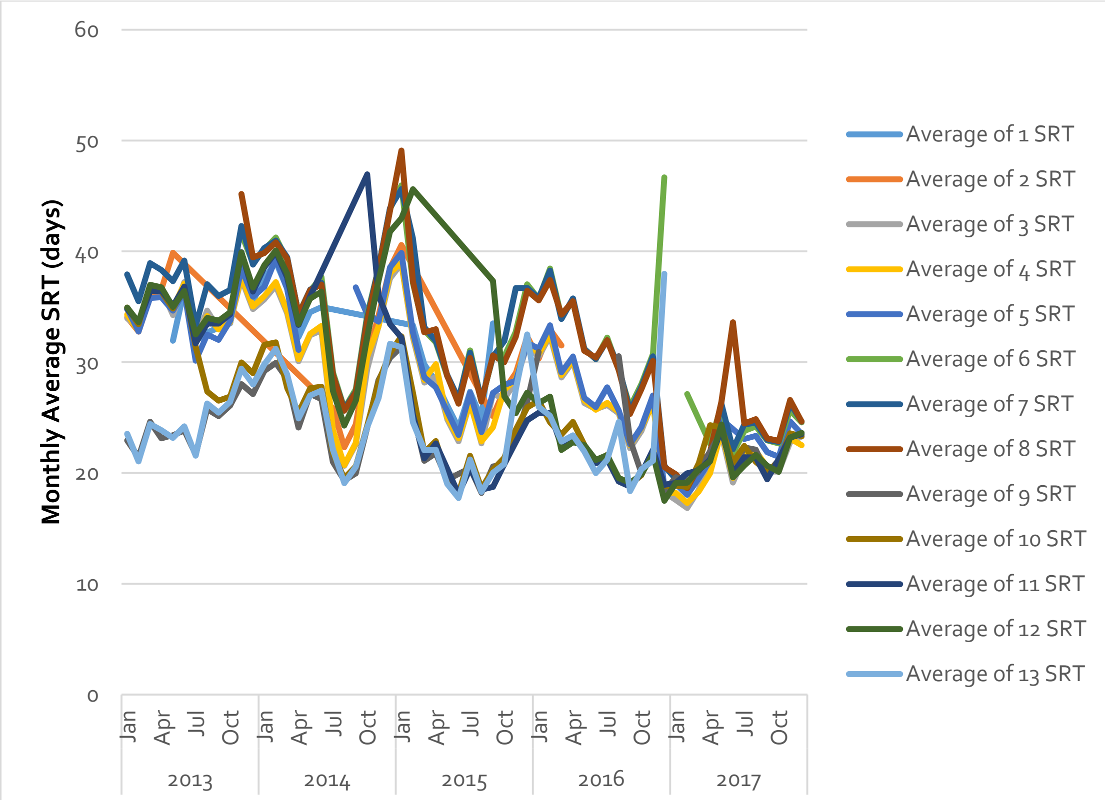

Figure 3.3 Monthly Average SRT by Digester

3.3.1.2 Vector Attraction Reduction

The RWRF achieves VAR requirements through VAR Option 1, 38 percent volatile solids reduction (VSR). Volatile solids concentration of the solids that enter the digestion process (VS_{in}) are reduced by 38 percent relative to the digested solids. Material Matters reviewed VSR data provided by Fresno, which is assumed to use the Van Kleeck Method:

$$\%VS_{reduction} = \frac{VS_{in} - VS_{out}}{VS_{in} - (VS_{in} * VS_{out})} * 100$$

Where VS_{in} = % VS / 100 of feed solids into the digesters

VS_{out} = % VS / 100 of solids contents of solids in the storage tank

Note that the Van Kleeck Method has underlying assumptions that the digesters are operating under steady state condition, in which fixed solids are not destroyed. Daily VSR is depicted graphically for Digesters 1 through 7 in Figure 3.4 and Digesters 8 through 13 in Figure 3.5.

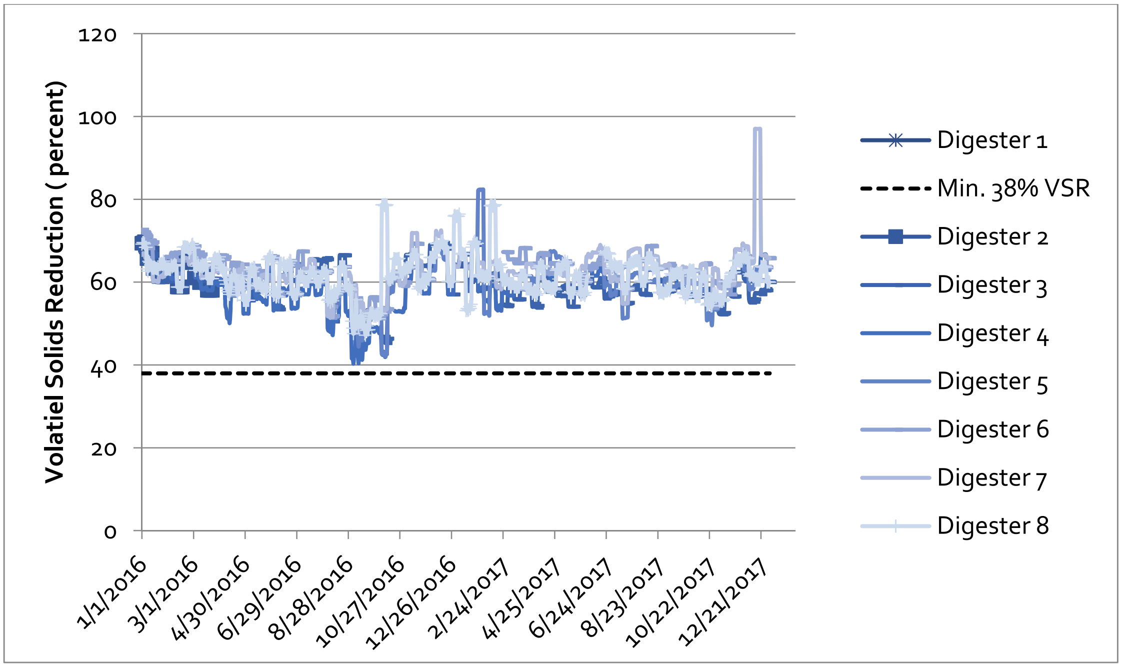

Figure 3.4 Daily VSR for Digesters without ADM (1 through 8)

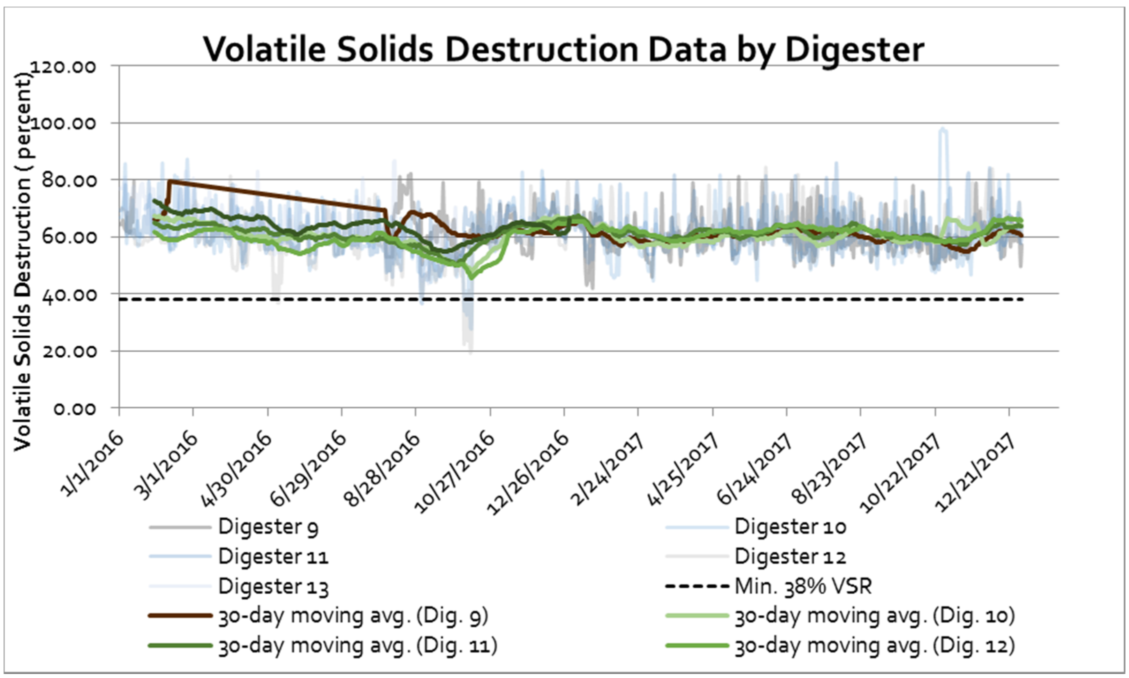

Figure 3.5 Daily VSR for Digesters without ADM (9 through 13)

In general, daily VSR meets the 38 percent minimum for the digesters that receive anaerobically digestible material (ADM) (i.e., hauled-in waste) and those that do not. However, in August of 2016 daily VSR was reduced, falling near or below 38 percent, especially for the solids in the digesters receiving ADM. Although some daily VSR fell below the 38 percent VSR minimum, when evaluated on a 30-day moving average basis (which is the appropriate timeframe to meet regulatory requirements), the City's biosolids consistently met the 38 percent VSR minimum requirement.

3.3.1.3 Pollutant Standards

As noted in the Regulatory Chapter, federal and state regulations define limits on nine (9) pollutants to allow for beneficial use of biosolids products. Table 1 of 40 CFR Part 503 defines 'ceiling concentration limits' and Table 3 defines high quality pollutant concentration limits. The concentration of all nine (9) pollutants in the City's biosolids is consistent over time, and easily meets the pollutant limits (Table 3.1).

Table 3.1 Biosolids Pollutant Limits for Beneficial Use Relative to Maximum Pollutant Concentration in Fresno-Clovis RWRF Biosolids from 2016 to 2018

Constituent	Table 1 Ceiling Conc. Limits(1)	Table 3 Monthly Average Limits(1)	Fresno-Clovis RWRF Maximum Pollutant Concentration (2016-2018)
As	75	41	11.3
Cd	85	39	4.3
Cu	4300	1500	345.6
Pb	840	300	21.6
Hg	57	17	4.5
Mo	75	*	25.6
Ni	420	420	35.7
Se	100	100	6.9
Zn	7,500	2,800	1,036.9

Notes:
(1) Title 40, Part 503 - Standards for the Use or Disposal of Sewage Sludge, Subpart B - Land Application, §503.13, 1993.

3.3.1.4 Nutrients

The biosolids nutrient content is generally the most valuable characteristic for potential customers, and the nutrient content is directly influenced by all processes and chemicals used during the treatment process. The nutrient concentration in the City's biosolids is depicted in Figure 3.6. Nutrients are categorized into three (3) categories based on the nutrient amount essential for plant growth. Primary nutrients are needed in the greatest quantities by plants and include nitrogen (N) (usually the most limiting nutrient), phosphorus (P), and potassium (K). Biosolids supply a moderate amount of N and P relative to conventional fertilizers, but a small amount of K. Biosolids are typically applied to meet the nitrogen requirement of a crop. Nitrogen in biosolids is categorized into organic nitrogen (requires microbes to process before it is available by plants) and ammonia nitrogen (readily available and volatile). The City's biosolids have average organic-N concentration of 4.9 percent on a dry weight basis, which is comparable to other water reclamation facilities (WRFs), and ammonia-N concentration of 0.81 percent, which is high relative to typical biosolids products, and may be an indicator of product instability and potential for malodors. The concentration of P and K in the City's biosolids, at 2.98 percent and 0.17 percent respectively, is consistent over time and comparable to other biosolids products.

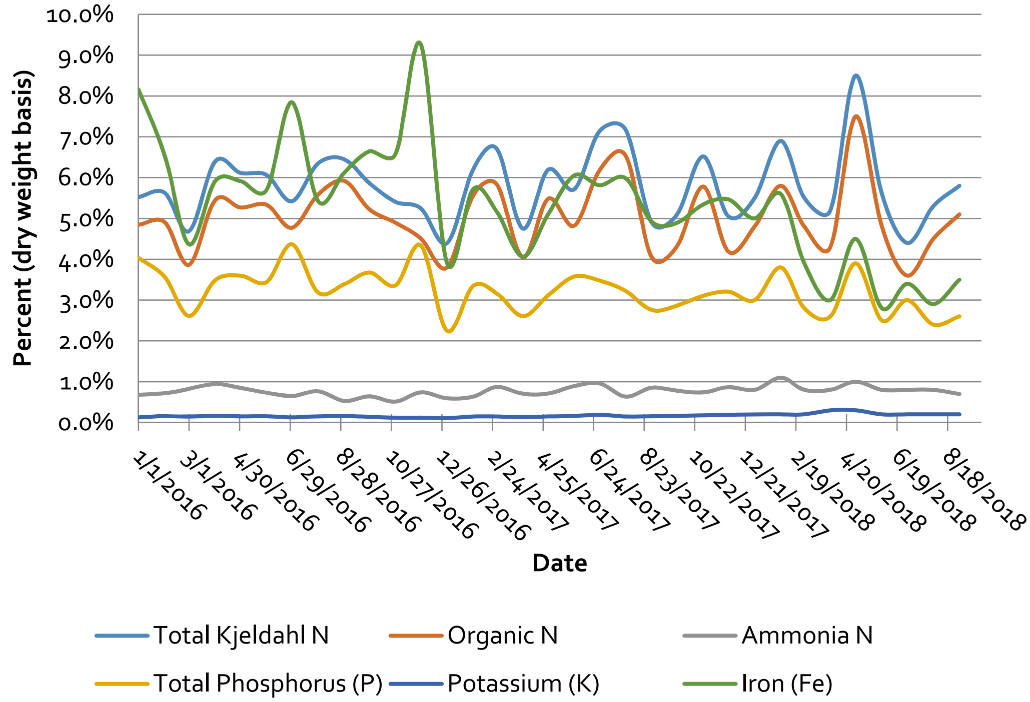

Figure 3.6 Biosolids Nutrient Data in Fresno-Clovis RWRF Biosolids from January 2016 to September 2018

Plants require secondary nutrients in lesser amount relative to primary nutrients; secondary nutrients include calcium (Ca), magnesium (Mg), and iron (Fe). The quantity of secondary nutrients in biosolids products is greatly influenced by treatment processes; for example, utilities that use iron for nutrient removal will have high quantity of iron (up to 12 percent or more) and utilities that use lime for biosolids stabilization will have a very high concentration of calcium (30 percent or more). The concentration of Fe in the City's biosolids has decreased over time, from approximately (~) 8 percent in 2016 to ~3.5 percent in 2018. The reduction in Fe in the biosolids is directly linked to reduced ferric use at the RWRF. Micronutrients are essential nutrients needed in very small amounts and include copper and zinc. Biosolids provide many micronutrients that most fertilizers will not provide.

3.3.1.5 Percent Total Volatile Solids

Total volatile solids (percent TVS) of the final product for anaerobically digested products is an indicator of product stability and potential to generate malodors, in which higher percent TVS is correlated with more intense product odors (WERF, 2018). Furthermore, product malodors are the number one thing that will end an otherwise-successful biosolids beneficial use program. The total volatile solids of the RWRF has increased steadily from 2016 to the end of 2018, from ~68 percent TVS in January 2016 to ~74 percent TVS in September of 2018. The increase is especially pronounced beginning in March 2018 (Figure 3.7). As discussed in Chapter 1, this increase in percent TVS correlates closely with the increase in the daily volume of ADM received. The percent TVS is higher than industry standards of 60 to 65 percent TVS for anaerobically digested biosolids. An increase in percent TVS will typically increase the potential for malodor generation.

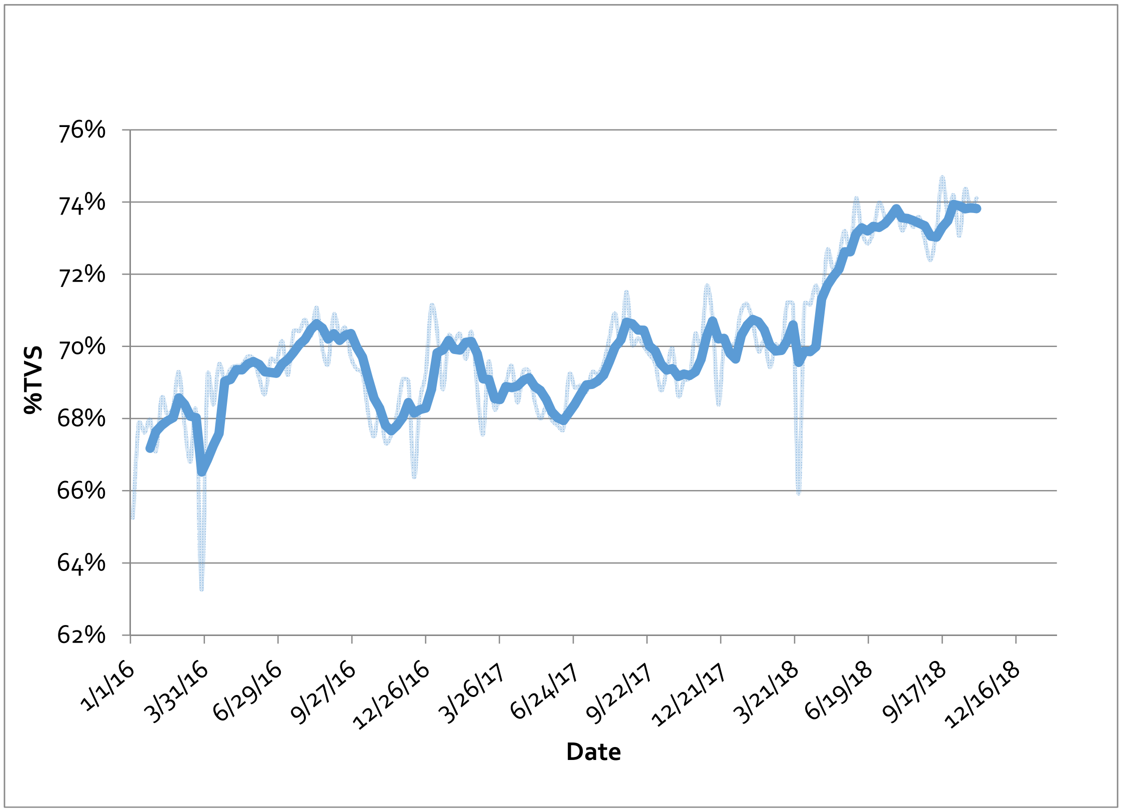

Figure 3.7 Percent Total Volatile Solids of Fresno-Clovis RWRF Biosolids (January 2016 to September 2018)

3.3.2 Potential Product Characterization

Material Matters used information gathered from existing biosolids quality data to characterize the other products considered in the BMP. The product characterization helps potential customers understand the product benefits and helps to address questions and concerns that are commonly asked related to nutrient value, odors, metal concentration, and pathogens. A summary of potential technologies and resulting products is found in Table 3.2.

Table 3.2 Biosolids Processing Technologies under Consideration and Resulting Products

Technology	Resulting Product
Mesophilic Anaerobic Digestion (MAD)	Class B Cake
Thermal Hydrolysis Pre-Treatment	EQ Cake
Thermo-Chemical Hydrolysis	EQ Liquid
Plasma-Arc Gasification	Biochar
Fluidized Bed Gasification	Biochar
Pyrolysis	Biochar
Thermal Drying	EQ Granule/Pellet
Composting	EQ Compost

Each technology was reviewed relative to federal and state regulations, and the biosolids generated by each technology were characterized based on physical and chemical attributes, such as nutrient content, nuisance odor potential, and storability. Each product was also quantified related to the existing MAD cake production. Once each product was characterized, user information sheets were produced with information about each product to aid in the biosolids market interviews (Appendix 3-A).

3.3.2.1 Thermal Hydrolysis Pretreatment: Class A/EQ Cake

Thermal hydrolysis pretreatment (THP) is a batch hydrolysis process that combines high pressure and temperature to make organics more readily available for digestion. Pre-dewatered cake is pumped into a pulper (preheated to ~97 degrees Celsius [°C]) which homogenizes the cake, preheats the solids, and reduces viscosity. Homogenized solids are pumped to the THP reactors where steam heats (and hydrolyzes) the solids to 165°C. Hydrolyzed solids are cooled and diluted to 8 percent to 12 percent TS with water and are then pumped into the mesophilic digesters. Hydrolysis greatly increases the availability of organic material to decomposition, resulting in 65 and 70 percent volatile solids destruction. Thermal hydrolysis improves dewaterability of solids, to create a much drier cake (30 to 35 percent TS on a BFP and 35 to 40 percent on a centrifuge). As such, the product is very stackable, easily stacking to six (6) feet or more. The increased volatile solids destruction and improved dewaterability reduces the number of wet tons of biosolids produced by 50 percent or more. THP is estimated to reduce solids production from ~88,000 wet tons per year to ~46,000 wet tons per year.

Thermal hydrolysis meets regulatory processing requirements through PR Class A Alternative 1 (time and temperature), and meets VAR through Option 1, 38 percent volatile solids destruction, which occurs in the mesophilic anaerobic digesters.

THP produces a Class A/EQ cake that will typically have a higher ammonia N relative to mesophilically-digested solids, but most other nutrients are not anticipated to change greatly.

Fresh Class A/EQ cake tends to have a moderate to strong ammonia odor (Figure 3.8); however, utilities have employed an additional 'curing' step, in which the product is mechanically mixed, which facilitates dissipation of ammonia odors and increased solids content.

Figure 3.8 Example of 'Fresh' THP Class A/EQ Cake

Fresh THP cake has only been used in the bulk agriculture market, but also shows potential for other low value markets such as mine land reclamation. However, with a robust marketing campaign, 'cured' THP cake has been successfully distributed to homeowners, landscapers, and gardeners in the United States.

3.3.2.2 Thermo-Chemical Hydrolysis: Class A/EQ Liquid

Thermo-chemical hydrolysis (the Lystek process) exposes dewatered biosolids to heat, alkalinity (elevation of pH to between 10 and 10.5), and high-speed sheering to create a high-solids (~12 to 15 percent TS) flowable Class A product called LysteGro. The Lystek process does not significantly increase or decrease the quantity of solids (on a dry weight basis) produced; compared with existing MAD cake production of ~88,000 wet tons per year, the Lystek process estimated to generate 92,000 wet tons per year.

LysteGro meets regulatory processing requirements through Class A PR Alternative 1 (time and temperature) and meets VAR through either Option 2 (process VAR), additional anaerobic digestion in a bench-scale unit, or Option 9 (barrier VAR), injection.

LysteGro will have a slightly lower N and P nutrient content relative to anaerobically digested solids (the RWRF existing process) due to the addition of lime; however, the lime will provide calcium and liming value (the ability for a product to neutralize acidic soil).

The Lystek product has a moderate odor (especially after storage), which is mitigated, at least in part, through injection into the soil. The final product will be high solid (~12 to 15 percent TS), black liquid, with the consistency of thick paint (Figure 3.9). As the material is stored, the biosolids will have a different odor profile as well as reduced pH and viscosity in comparison to the product taken directly from the process.

Because LysteGro is a liquid, product storage is a significant consideration for this technology. Suitable storage options include lined and covered lagoons, below or above ground concrete tanks, and glass lined tanks; if stored off-site, LysteGro may also be stored in existing liquid manure storage tanks. LysteGro is spread using injection liquid manure application equipment, which is conventionally used to spread liquid dairy manure.

While LysteGro meets Class A/EQ requirements, to date, the Lystek products have only been distributed into the bulk agriculture market.

Figure 3.9 Example of LysteGro

3.3.2.3 Gasification and Pyrolysis: Biochar

Gasification and pyrolysis are processes in which feedstocks (usually carbon-rich material) are heated to very high temperatures (1,400 to 1,500°F) in the absence of oxygen (pyrolysis) or controlled amount of oxygen (gasification), resulting in the production of biochar, bio-oil, and syngas. Gasification and pyrolysis will substantially reduce the volume of product produced, by at least 90 percent on a wet weight basis relative to MAD, from ~88,000 wet tons per year to 8,900 wet tons per year. While some gasification and pyrolysis technologies with woody feedstocks are well established, gasification and pyrolysis are new technologies for processing biosolids.

Gasification and pyrolysis create biochar, which is a high-carbon, fine-grain residue. Both processes meet regulatory processing requirements through PR Alternative 5 (Processes to Further Reduce Pathogens, thermal drying) and VAR Option 8, increase percent total solids to greater than 90 percent. The characteristics of biochar are influenced mainly by the operating temperature and type of biomass. Higher pyrolysis temperatures often result in increased surface area and carbonized fraction of biochar, which leads to high sorption capability for pollutants. In all cases, however, biochar will have a neutral odor.

The gasification process converts volatile solids found in the dried biosolids into gas; therefore, any non-volatile metal or nutrient will be concentrated in the biochar. Except for mercury, which has a low evaporation temperature (~350°C), metal concentrations are anticipated to increase by one (1) to three (3) times in the char sample relative to the MAD cake (on a dry weight basis). In the case of Fresno, if the metal concentration is tripled, the char easily meets the EPA 40 CFR 503 Table 3.3 (Class A) metal limits. If metal concentrations exceed Table 3.3 limits, however, the product will be limited to the bulk agriculture market, alternative daily cover, or landfill disposal and will require additional site/monitoring restrictions.

With respect to nutrients, the gasification process will generally increase the concentration of phosphorus and potassium in the biochar relative to MAD cake. However, the gasification process converts much of the nitrogen content into nitrogen gas (N_2), thereby reducing the total nitrogen content of the biochar. Increasing phosphorus and reducing the nitrogen will typically create an ‘unbalanced’ fertilizer, in which application of the product will provide too much P or not enough N relative to plant needs.

The final product will be a high solid (>99 percent TS) product, that is granular or dusty, depending on the technology. Some technologies have implemented spraying systems at the discharge, which adds up to 20 percent moisture to reduce dust potential and improve handleability. Because biochar contains such high percent TS the product should be stored under a roof, and preferably in a storage silo.

Biosolids-based biochar (Figure 3.10) has typically been used in the bulk agriculture market, although expansion into other markets (i.e., as an activated carbon replacement) is currently being explored.

Figure 3.10 Example of Biosolids-Based Biochar

3.3.2.4 Thermal Drying: Class A/EQ Granule

Thermal drying is the process of adding heat to evaporate water in the biosolids that cannot be mechanically removed with a mechanical dewatering device. In the thermal drying process, dewatered biosolids are fed into a dryer, subjected to temperatures greater than 200°F, and dried to greater than or equal to 90 percent TS. Thermal drying following anaerobic digestion greatly reduces product volume (reduction from ~88,000 wet tons to ~28,800 wet tons) and transforms a Class B product into an EQ product. Figure 3.11 shows an example of a thermally dried Class A/EQ Biosolids.

Figure 3.11 Example of a Thermally Dried Class A/EQ Biosolids

Dried, anaerobically digested biosolids products will meet Class A/EQ processing requirements through PR Alternative 5 (Processes to Further Reduce Pathogens, thermal drying) and VAR Option 8, increase percent total solids to greater than 90 percent.

While well-digested thermally dried products tend to have low odor intensity when dry, when the product is rewetted for the first time, it can produce an intense odor that can be considered offensive to the public. Dried biosolids will have nearly the same nutrient concentration as MAD cake on a dry weight basis; however, because it contains one-fifth the amount of moisture, dried biosolids have four (4) to five (5) times the nutrient concentration relative to MAD cake on a wet weight basis. The final product will be granular, typically ranging in size from two to eight mm and will contain dust that can be controlled through screening and the addition of dedusting oils. Some dried biosolids products have experienced reheating when stored in piles; while the exact cause of reheating is not well understood, the reheating is attributed to a combination of oxygen and moisture content. To address this challenge, many utilities store biosolids in nitrogen-blanketed storage silos until they are ready for final use.

Depending on the size, uniformity, and density of the dried biosolids product, dried biosolids can be marketable to a variety of low and high public access markets including bulk agriculture, soil blending, sod production, landscaping, and others.

3.3.2.5 Composting: Class A/EQ Compost

Composting is a process in which the organic fraction of biosolids undergoes biological degradation in the presence of air (oxygen) to create a stable, humus-like product. Biosolids are blended with a high-carbon feedstock (typically woody material) and aerated, resulting in accelerated material decomposition to produce the temperature rise required for pathogen destruction. A successful composting operation will have control over the many inputs to the composting process including the carbon to nitrogen ratio, air supply, moisture content, pH control, temperature, and mixing/turning. Composting greatly reduces the volatile content and increases the total solids of the final biosolids product; however, the process adds a large amount of woody waste. As a result, the total wet tons produced are reduced by about 25 percent - from 88,000 to 69,700 tons.

Compost produced with anaerobically digested biosolids will meet Class A biosolids requirements through PR Alternative 5, and VAR Option 5. By utilizing a processed biosolids feedstock (through MAD), the composting process will have a lower potential for site malodors, and, if composted correctly, the finished product will have a rich, earthy (musty) aroma that most people do not find offensive.

Class A/EQ biosolids compost is a direct substitute for other compost products, allowing for beneficial use in a wide variety of markets including topsoil manufacturing, landscaping, sod production, and others. An example of Class A/EQ compost is shown in Figure 3.12.

Figure 3.12 Example of a Class A/EQ Biosolids Compost

The expected product characteristics for each product considered is found in Table 3.3.

Table 3.3 Projected Biosolids Characteristics for each Product under Consideration

Parameter	Class B AD Cake(1)	Class A EQ Cake(2)	Class A/EQ Liquid(3)	Biochar(4)	Thermally Dried(5)	Class A/EQ Compost(6)
pH	7.5	8	8	7.5	7.5	7.5
% Total Solids	19%	30%	15%	99.5%	95%	65%
% Volatile Solids	72%	60%	72%	<1%	72%	60%
Nutrients (% dry wt)						
Total Kjeldahl N	5.4%	5.4%	5.4%	1.8%	5.4%	1.8%
Organic N	4.6%	4.6%	4.6%	1.5%	4.6%	1.5%
Ammonia N	0.8%	0.8%	0.8%	0.3%	0.8%	0.3%
Total Phosphorus (P)	3.0%	3.0%	3.0%	6.0%	3.0%	1.0%
Potassium (K)	0.2%	0.2%	0.2%	0.3%	0.2%	0.1%
Iron (Fe)	5.2%	5.2%	5.2%	11.9%	5.2%	2.6%
Regulated Metals (mg/kg dry wt)						
Arsenic (As)	8.6	8.6	8.6	21.6	8.6	2.9
Cadmium (Cd)	2.6	2.6	2.6	6.4	2.6	0.9
Chromium (Cr)	39.7	39.7	39.7	99.3	39.7	13.2
Copper (Cu)	238.2	238.2	238.2	595.5	238.2	79.4
Lead (Pb)	13.9	13.9	13.9	34.7	13.9	4.6
Mercury (Hg)	1.3	1.3	1.3	1.3	1.3	0.4
Molybdenum (Mo)	14.5	14.5	14.5	36.2	14.5	4.8
Nickel (Ni)	23.1	23.1	23.1	57.7	23.1	7.7
Selenium (Se)	4.2	4.2	4.2	10.6	4.2	1.4
Zinc (Zn)	749.0	749.0	749.0	1872.5	749.0	249.7
Production						
Dry Tons / Year	19,700	13,790	19,700	8,800	19,700	45,310

Parameter	Class B AD Cake(1)	Class A EQ Cake(2)	Class A/EQ Liquid(3)	Biochar(4)	Thermally Dried(5)	Class A/EQ Compost(6)
Wet Tons / Year	88,000	46,000	131,400	8,844	20,800	69,708
Additional Parameters						
Dust Potential	NA	NA	NA	Moderate/High	Low	Low
Hardness	NA	NA	NA	Low-Moderate	Hard	NA
Odor Potential	Moderate	Moderate	Moderate	Low	Low	Low

Notes:

(1) Average of 2016 to 2018 data provided by RWRF.

(2) Reduced volatile solids and increased %TS based on results achieved by DC Water, the first THP unit installed in the United States. Nutrients and metals assumed to be the same as baseline (dry weight basis).

(3) Because hydrolysis occurs after digestion, volatile solids assumed to be similar to baseline. Assume nutrient and metals same as baseline (dry weight basis).

(4) Gasification volatilizes volatile solids; as such, non-volatile nutrients (all except nitrogen) and metals (all except Hg) are concentrated. Metals and nutrient results multiplied by 2.5 to 3.0 based on data collected from MaxWest Energy Sanford, FL biosolids gasifier.

(5) Thermally dried biosolids must meet minimum of 90 %TS to meet regulatory requirements; utilities typically operate dryers closer to 95 percent to ensure compliance. Temperature regime experienced during thermal drying is not hot enough to alter nutrient and metal concentration on dry weight basis.

(6) Composting requires addition of woody waste at a woody waste to biosolids volumetric ratio of 3:1 (i.e., 3 cubic yards (yd3). woody waste to 1 yd3 biosolids). Additional biomass dilutes nutrient and metals concentration, and typically increases dry tons produced by 3 to 4 times.

3.4 Biosolids Management Practices

In this section, the City's biosolids management program is reviewed and compared to other biosolids management programs across California.

3.4.1 Current Beneficial Use Program

Material Matters reviewed the City's biosolids management contract (effective November 21, 2013 through November 2018) and biosolids final disposition to understand the City's baseline biosolids management program.

3.4.1.1 Contract Overview

The Fresno-Clovis RWRF was under contract with Synagro for the management of its Class B biosolids. The contract was awarded on November 21, 2013 and was effective for an initial three (3) year term, with the option for two (2) one-year extensions. Ultimately, the City elected to issue both one-year extensions (i.e., the contract was ultimately effective through November 2018).

The contract provides up to 100,000 wet ton (WT) of biosolids, but never guaranteed a minimum amount to be provided to the contractor and allowed the City to manage up to 10,000 tons for other purposes. The contract requires the contractor to beneficially use 100 percent of the biosolids generated by the Fresno-Clovis RWRF via composting, biomass fuel, mine reclamation, land application, as a soil amendment, or via another approved beneficial use option. The contract also defines the contractor as being responsible for storage, processing, transfer, sale, and final disposition of the City's biosolids at the processing facility in compliance with all necessary permits. The contractor was also responsible for providing tonnage summaries and daily disposition of the City's biosolids by product, end use, and final disposition by weight.

The contract defines the processing facility as Liberty Composting, Inc., which is located 82 miles away from the RWRF in Lost Hills, California. Ultimately, the majority of Fresno's biosolids that were composted were sent to a closer facility - the Central Valley Compost (CVC) composting facility, which is located 60 miles from the RWRF, in El Nido, California.

The contracted biosolids management cost on the outset of the contract was $26.00 per wet for the first year, and after 12 months, the contractor had the opportunity to submit a proposal for a price increase based on escalation percentages and consumer price index changes. At the end of the contract, Fresno was paying $28.00 per wet ton for Synagro to manage the biosolids. In Fresno's new biosolids management contracts with Synagro and Holloway, effective December 2018, the biosolids management cost increased to a price of $31.86 and $33.85 per wet ton, respectively. Even with these price increases, Fresno's current pricing is substantially less than other utilities that bring biosolids to the CVC. According to Synagro's presentation in October 2018, other local utilities are paying a price of $44.13 per wet ton, and an average of local utilities and utilities in the Bay area are charged a price of $52.08 per wet ton to have their biosolids transported to and processes at the CVC.

3.4.1.2 Disposition

Material Matters reviewed 2016 and 2017 biosolids management data provided by the City. Earthwise Organics, a subsidiary of Synagro, manages the City's biosolids. Earthwise Organics typically transports the City's biosolids to the Central Valley Compost facility, and, in turn, transfers the biosolids to direct land application or further processes the biosolids into compost.

On rare occasions, Earthwise Organics diverts the City's biosolids to a different compost facility or for use as alternative daily cover.

Land Application

Synagro provides the City with Monthly Activity Reports, which reports the quantity of biosolids that was land applied during the month, pollutant information, the field(s) where the land application event took place and the cumulative pollutant loading rate for each field.

The land application sites are approximately 60 miles away (all in Merced County), and biosolids are typically applied as a fertilizer for corn silage and wheat. In 2016 and 2017, approximate 48 percent and 44 percent respectively, of the RWRF's biosolids were directly land applied. Land application primarily occurs in the spring and fall prior to crop planting (Figure 3.13 and Figure 3.14).

Composting and Other Management

During times when the fields are not suitable for direct land application (either due to wet weather or standing crops), biosolids are transported for composting. The majority of biosolids transported to composting are transported to the CVC composting facility in El Nido, but in 2016, ~2,400 wet tons (~5 percent of quantity sent to composting) was transported to the South Kern Composting Facility, located 140 miles from the RWRF. Composting accounted for ~52 percent and 56 percent of biosolids management for the City's biosolids in 2016 and 2017, respectively.

On rare occasions, a small amount of biosolids is transported to landfill for use as alternative daily cover. In 2017, 75 wet tons (0.1 percent) of biosolids were transported to the Fairmead Landfill.

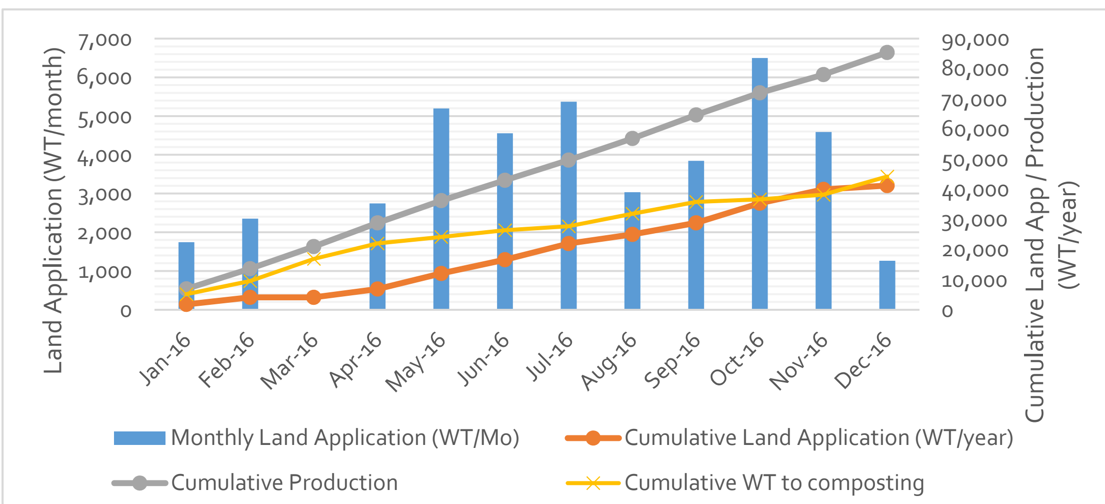

Figure 3.13 2016 Biosolids Management

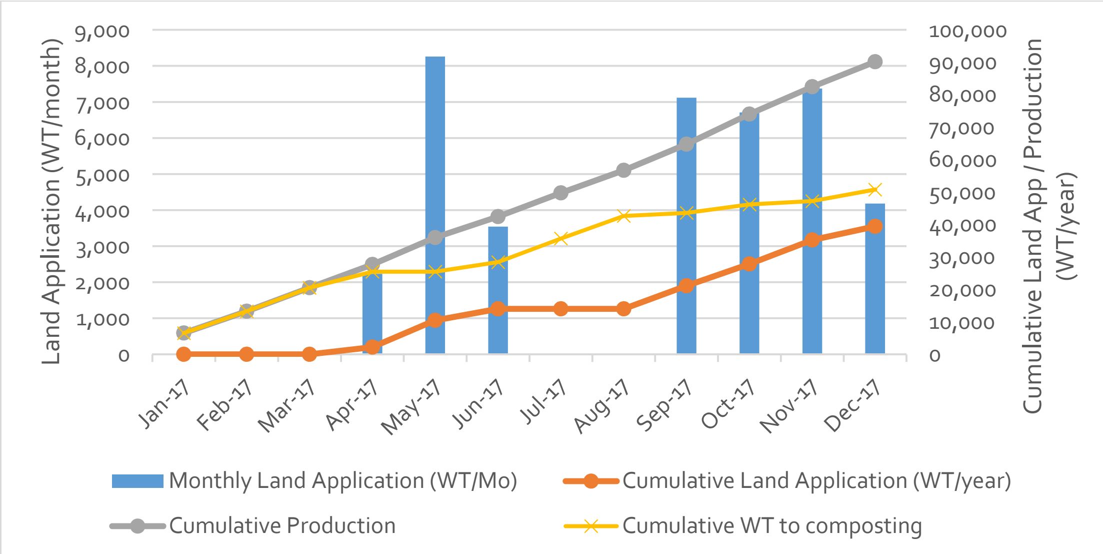

Figure 3.14 2017 Biosolids Management

Third-Party Biosolids Management Program Costs

As previously noted, the biosolids management contract included an initial biosolids management fee of $26 per wet ton in 2016, which was increased to $28 per wet ton in 2017. On a dry weight basis, the biosolids management fee averaged $115 per dry ton in 2016, and $121 per dry ton in 2017. By increasing biosolids management fees by $2 per ton, monthly biosolids management costs increased by nearly $26,000 per month, from an average of $184,510 per month in 2016 to $210,435 in 2017 (Figure 3.15).

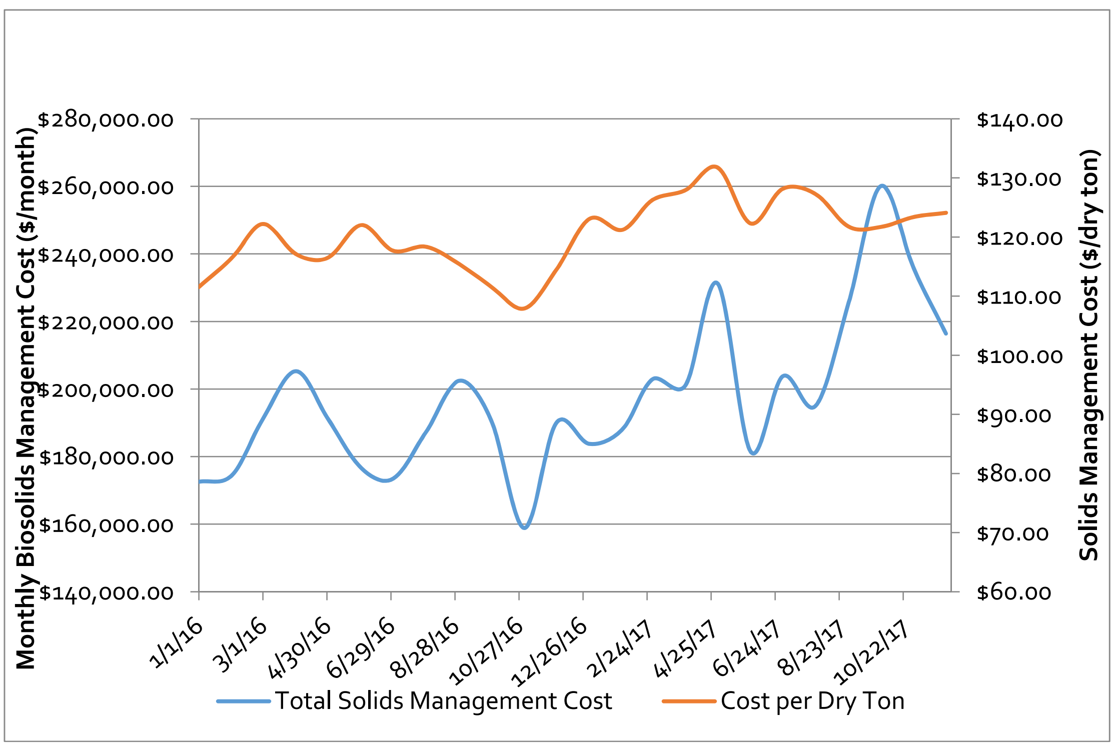

Figure 3.15 RWRF Biosolids Hauling Costs in Dollars per Month and Dollars per Dry Ton

3.4.2 Other California Biosolids Programs

Material Matters conducted a survey of other California biosolids programs to understand how other utilities are managing their biosolids now, and to understand major drivers/challenges impacting other utilities across California.

3.4.2.1 Approach

Material Matters secured calendar year 2017 biosolids production and general management information for Environmental Protection Agency (US EPA) Region 9 from the US EPA Regional Coordinator, Ms. Lauren Fondahl. The US EPA utility list was then narrowed to focus on WRFs of similar size to the Fresno-Clovis RWRF. Note that in 2017, the Fresno-Clovis RWRF produced over 18,750 dry tons of biosolids, which puts the RWRF in the top ten relative to other California biosolids producers. Because large wastewater facilities typically have similar opportunities (larger operating budgets and greater biosolids volumes for innovative technologies) and challenges (large volume to manage) when it comes to biosolids management, the California biosolids survey focused on the 48 largest biosolids producers (not including Fresno). Contact information for each utility was identified through internet searches performed by Material Matters.

Material Matters conducted phone interviews to confirm/refine information gleaned from the US EPA Region 9 database pertaining to: production and beneficial use outlets and information pertaining to transportation and management costs. To aide in collecting information during telephone interviews, an inquiry form was developed by Material Matters containing questions in a variety of strategic categories, including:

1. Quantity of biosolids produced.
2. Type and classification of biosolids products generated by each facility.
3. The beneficial use or disposal options currently utilized.
4. Current transportation and disposal/beneficial use costs.
5. Fundamental biosolids program drivers of special significance to decision-makers at each WRF.

3.4.2.2 Results

Utilities Contacted

Material Matters identified and attempted to contact each of the 48 largest wastewater treatment plants in California and was able to conduct interviews with 32 facilities. The summary of utilities and the interview outcome is summarized in Table 3.4.

Table 3.4 California Utilities Contacted during the Biosolids Market Assessment

Facility Name	Contact	2017 Biosolids Production (DT)	Interviewed
LACSD - JWPCP	Tom Fang	123,755	Yes
Los Angeles Hyperion WWTP	Christina Jones	66,208	Yes
San Jose/Santa Clara WRF	Anthony Pasqual	47,988	Yes
San Diego MBC - Point Loma WWTP	Richard Pitchford	38,646	Yes
Orange County SD 2	Deirdre Bingman	30,977	Yes
Sacramento RWTP	Jeremy Boyce	30,504	Yes
Orange County SD #1	Deirdre Bingman	23,167	Yes
East Bay MUD	Alicia Chakrabarti	19,818	Yes
Central Contra Costa WWTF	Doug Little	17,230	Yes
San Francisco Southeast WWTP	Manon Fisher	12,832	***No***
Santa Cruz WWTP	Anne Hogan	10,060	Yes
Hayward WPCF	David Donovan	9,921	Yes
Inland Empire Utilities Plt 1	Rocky Welborn	9,569	Yes
Inland Empire Utilities Plt 2	Rocky Welborn	7,824	Yes
Riverside RWQCP	Gilbert Perez	7,162	***No***
Colton WRF	David Kolk	6,626	Yes
Palo Alto RWQCP	Jamie Allen	6,560	Yes
West Basin Municipal Water District	Stephanie Olagole	6,462	Yes
Encina WPCF	Doug Campbell	5,978	Yes
Victor Valley	Eugene Davis	5,766	No
Oxnard WWTP	*Not Provided*	5,625	***No***
Oro Loma WWTF	Manuel Garcia	5,300	***No***
Simi Valley WQCP	Mark Moine	5,207	Yes
LACSD - Valencia WRP	Tom Fang	5,206	Yes
San Bernardino WRF	Allen Harralson	4,923	Yes
Santa Rosa Laguna WWTP	Zachary Kay	4,777	Yes
Union Sanitary District	Armando Lopez	4,668	Yes
Lamont WWTP	Fernando Pantoja	4,413	Yes
Valley Sanitary District	Ian Wilson	4,384	Yes
Monterey RWPCA	Richard Gilliam	4,325	Yes
Stockton RWCF	Dee Anytpas	4,203	Yes
Bakersfield WWTP	Sameena Gill	3,923	Yes
Silicon Valley Clean Water	*Not Provided*	3,812	***No***
Vallejo SFCD	Dan Ferguson	3,562	***No***
Escondido Hale Ave RRF	*Not Provided*	3,445	***No***
San Francisco Oceanside	*Not Provided*	3,268	***No***

Facility Name	Contact	2017 Biosolids Production (DT)	Interviewed
South County Regional WWTP	*Not Provided*	3,250	***No***
Elsinore Valley Regional Facility	Keith Martinez	3,235	***No***
Oceanside San Luis Rey WWTP	*Not Provided*	3,209	***No***
San Luis Obispo WRF	David Hix	3,159	Yes
EMWD - Perris Valley RWRF	Chuck Underwood	3,150	Yes
Delta Diablo WWTP	Joaquin Gonzalez	3,131	Yes
Fairfield Suisun WWTP	Ben Carver	3,061	Yes
Los Angeles Terminal Island WRP	*Not Provided*	3,035	***No***
Roseville Pleasant Grove WWTP	*Not Provided*	2,859	***No***
EMWD - Temecula Valley	*Not Provided*	2,738	***No***
Paso Robles WWTP	Nick Kamp	2,671	Yes
Modesto WQCF	*Not Provided*	2,615	***No***

Production Volumes and Classification of Biosolids

In 2017, the majority (79 percent) of biosolids produced by the largest WRFs in California met Class B standards **at the time of transport out of the WRF's management**. For example, the Fairfield-Suisun Sewer District produces anaerobically digested Class B biosolids, and the biosolids are then transferred to the Lystek owned and operated facility for further processing to meet Class A/EQ standard; in this case, Fairfield-Suisun's biosolids are classified as 'Class B'. The same scenario holds true for the Sacramento biosolids, which are anaerobically digested by Sacramento to produce Class B biosolids, and then a portion of the finished product is transferred to the Synagro owned and operated drying facility to produce Class A/EQ thermally dried biosolids; Sacramento's biosolids are also categorized as 'Class B'.

Thirty-five (35) of the largest facilities produced Class B biosolids at the WRF, seven (7) produced Class A/EQ biosolids, two (2) produced incineration ash, and four (4) produced unclassified biosolids. The quantity of biosolids produced in each biosolids classification, reported in both percentage and dry tons (DT), is depicted in Figure 3.16.

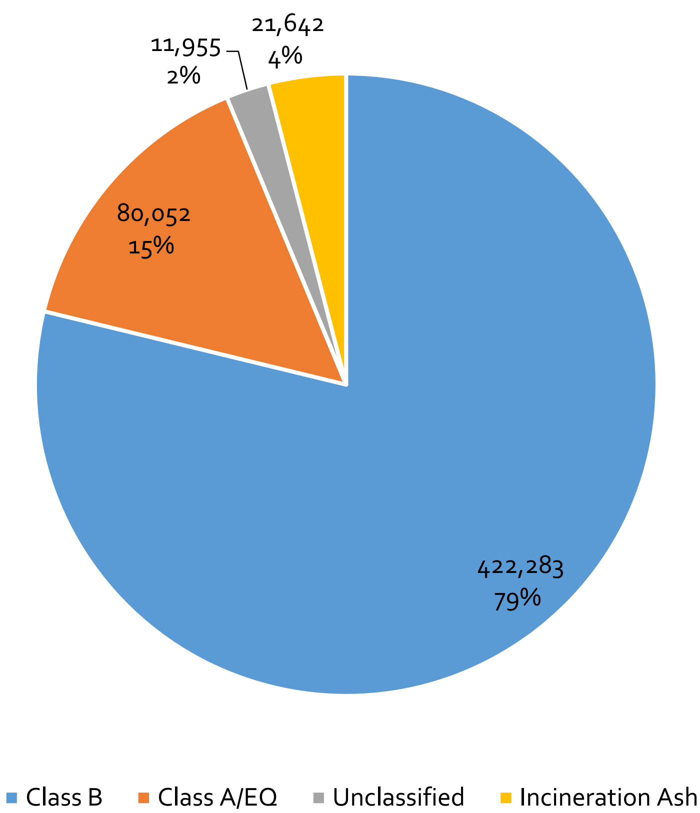

Figure 3.16 Quantity and Classification of Biosolids Produced by California's 48 Largest WRFs (excluding Fresno)

The majority (77 percent) of biosolids produced by the largest wastewater treatment plants in California in 2017 were processed through mesophilic anaerobic digestion. Two (2) WRFs utilized thermophilic anaerobic digestion, two (2) operated incinerators, two (2) stabilized biosolids through air/solar drying, three (3) employed aeration ponds, two (2) utilities utilized lime stabilization, and one (1) utility operated mesophilic anaerobic digestion followed by a thermal dryer. Two (2) utilities anaerobically digest their solids to produce a Class B product, which is transferred to be further processed through thermal drying (Sacramento) or thermo-chemical hydrolysis (Fairfield-Suisan) at adjacent sites owned and operated by a third-party. For this evaluation, the solids produced by these two facilities is classified as mesophilic anaerobic digestion. The quantity of biosolids produced by each process (in dry metric tons) is summarized in Figure 3.17.

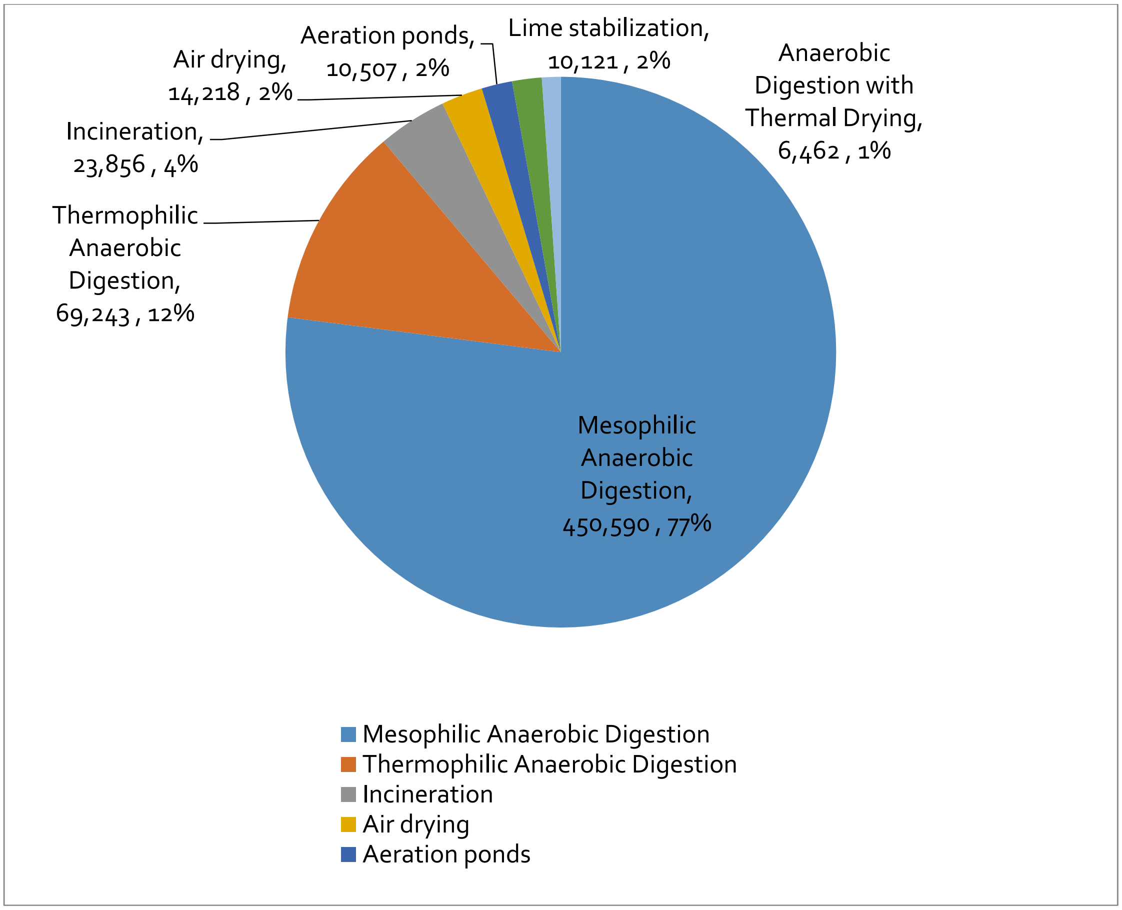

Figure 3.17 Solids Stabilization Methods Used for Biosolids Produced by California's 48 Largest WRFs (excluding Fresno)

Biosolids Management Method(s)

In 2017, eight (8) biosolids management methods were utilized by the 48 largest utilities in California, including:

- Third-party further processing: Unstabilized solids or biosolids are produced by a WRF and transported to a third-party for additional processing (typically to meet Class A standards).
- Landfill alternative daily cover: Biosolids are produced by a WRF and transported to a landfill to be used as cover over the working face of a landfill.
- Landfill disposal: Unstabilized solids or biosolids are produced by a WRF and transported to a landfill for disposal.
- Third-party management/land application: Biosolids are produced by a WRF and are transported and land applied by a third-party contractor. The third-party contractor land applies the biosolids 'as-is' and does not carry out any additional processing.
- Self-managed land application: Biosolids are produced by a WRF; the WRF also oversees the transportation and land application activities.
- Incineration: Biosolids are incinerated at a WRF; the resulting ash is generally landfilled.

- Deep-well injection: Biosolids are produced by a WRF and are injected into a deep well with the aim to convert biosolids into clean energy through geothermal biodegradation.
- Surface disposal: Biosolids are produced by the WRF and are land applied on a dedicated surface disposal site for final disposal.

In 2017, 35 percent of the biosolids produced by the largest wastewater treatment plants were transported to a third-party facility for further processing. Third-party processing includes compost, thermal drying, and thermo-chemical hydrolysis. Compost accounts for most of the off-site processing category, making up 189,335 of 203,908 dry tons (93 percent) of the biosolids processed by a third-party. Compost facilities that process California's biosolids include:

- Arizona Soils.
- Engel & Gray.
- Griffith Park.
- Inland Empire Regional Compost Facility.
- Liberty Composting.
- Synagro Central Valley.
- Synagro Hawes Road (formerly known as Nursery Products).
- Synagro South Kern County.
- Tulare Lake.
- Tule Ranch.

Other third-party processing facilities include Synagro's Sacramento drying facility (8,219 DT), the thermo-chemical hydrolysis facility located at the Fairfield-Suisun WRF (3,061 DT), and the pyrolysis facility at the Silicon Valley WRF (118 DT).

Approximately 20 percent of biosolids produced in 2017 were utilized for landfill alternative daily cover at landfills (considered a beneficial use option in 2017) including the Altamont, Marina, Newby Island, and Otai Mesa Landfills. Landfill disposal accounted for 6 percent of solids management in 2017. Biosolids were disposed at the Forward Landfill, Highway 59 Landfill, Holloway Landfill, Mesa Landfill, Prima Deshecha Landfill, Simi Valley Landfill, and the Toland Road Landfill. Note that additional landfills may have been utilized for both ADC and landfill disposal; however, not all landfill names were obtained during phone interviews.

An additional 19 percent of 2017 biosolids was directly land applied by third-party land application companies, which include Ag Tech, Denali, and Synagro. Eleven (11) percent of biosolids were managed directly by the utility through a self-managed program. Note that LASAN's Hyperion accounts for over 75 percent (48,972 DT) of the biosolids in this category.

Incineration accounted for 23,856 DT (4 percent) of solids management in 2017. However, starting in January 2019, the Palo Alto incinerator went offline, and biosolids (6,626 DT) will be managed through off-site composting (two-thirds of production) and through the thermo-chemical hydrolysis process at the Fairfield-Suisun WRF.

The remaining 2 percent (9,775) is managed through a demonstration deep well injection project employed by the Los Angeles Terminal Island WRF. The number of dry metric tons in each biosolids management category is summarized in Figure 3.18.

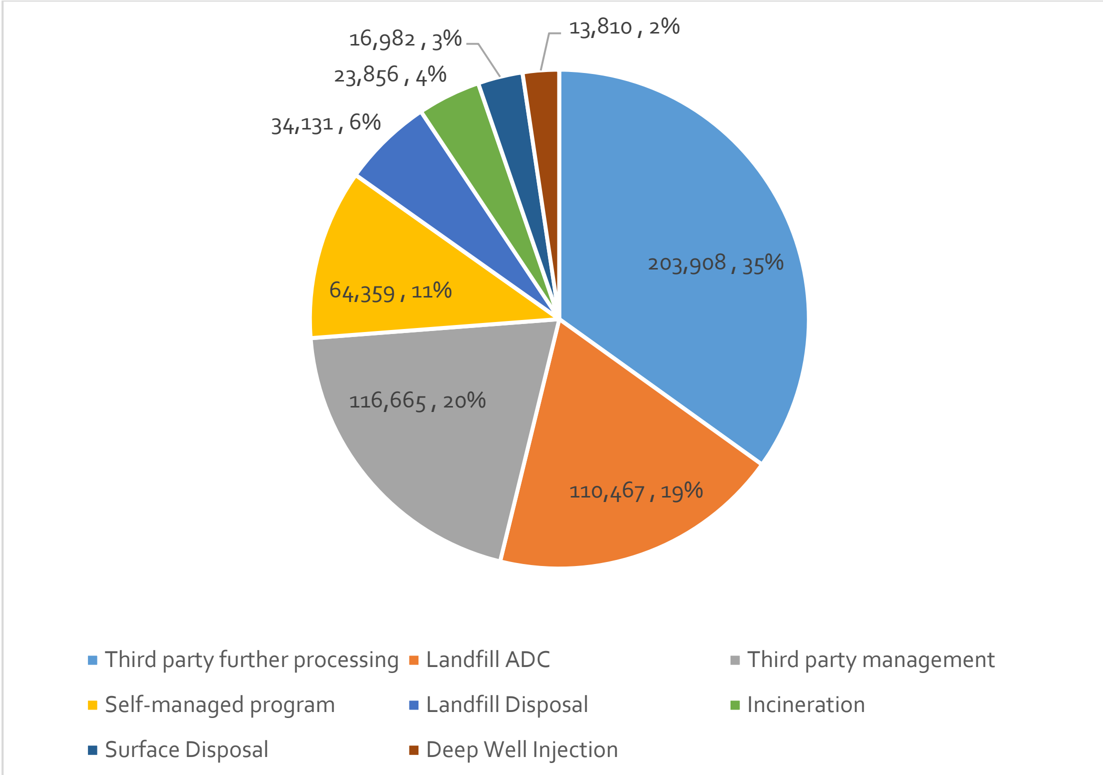

Figure 3.18 Biosolids Management Methods Used in 2017 for Biosolids Produced by California's 48 Largest WRFs (excluding Fresno)

Outside-the-Gate Costs

Material Matters obtained pricing information for approximately 40 percent of all biosolids management methods reported (Figure 19). Pricing for incineration, surface disposal, and deep well injection were not provided. Management via third-party further processing was reported to be more costly than any of the other options for which pricing was received. Responses for 21 unique third-party further processing options were received with reported pricing ranged from $40 to $73.55 per WT. Third-party management, with pricing received from 11 utilities, was the next most costly, with prices ranging from $31.95 to $63.60 per wet ton. Reported landfill disposal pricing ranged between $32 and $50.77 per WT (three (3) prices reported). Self-managed program pricing, reported by two (2) utilities, ranged from $18 to $39 per wet ton. Only one (1) utility reported pricing for alternative daily cover of $11.52 per WT; this utility has a unique agreement with the landfill, which has artificially lowered this price.

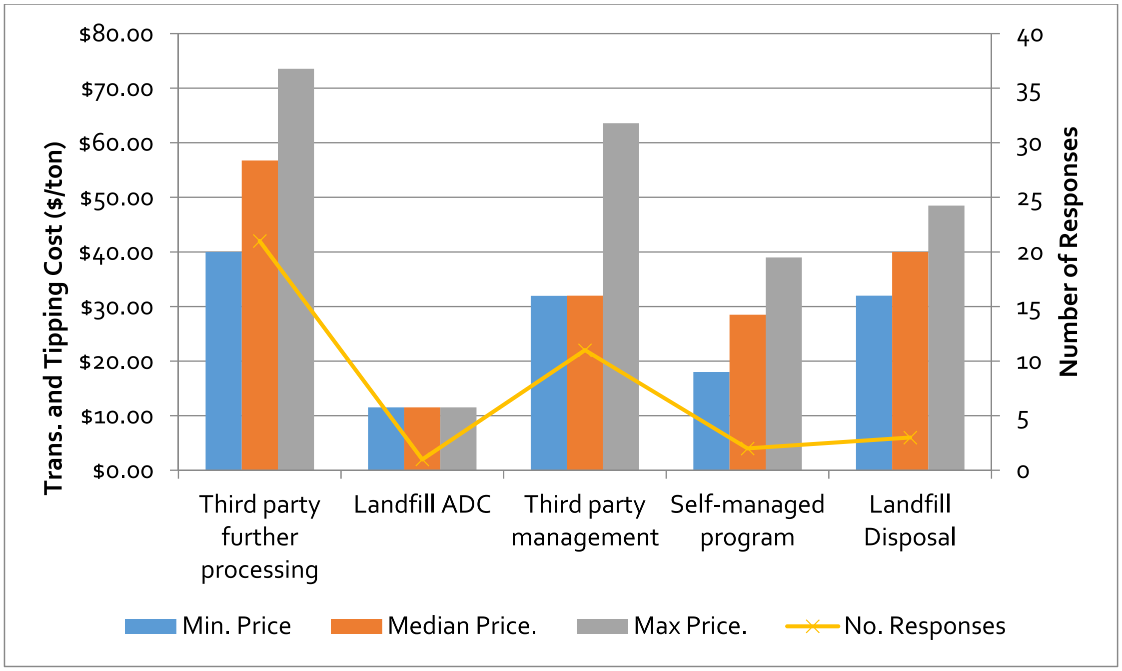

Figure 3.19 2017 Reported Biosolids Management Pricing for Biosolids Produced by ~40 Percent of California's Largest WRFs (excluding Fresno)

Future Plans

Material Matters asked utilities if they have any plans to change their biosolids management method in the next five (5) years to obtain a better understanding of the future of biosolids management in California. Of the 32 utilities Material Matters successfully connected with, 17 utilities reported they are not planning to make any significant changes to their biosolids processing or management and four (4) utilities reported minor changes to their biosolids processing (i.e., dewatering upgrades, potential plans for changing biosolids management companies). Six (6) utilities reported they would potentially change their biosolids technology and management, depending on the continued success of their current biosolids management programs. Many of the largest utilities cited product and program diversification (including upgrading at least a portion of biosolids production to Class A/EQ) critical to the ongoing success of their biosolids management programs (Table 3.5).

Table 3.5 Plans for Future Changes in Biosolids Processing and/or Biosolids Management at Other Utilities

Facility	Future/Recent Plans to Change?	Any Additional Comments
East Bay MUD WWTP	Yes	Biosolids Master Plan in progress
Palo Alto RWQCP	Yes	Starting Jan. 2019, cease incinerator operations. Transport to compost (2/3) and Lystek facility (1/3).
Santa Rosa Laguna WWTP	Yes	Plan to increase product diversification. Considering THP and thermal drying.
Union Sanitary District WWTP	Yes	Exploring adding possible alternatives via a regional collaborative effort w/Bay Area Biosolids Coalition
Monterey RWPCA	Yes	In early stages of planning to produce Class A/EQ biosolids product; considering drying or composting.
Colton WRF	Yes	Do not plan to change treatment process but plan to change biosolids contractor.
West Basin Municipal WD	Yes	Do not plan to change treatment process. Potentially planning to change contract hauler and final disposition site (currently Mecca Resource Facility and Nursery Products).
Encina WPCF	Yes	Do not plan to change treatment process. Biosolids not sold as fertilizer are currently land applied in Yuma, AZ. Interested in reducing land application hauling from Yuma, AZ to Imperial County, California.
Stockton RWCF	Yes	Do not plan to change treatment process. Potentially planning to change contract hauler.
LACSD - JWPCP	Potentially	Based on cost and beneficial use. Diversification is important.
Point Loma WWTP	Potentially	Completed Master Plan 2 Years Ago; planned to go to Class A, but now maintaining current process.
Orange County SD 2	Potentially	Completed Master Plan 2 Years Ago; follow '10 Tenants' in Plan. Diversification is critical.
Orange County SD #1	Potentially	Completed Master Plan 2 Years Ago; follow '10 Tenants' in Plan. Diversification is critical.
LACSD - Valencia WRP	Potentially	Based on cost and beneficial use. Diversification is important.
Delta Diablo WWTP	Potentially	Potential for gasification and be 'net energy exporter'. Interested in more diversification.
Los Angeles Hyperion WWTP	No	Maintain a very diverse program, although will have to adjust based on legislative changes.
San Jose/Santa Clara WRF	No	No plans to change in the near future.
Sacramento RWTP	No	No plans to change in the near future.
Central Contra Costa WWTF	No	No plans to change in the near future.
Santa Cruz WWTF	No	No plans to change in the near future.

Facility	Future/Recent Plans to Change?	Any Additional Comments
Hayward WPCF	No	No plans now, but this may change if not permitted to go to landfill in future.
Inland Empire Utilities Plt 1	No	Maintain successful operation of IERCF since 2007.
Simi Valley WQCP	No	No plans to change in the near future.
San Bernardino WRF	No	No plans to change in the near future.
Inland Empire Utilities Plt 2	No	Maintain successful operation of IERCF since 2007.
Lamont WWTF	No	No plans to change in the near future.
Valley Sanitary District	No	No plans to change in the near future.
Bakersfield WWTP 3	No	No plans to change in the near future.
San Luis Obispo WRF	No	No plans to change in the near future.
EMWD - Perris Valley RWRF	No	No plans to change in the near future.
Fairfield-Suisun WWTP	No	No plans to change in the near future.
Paso Robles WWTP	No	No plans to change in the near future.

3.5 Biosolids Market Assessment

Material Matters conducted a regional market assessment within approximately 50 miles of the Fresno-Clovis RWRF to determine the markets available for Class A/EQ and Class B biosolids products produced by the technologies under consideration by the City.

3.5.1 Approach

The Biosolids Market Assessment was conducted in a systematic manner, with each step building on the findings of the previous one. Material Matters developed a broad list of markets available within 50 miles of the Fresno-Clovis RWRF at the outset of the assessment. While the search radius for markets was predominantly limited to 50 miles, Material Matters expanded the search to 100 miles to potential opportunities and biosolids management options commonly utilized in the region.

Material Matters conducted an internet search to confirm markets available in the region, and to identify businesses within each market. Ultimately, Material Matters identified four (4) market categories and 13 markets within those categories and identified businesses within each market.

A list of specific survey information was developed to ensure adequate and consistent data collection and compilation for each interview. Material Matters personnel conducted on-site visits with identified businesses, during which time product samples (compost, thermally dried pellets, biochar, and LysteGro) and user information sheets were provided to the potential customers. When additional information was required, follow-up phone calls were conducted. Findings were compiled, organized, and analyzed.

3.5.2 Findings

Material Matters conducted interviews with potential customers from each distribution pathway to understand the advantages and disadvantages of each product, as well as outside-the-gate expenses and revenues. Material Matters identified and contacted beneficial users in the San Joaquin Valley as shown in Figure 3.20. Contact information and the status of each interview is summarized in Appendix 3-B.

In total, 13 biosolids beneficial use markets, within four (4) main categories were identified as depicted in Table 3.6.

Material Matters interviewed entities within each market to better appreciate and understand their critical market factors, including capacity, seasonality, storage needs and availability, product characteristic preferences, and outside-the-gate costs and revenues.

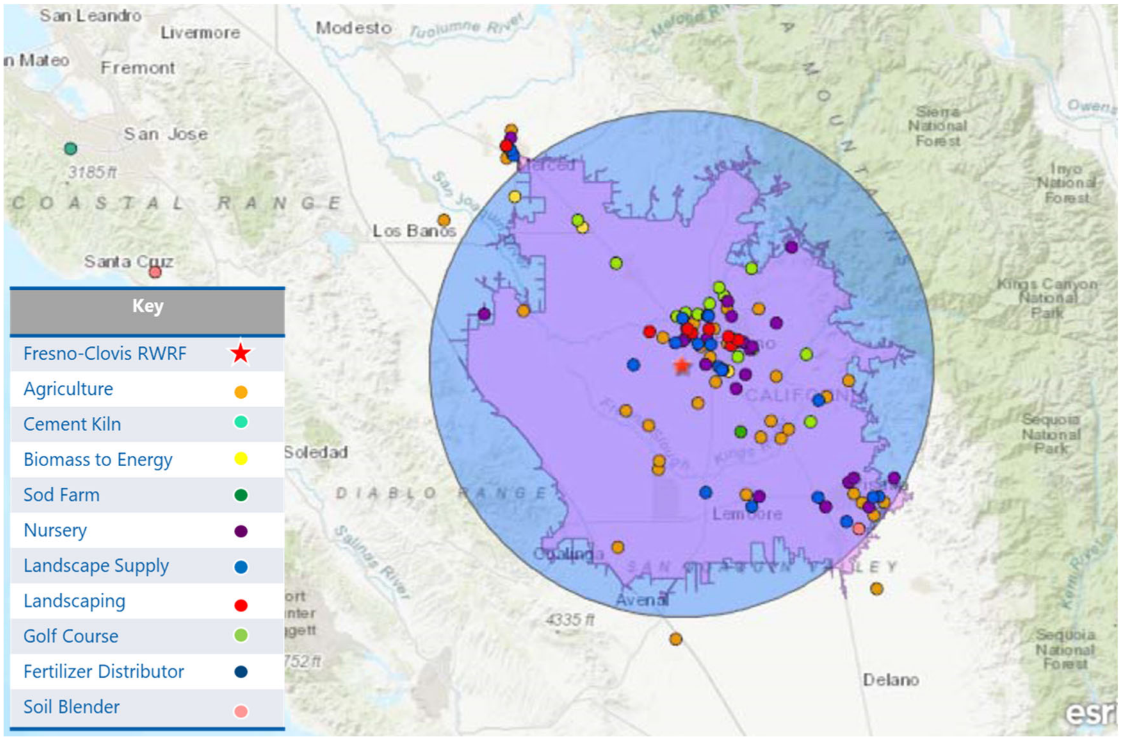

Figure 3.20 Markets Contacted during the Market Assessment

Table 3.6 Biosolids Beneficial Use Markets Identified during the Market Assessment

Agriculture	Energy	Specialty	Land Reclamation
• Feed and Fiber Crops • Food Crops • Rangeland	• Cement Kiln • Biomass to Energy	• Landscape Supply • Topsoil Manufacturers • Nurseries • Turfgrass Producers • Golf Courses • Fertilizer Distributors	• Mine Land Reclamation • Fire-Ravaged Land

3.5.2.1 Agriculture Markets

Fresno County is in the San Joaquin Valley, which has maintained an extremely robust agriculture market since the mid-1950s. Agriculture in Fresno County is extremely robust, accounting for more than seven (7) billion dollars of sales in 2017. In the San Joaquin Valley, which includes Fresno, Tulare, Merced, Kings, and Madera Counties, agriculture is categorized into three (3) major categories: feed and fiber crops, food crops, and rangeland.

The estimated range of acres required based on typical crop yields and projected portion volumes if agricultural land application is the only market pursued is shown in Figure 3.21. The 'Low' acreage assumes the same acreage can be used every year at the maximum application rate, whereas the 'High' acreage assumes some acreage may not be used every year and/or the biosolids are not land applied at the maximum agronomic rate (i.e., the rate to supply a crop with its entire nitrogen need). In the case of Class B AD cake, Class A/EQ Cake, Class A/EQ liquid, and thermally dried granules, it is assumed biosolids will be applied at a rate to meet the nitrogen needs of the crop. For biochar and Class A/EQ compost, it is assumed biosolids will be applied at a rate of two (2) to five (5) tons per acre. All products except compost can be accommodated within 6,000 acres of land; however, because compost is typically applied at a low application rate and is produced in large volumes, nearly 35,000 acres are required for land application of Class A/EQ compost.

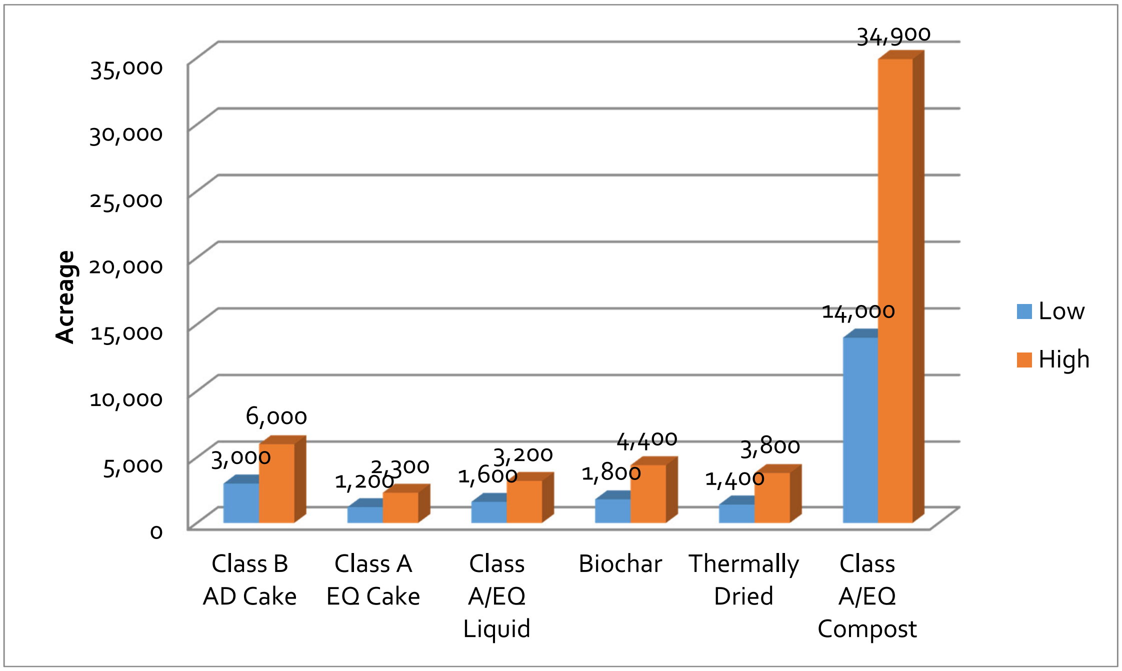

Figure 3.21 Estimated Acreage Required for each Biosolids Product

Material Matters identified and attempted to contact 42 entities in the agriculture market. Twenty-two (22) entities were successfully interviewed to understand the local agriculture market, and to gauge the level of interest in using biosolids products by local growers (Figure 3.22). These included University of California Extension; the Fresno, Merced, and Tulare County Farm Bureaus; and individual growers.

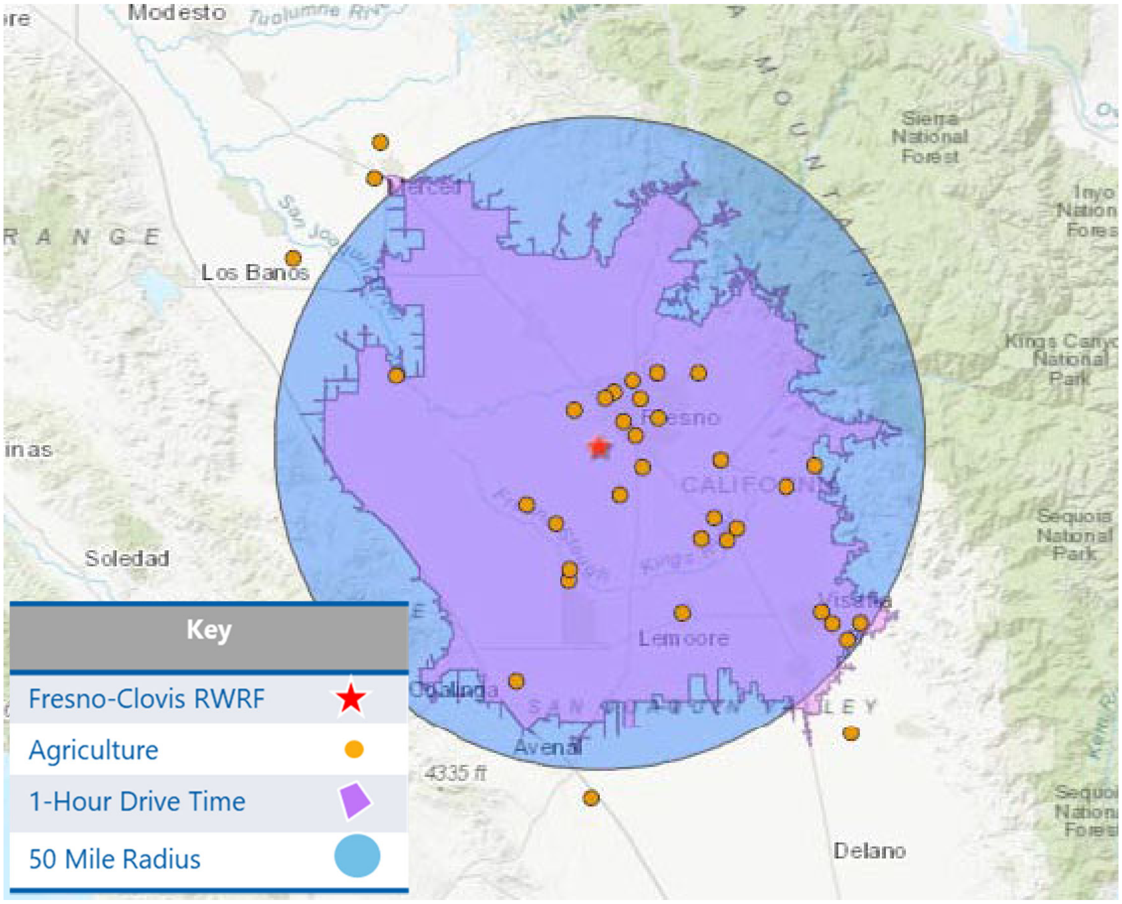

Figure 3.22 Location of Growers and Agriculture Professionals Contacted

Feed and Fiber Crops

Feed and fiber crops are crops grown to be consumed by animals or used to produce products not directly consumed by humans. Feed crops include corn, hay, and small grains, and fiber crops include cotton. Land application of biosolids as a fertilizer for feed and fiber crops is a well-established biosolids outlet in the United States that has been accepted for many decades. Biosolids provide essential nutrients and organic matter as a fertilizer and are typically applied at rates to meet the nitrogen needs of crops.

In the San Joaquin Valley, feed and fiber crops are predominantly located in southcentral Fresno County and Tulare County (Figure 3.23). Major crops locally include alfalfa hay, corn silage, and small grain silage.

In total, there are 1.2 million acres of forage land including and surrounding Fresno County (Figure 3.23); therefore, if Fresno elects to land apply all of its biosolids on forage it will only require a small fraction (between 0.19 percent and 2.9 percent) of existing forage land (Table 3.7).

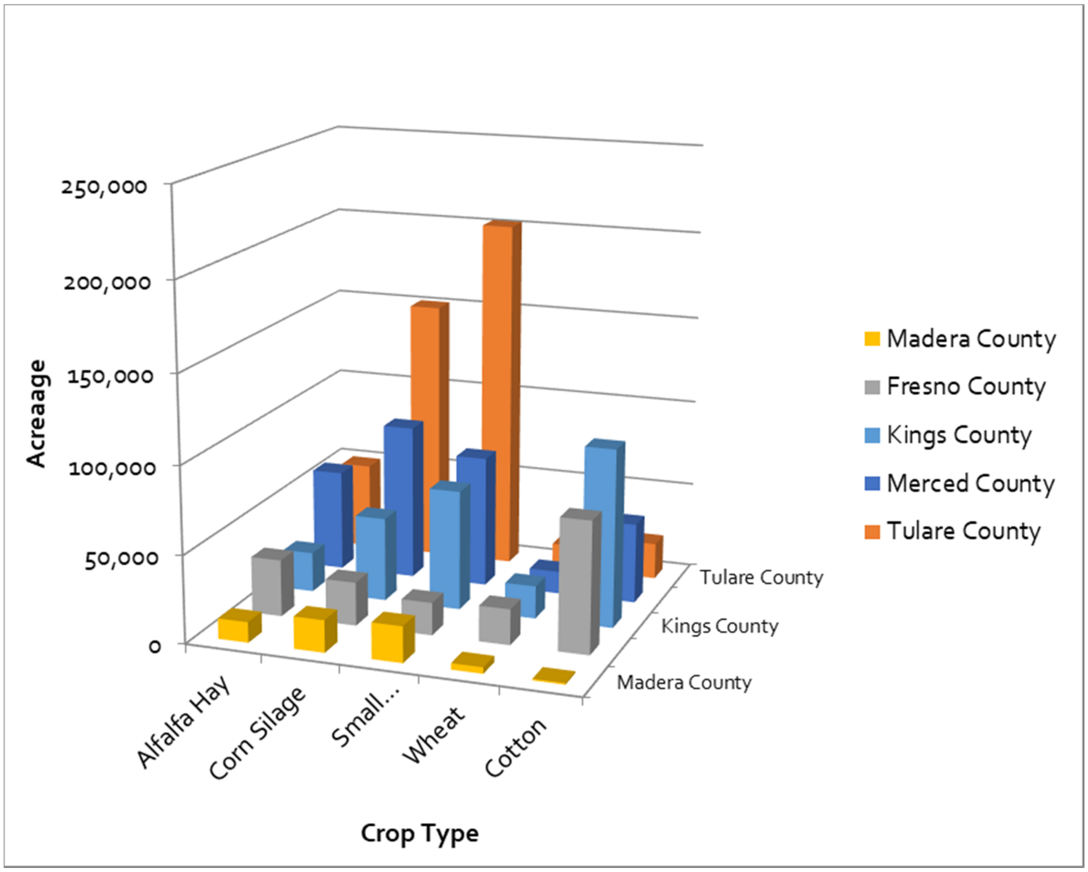

Figure 3.23 Number of Acres Growing Feed and Fiber Crops in Fresno, Tulare, Merced, Kings, and Madera Counties

Table 3.7 Percent of Local Feed and Fiber Crop Land Required to Use 100 Percent of RWRF Biosolids

Product	Percent of All Feed and Fiber Crop Land Required
Class A/EQ Cake	0.19
Class A/EQ Liquid	0.27
Biochar	0.36
Thermally Dried	0.31
Class A/EQ Compost	2.90

Feed and fiber crops are very low value crops, and, when combined with the high price of water in the San Joaquin Valley, only enough feed and fiber crops will be grown to feed the local animal population. Generally, feed and fiber cropland is directly adjacent to dairies to minimize transportation costs and so these crops already have an inexpensive source of nutrients from the local dairy.

Forage land closest to the dairy (<1/2 mile away) will typically receive liquid dairy manure (the nutrient rich wash water resulting from flushing of manure from concrete feed lanes, free stalls and milking facilities). Fields located farther away may receive cake manure (manure scraped form the dirt-floored corrals) or, in some cases, no material. It is generally difficult and expensive to move manure far from the site, which is why forages tend to be located very close to dairies. Typically, forage crops do not receive compost because compost is too expensive.

Many growers will 'double crop', meaning two (2) crops are planted in a single year. Therefore, many farmers will land apply manures two (2) times per year, in coincidence with crop rotations. Winter wheat or triticale will be planted in November and will be harvested in March. In turn, corn will be planted between March and July and will be harvested between July and August. Typically, growers spread manure after each crop comes off. Manure will be spread, the soil will be disked under, and then the field will be irrigated prior to the next crop planting. Depending on the year and if water availability is favorable, forages may also be rotated with higher value crops including cotton, processing tomatoes, onions, safflower, and garbanzo beans. As discussed in the food crop section, rotating feed and forage crops with food crops may prohibit some sites from receiving any biosolids product due to international food standards and certifications that prohibit the use of biosolids on any land used to grow certain food crops.

Most growers rely on agriculture advisors such as GAR Tootelian or Wilbur Ellis for guidance on which fertilizers and soil amendments to use. Material Matters spoke briefly with GAR Tootelian, and gained insight on opinions of the agriculture community, but was unable to connect with anyone from Wilbur Ellis or other fertilizer companies. When Fresno has decided on a technology, it is strongly recommended to connect with agriculture advisors and fertilizer distribution companies to obtain greater respect and penetration into the agriculture market.

Forage growers appear to have low to moderate interest in using a biosolids-based product (Table 3.8). In all cases, growers and professionals reported the product will need to be cost effective for a grower to use it, generally less than $2 per ton. Multiple farmers and professionals cited previous experiences with Los Angeles biosolids entering the San Joaquin Valley, and overall there was a general negative connotation with biosolids products. Additionally, growers noted the product will need to be marketed, and a product that does not 'look' like a biosolids product (i.e., compost and biochar) will have a better connotation versus Class A/EQ or Class B cake products.

Table 3.8 Feed and Fiber Crops Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Strong negative connotation from LA history	Very Low
Class A/EQ Liquid	• Infrastructure not currently in place • Active research on injecting cake manure for food safety	Low
Biochar	• Low value market; limited funds for expensive soil amendments • Little familiarity with biochar • Will need to be proven	Low
Dried Granules	• Granular fertilizer not commonly used; spread	Very Low
Compost	• Will have more of a positive connotation • Combined transportation + price key • Strong marketing campaign • Potential challenge with tomato growers (see discussion in food crops section)	Low to moderate

Food Crops

Food crops are crops grown to be directly consumed by humans. Food crops include a wide assortment of foods; specifically, in the San Joaquin Valley, food crops are dominated by nut trees (almonds and pistachios), grape vines, citrus trees, processing tomatoes, and an assortment of fruits and vegetables (Figure 3.24). Land application of biosolids products is not widely practiced due to the requirement to meet Class A/EQ standards (from a regulatory standard) and due to other industry and international restrictions. However, due to the abundance of land dedicated to growing food crops in the San Joaquin Valley, this market was explored thoroughly. As with forage crops, biosolids will provide essential nutrients and organic matter and will typically be applied at rates to meet nitrogen needs of crops.

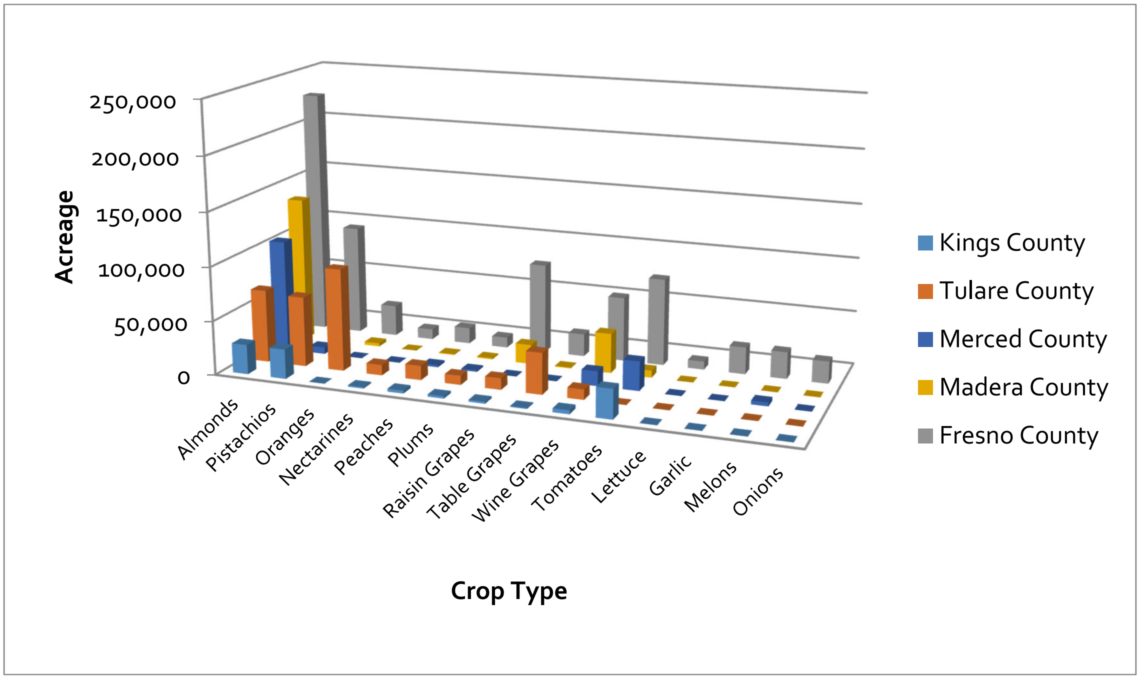

Figure 3.24 Number of Acres Growing Major Food Crops in Fresno, Tulare, Merced, Kings, and Madera Counties

Table 3.9 Percent of Local Food Crop Land Required to use 100 Percent of RWRF Biosolids

Product	Percent of All Food Crop Land Required
Class A/EQ Cake	0.15
Class A/EQ Liquid	0.21
Biochar	0.29
Thermally Dried	0.25
Class A/EQ Compost	2.30

Unlike feed and fiber crops, food crops are high value crops, so growers are more willing to dedicate resources to purchase water and nutrients to maximize crop yields (i.e., amount of product per plant). Food crops are located throughout the San Joaquin Valley.

Food crops will receive a variety of fertilizers and soil amendments, depending on the crop and grower preference. Many permanent crops (i.e., trees and vines; crops not planted every year) are irrigated through drip irrigation and receive urea-ammonium-nitrate 32 (UAN-32). While these crops receive liquid fertilizer through drip irrigation, there is minimal land application of liquid manures injected into the soil (i.e., existing drip irrigation systems would not be compatible with the Lystek high-solids liquid product.)

Approximately 25 percent of permanent crops growers will also use manure-based compost or green waste compost, at a typical application rate of two (2) to five (5) tons per acre. Manure-based compost is typically sold for $18 to $24 per ton plus transportation, and green-waste compost pricing ranges between $10 and $18 per ton plus transportation. Most compost is certified as organic by the Organic Materials Review Institute (OMRI). Notably, biosolids-based compost may not be certified by OMRI as 'organic'. Biosolids-based compost has been used in Fresno County as well. However, in October 2018, a local farm received biosolids-based compost that was malodorous, leading to multiple news stories and fostering the negative perception of biosolids in the Valley.

Some growers will also apply manure, but this is predominantly limited to grape growers. Dairy manure pricing was reported to be $3 to $4 per ton plus transportation, and chicken litter was reported at a price of $15 to $20 per ton including transportation. Row crops (i.e., vegetables including tomatoes, lettuce, garlic, melons, onions, etc.) will generally receive conventional fertilizer and some compost; use of raw manure and composted manure is limited due to concerns with bacterial contamination.

Biochar is not widely used because it is costly, and it is a very new product in the region. When asked about biochar, growers either did not know what biochar is or thought the product to be too expensive. Two (2) growers noted they have used woody waste-based biochar in the past (purchased for $300 per ton and a recommended application rate of 1 to 2 ton per acre), but the growers did not see yield increases to justify the cost of the biochar.

Most food crops (both permanent and row crops) are harvested in the fall, and compost is typically land applied after the fall harvest to allow the nutrients to be absorbed into the soil during the rainy season (November through March). Growers with drip irrigation systems will apply doses of nutrients in the spring and summer, when crops need the nutrients. As discussed in the Feed and Fiber Crops section, food row crops are often rotated with forage crops.

Food crop growers generally have a low interest in using biosolids-based products because of standards set by organizations and food buyers, and previous experience with biosolids; however, if the price is cost effective (i.e., similar cost or less costly than current product) there appears to be some opportunity for compost and biochar (Table 3.10). Notably, transportation cost was identified as a major factor in determining what soil amendments (if any) are utilized. Many growers sell food crops internationally and are certified with Global Good Agriculture Practices (Global GAP), a program that prohibits the use of any fertilizers that originated from 'human sludge'. Multiple growers also cited concerns related to new standards set by the Food Safety Modernization Act and food safety scares that have led to large product recalls. Additionally, a few growers reported the buyers of their produce (specifically tomatoes) would not purchase product from them if biosolids have ever been utilized on the land where the food crop is growing. Multiple growers had unfounded concerns of 'high metals'. As with the feed and fiber crops, food crop growers also referenced history with Los Angeles bringing biosolids into the San Joaquin Valley. Additionally, growers noted the product would need to be marketed, and a product that does not 'look' like a biosolids product (i.e., compost and biochar) will have a better connotation versus Class A/EQ or Class B cake products. In order to connect with the agriculture community, it is strongly recommended to complete research demonstrations and/or pilot studies with Fresno State University and advertise the study results through a field day, or via coordination with the Fresno County Farm Bureau.

Table 3.10 Food Crops Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Negative connotation related to historical LA application in the San Joaquin Valley	Very Low
Class A/EQ Liquid	• Liquid injection not commonly practiced; Concern that the transportation cost will be too costly	Low
Biochar	• Historically very expensive • Concern product claims are unfounded • Low product recognition • Education/demonstrations required	Low to Moderate
Dried Granules	• Most conventional fertilizer used is liquid.	Very Low
Compost	• Compost used by ~25 percent of permanent crop growers • Better perception relative to other biosolids products. • Low odor is critical (October 2018 odor event) • Will need to get 'buy-in' from County Commissioners • Price could be a driver – especially for vineyards. • Global GAP significant barrier	Low to moderate

Rangeland

Rangeland includes open land that is used for grazing animals including sheep and beef cattle. Locally, rangeland borders the eastern and western edges of the San Joaquin Valley and encompasses a large swath of land (Figure 3.25). Land application of biosolids products (and any fertilizers) is not widely practiced because rangeland operates at a narrow margin, and there is typically limited funding for soil amendments. As with feed and fiber and food crops, biosolids will provide essential nutrients and organic matter and will typically be applied at rates to meet nitrogen needs of crops.

In total, there are more than 2.9 million acres of rangeland in Fresno and surrounding Counties (Figure 3.25); therefore, if Fresno elects to land apply all of its biosolids on rangeland it will only require a small fraction (between 0.08 percent and 1.2 percent [Table 3.11]) of existing land.

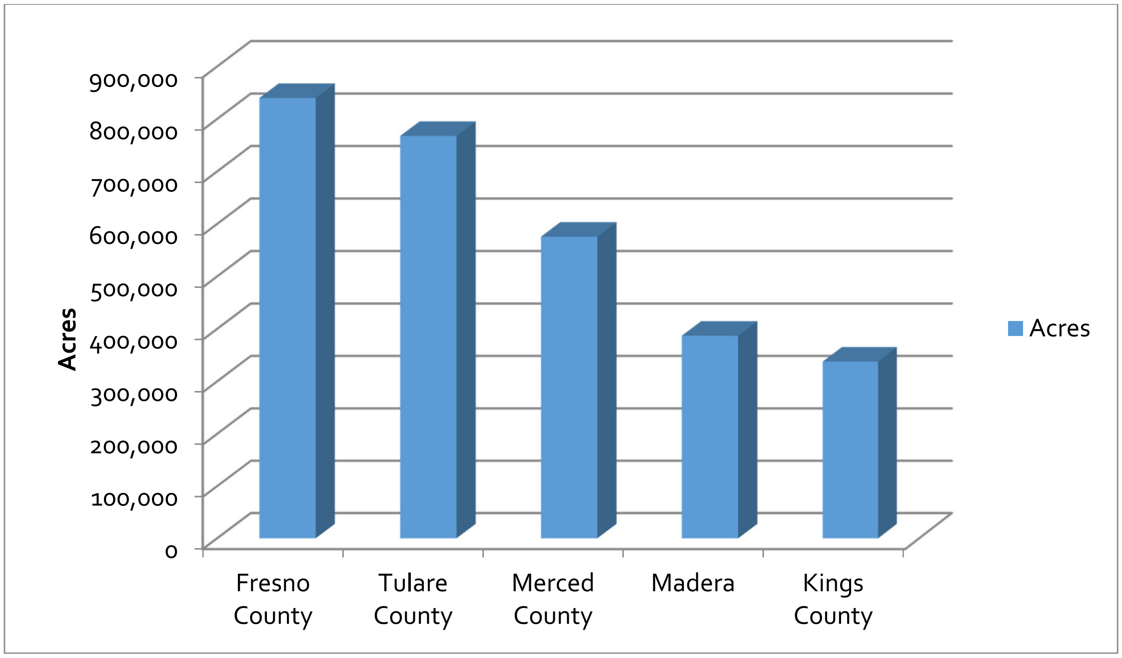

Figure 3.25 Number of Acres Dedicated to Rangeland in Fresno, Tulare, Merced, Kings, and Madera Counties

Table 3.11 Percent of Local Rangeland required to use 100 Percent of RWRF Biosolids

Product	Percent of Local Rangeland Required
Class A/EQ Cake	0.08
Class A/EQ Liquid	0.11
Biochar	0.15
Thermally Dried	0.13
Class A/EQ Compost	1.20

Similar to feed and fiber crops, rangeland is low value land, so ranchers generally do not apply any soil amendments to land used for grazing cattle, sheep, and goats. Rangeland is typically considered marginal land, so there does not appear to be a strong incentive to add soil amendments. As a result, the land typically can sustain a lower concentration of animals relative to conventional farming. In conventional animal operations, the land can generally support one animal unit (~2,000 lbs. of animal) per acre of land; however, local rangeland can tolerate approximately one (1) animal unit per five (5) to ten (10) acres.

Ranchers expressed hesitations and skepticism about the potential to apply biosolids-derived materials ranchlands. As with the food growers, there was misinformed concern about 'heavy metals,' and they generally held a negative perception of biosolids.

Ranchers have been approached by groups from Southern California, and the ranchers feel like land application of biosolids on ranchland would simply serve as a 'disposal area for waste byproducts'. Note, however, University of California (UC) Extension, which has a close connection with the local livestock and rangeland owners has begun developing a research project to use biochar on rangeland, which has temporarily been put on hold, but could serve as an impetus for using biosolids-based biochar products in the rangeland market. It appears that land application of biosolids on rangeland will require substantial incentives (i.e., payment) to ranchers to allow for land application, and entering this market will require substantial collaboration with UC Extension and other local agriculture advocates. See Table 3.12 rangeland market level of interest in biosolids products.

Table 3.12 Rangeland Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
All Products	• Very large amount of land potentially available • Spreading infrastructure not in place • Cost is critical; low margin market • Opportunity to piggy-back on UC efforts • Novel market; significant development required • Substantial incentives and education required	Low

3.5.2.2 Energy Markets

Biosolids products have been successfully utilized as a renewable energy source in multiple locations in the United States. Locally, the energy market can be divided into two (2) categories: cement kiln and biomass to energy plants (Figure 3.26). Material Matters identified three (3) and interviewed two (2) active biomass to energy plants within 50 miles of the Fresno-Clovis RWRF. There are no cement plants within 50 miles of the Fresno-Clovis RWRF; however, one (1) plant was contacted to understand if there is an opportunity to use biosolids as an alternative energy source locally.

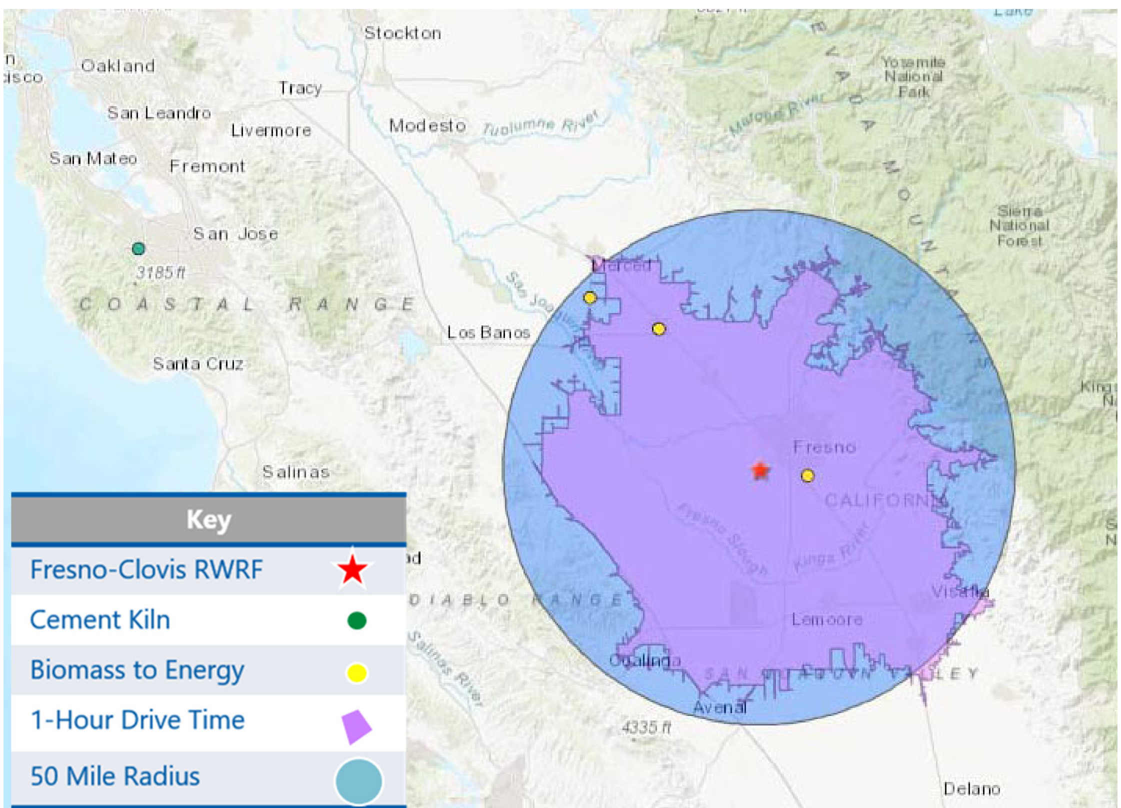

Figure 3.26 Location of Cement Kilns and Biomass to Energy Plants Contacted

Biomass to Energy

Biomass to energy plants burn organic material in a controlled manner to generate energy. Biomass to energy plants typically use chipped woody material, including agricultural waste (orchard trees and grape vines) and clean construction wood as a feedstock for the facility. Locally in the San Joaquin Valley, biomass to energy plants provide growers of permanent crops with an outlet for woody debris. Typically, biomass is transported to a biomass to energy plant and the plant will pay a small fee to the hauler for the product.

Biomass to Energy plants maintain Title V air permits which limits the types of material that can be accepted and processed as well as the quantity of material that can be burned. Biosolids is a novel product in the Biomass to Energy market, and therefore will not be included as a permitted material in any existing Title V permit.

Overall, biomass to energy plants have a low interest in using biosolids products (Table 3.13). In general, the existing biomass to energy plants are running at full capacity because multiple biomass to energy plants have been shut down permanently or idled in recent years due to challenges meeting air permit requirements and competition with lower costing alternative energy sources (i.e., solar). Additionally, in order to use biosolids, a biomass to energy plant will be required to modify their Title V permits, even to complete a demonstration burn. Local plants showed some interest in using biosolids if the 'price is right'; for example, if Fresno pays the Biomass-to-Energy plants a tipping fee to allow product to be burned at the plant.

Table 3.13 Biomass to Energy Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Not Applicable	None
Class A/EQ Liquid	• Not Applicable	None
Biochar	• Not Applicable	None
Dried Granules	• Low cost fuel source • Title V permit change required • Novel market, pilot test required	Low
Compost	• Not Applicable	None

Cement Kiln

Cement kilns require a significant amount of energy to convert limestone and other inputs into the final product called 'clinker'. Coal, a non-renewable fossil fuel, is conventionally used to heat these raw inputs to very high temperatures required for this process. Pelletized and/or heat-dried biosolids are beginning to be used to supplement traditional coal as a renewable fuel source in the combustion process for the purposes of heat recovery and energy generation at cement plants.

Lehigh Cement operates three (3) cement plants in California. The Silicon Valley Cement plant (identified on the map) is not permitted to accept biosolids, and they do not anticipate accepting alternative fuels in the future due to location sensitivities (odors, traffic, etc.). The Redding plant utilizes woody waste and tires as an alternative fuel source, and they are not planning to modify the permit to accept biosolids. However, the Tehachapi plant, located approximately two (2) hours south of the Fresno-Clovis RWRF, is permitted to accept and is actively using biosolids. The minimum biosolids characteristics are summarized in Table 3.14.

Table 3.14 Lehigh Cements' Required Biosolids Characteristics

Criteria	Acceptable Product
Free moisture, 'as received' (percent)	≤ 10%
BTU heating value (DW basis)	≥ 5,500 BTU
Sulfur (DW basis)	< 0.5%
Chlorine (DW basis)	< 0.1 ppm
Bulk density	35 lb/cu ft
Particle size	< 6 mm
Temperature at time of transport	<125°F

Lehigh Cement did not provide pricing information for the currently accepted product(s) and did not cite the source or quantity of biosolids currently utilized, or potential to accept additional biosolids in the future. They did provide a list of minimum requirements for any biosolids product accepted at Lehigh Cement plants. They noted that if Fresno does produce thermally dried biosolids in the future and they are looking for an outlet, they could contact Lehigh Cement to discuss their current capacity and ability to accept additional feedstocks (Table 3.15).

Table 3.15 Cement Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Not Applicable	None
Class A/EQ Liquid	• Not Applicable	None
Biochar	• Not Applicable	None
Dried Granules	• Low cost fuel source • Only permitted plant is in Tehachapi (2 hours away), potential for expansion, but no new permits	Low to Moderate
Compost	• Not Applicable	None

3.5.2.3 Specialty Markets

Specialty markets include markets that are generally smaller volume users, and include Landscape Supply Companies/Topsoil Manufacturers and Turfgrass Producers/Golf Courses/Fertilizer Distributors.

Landscape Supply/Topsoil Manufacturers

The first set of specialty markets, landscape supply companies and topsoil manufacturers, produce and/or supply soil products for commercial (construction, distribution to nurseries) and residential use. Landscape supply companies generally provide a suite of hardscapes (i.e., rocks, gravel, lime, etc.) and soft-scape products (i.e., compost, mulch, subsoil, soil blends, etc.) for use in landscaping and construction. Topsoil manufacturers mix soil (i.e., subsoil, topsoil), mineral components (i.e., sand), and materials with high organic matter content (i.e., bark, peat, compost, and biosolids) for a variety of industries including horticulture, landscaping, land development (construction), and site restoration. Landscape supply companies may only provide raw feedstocks as they receive them, or they may mix materials to create soil blends.

In the landscape supply market, biosolids are distributed as a single product, not blended with any other products. In the soil blending market, however, biosolids are blended with other materials such as subsoil, topsoil, and sand, to enhance the macro-and micronutrient content and organic matter content, and to improve soil drainage and water holding capacity. Material Matters identified 23 landscape supply and soil-blending facilities within 50 miles of the Fresno-Clovis RWRF. Interviews were conducted with 12 of these facilities (Figure 3.27).

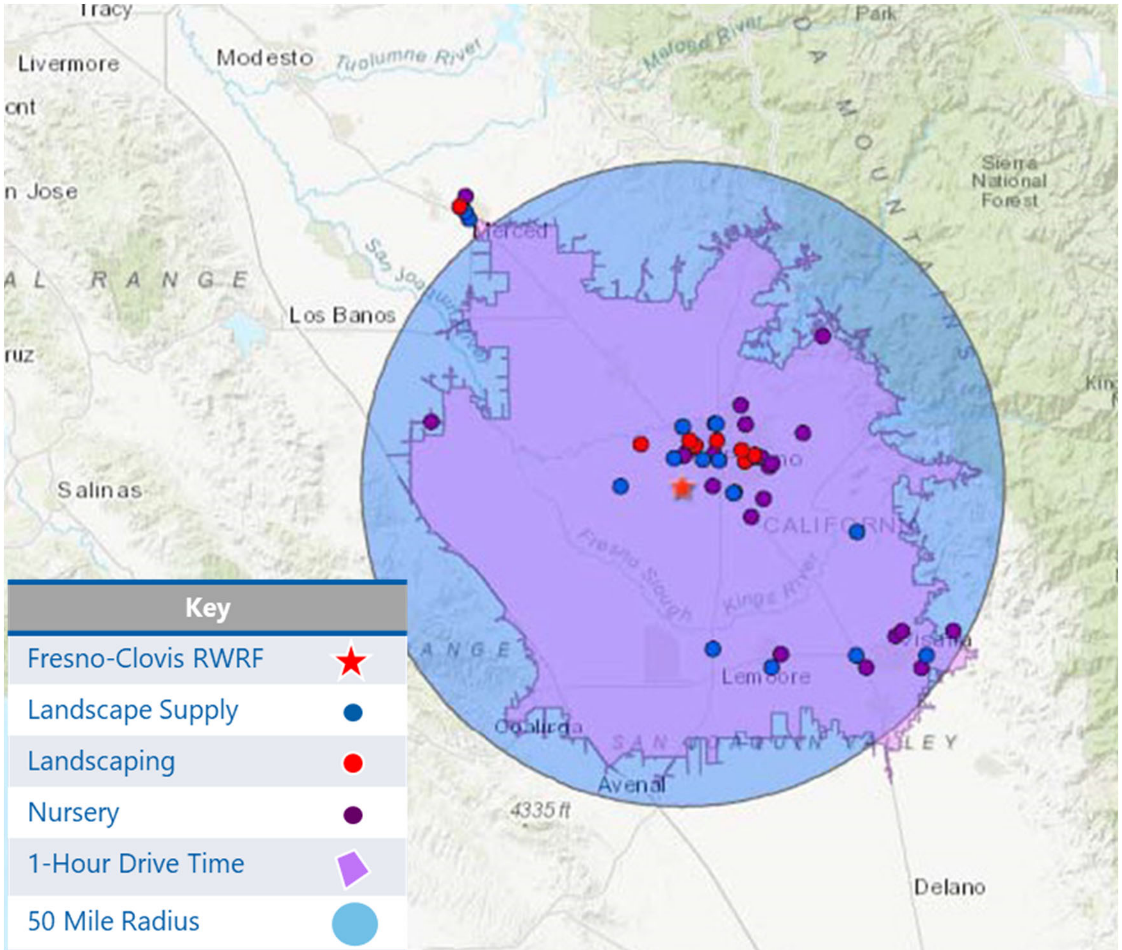

Figure 3.27 Location of Landscaping Supply Companies, Nurseries, and Landscapers Contacted

Landscape supply and topsoil manufacturing market are low-margin markets, so products are typically selected based on price; note, however, that some landscape supply companies will select a higher-priced product if the lower priced product as poor quality (i.e., presence of inert material, inconsistent particle size, etc.) or product is not available when needed. Landscape supply and soil blending companies contacted during that market assessment reported selling bark ($55/yd^3), humus ($30/yd^3), fill dirt ($27/yd^3), planting mix, dairy manure compost ($32/yd^3), green waste compost ($30/yd^3), and peat moss ($60/yd^3). Most landscape supply companies were unfamiliar with biochar or had heard briefly of biochar and noted it to be an emerging product. Most of the products are OMRI certified. It is estimated these companies have a ~50 percent mark-up on these products, so their purchase price is approximately half the price listed herein.

Locally, most landscape supply companies sell most of their products (specifically compost products and gypsum) to the bulk agriculture market, with secondary distribution to nurseries, and directly to homeowners. The bulk agriculture market demands product in the fall, while nurseries and homeowners have a greater demand for product in the spring. Most landscape supply companies contacted sell between 100 and 300 yd^3 of compost and humus products/month, with a few larger facilities selling more than 500 yd^3/month.

Landscape supply businesses typically sell most products in bulk, either by the cubic yard or ton. However, very large soil blending companies that will ship products throughout the United States such as Kellogg's, E.B. Stone, and G&B organics will bag products into ~50 lb. bags for distribution.

Landscape supply and soil blending companies have low to moderate interest in using a biosolids-based product (Table 3.16). Of all products available, compost appears to be the most favorable opportunity, as these companies already sell compost. Most interviewed companies did not oppose using/selling a biosolids-based product but noted some of there is a negative stigma associated with 'human waste' from some of their customers (primarily homeowners). For landscape supply companies to consider using biosolids-based product, it will need to be cost effective, have a low odor profile, and be available when needed.

Table 3.16 Landscape Supply and Soil Manufacturing Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Product 'as-is' not compatible with equipment • Will need to allow biosolids to cure / dry for use	Very Low
Class A/EQ Liquid	• Product not compatible with market	Not Applicable
Biochar	• Some soil blends contain biochar • Emerging market; many unfamiliar. Will require education	Low
Dried Granules	• Negative experience with other granular products	Very Low
Compost	• Best potential is for ornamentals, non-consumables • Users very familiar with compost; price critical • Must be available when needed (i.e., storage at WWTP) • Product must be low-odor and consistent over time	Low to Moderate

Sod Production/Golf Courses/Fertilizer Distributors

Sod production is a specialized agricultural market that involves growing a stand of high quality turfgrass and harvesting the grass with the roots and a thin layer of topsoil. Sod is typically used by landscapers and building contractors for parks, golf courses, athletic fields, schools, garden centers, home lawns, road construction sites, and commercial cemeteries. In most cases, sod is used locally to minimize cost, and to maintain the sod's physical integrity.

Similarly, the golf course market is a specialized market that takes extreme care to manage the quality of the greens, fairways, and overall landscaping to achieve the professional look demanded by the industry's customers. In fact, most golf courses hire a Superintendent whose primary responsibility is to attend to the golf course landscaping.

Fertilizer distributors sell a variety of conventional and/or natural fertilizer products specialty markets such as the sod production and golf course markets, as well as the bulk agriculture market. Fertilizer distributors may carry only their own brand of fertilizers or may carry a wide assortment of fertilizers produced by multiple fertilizer companies. Fertilizer distributors have a close connection with many individuals from each regional specialty markets, and many of these markets rely on fertilizer distributors for advice pertaining to appropriate fertilizers, herbicides, and fungicides.

In the sod production market, biosolids can be incorporated into the soil prior to planting to provide soil amending and fertilizer benefits for turfgrass establishment. Biosolids can also be top-dressed on the turfgrass as a slow-release nitrogen fertilizer in both the Turfgrass Production and Golf Course Market. Material Matters identified 14 and interviewed four (4) golf courses within 50 miles of the Fresno-Clovis RWRF and identified one (1) sod producer near the Fresno-Clovis RWRF (Figure 3.28). Material Matters was unable to connect directly with the sod producer in the region; however, this market is anticipated to be very small due to limited locations and the local transition away from sod and towards drought-tolerant landscaping.

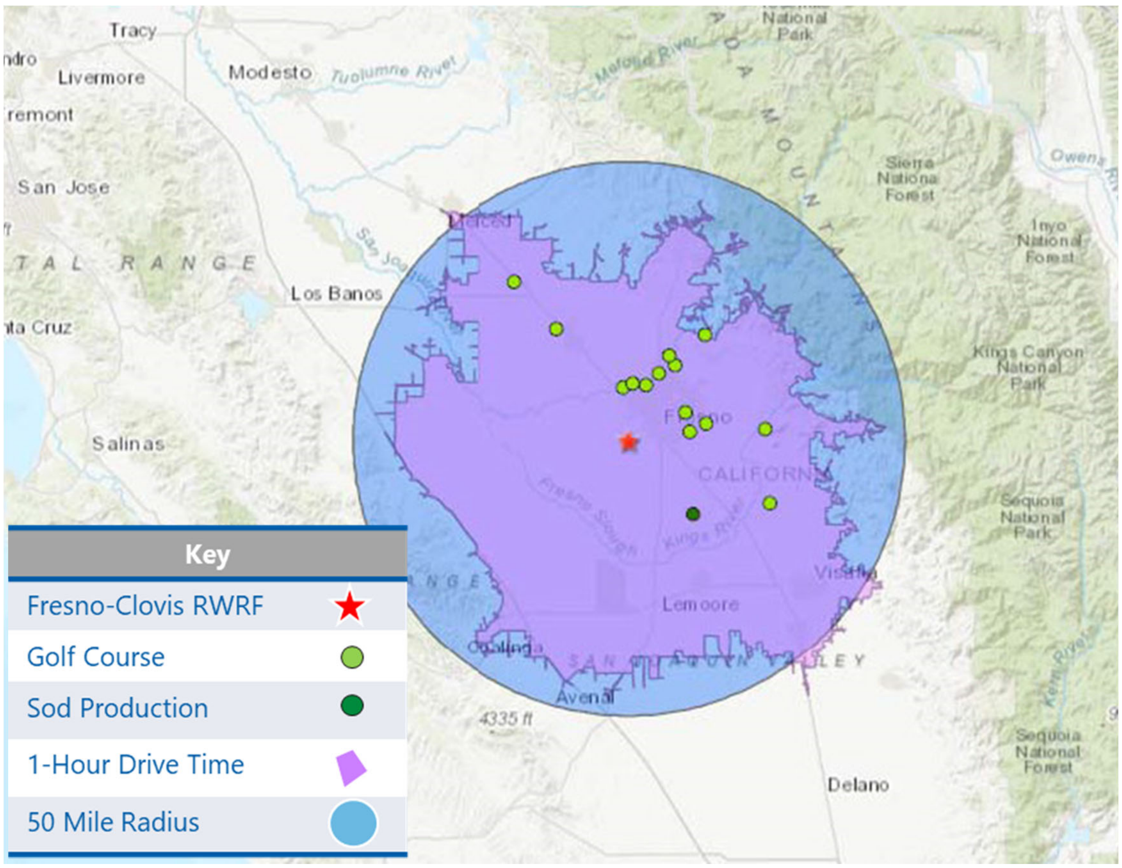

Figure 3.28 Location of Golf Courses and Sod Producers Contacted

Golf courses apply fertilizers on the tees, fairways, and greens three times per year – generally in the spring, mid-summer, and fall. Locally, the fairways are primarily fertilized through fertigation; that is, fertilizer is included with the irrigation water. In contrast, tees and greens are commonly fertilized with both foliar and granular fertilizers. Assuming tees and greens comprise approximately 10 to 20 acres of a golf course, and these areas receive ~3 lbs. of plant available nitrogen (PAN) per year, each golf course could potentially use 50 to 100 tons of dried biosolids per year (<0.5 percent of Fresno-Clovis RWRF production). Note that conventional fertilizers are much more concentrated relative to biosolids products; whereas, a golf course may need 50 to

100 tons of biosolids to meet nitrogen needs, the same amount of nutrients can be provided by three (3) tons of conventional fertilizer.

Products used in the golf course market have very specific physical and chemical requirements. Because golf courses have very high public access, fertilizers must be low odor. Fertilizers must also meet specific sizing requirements, which are measured by size guide number (SGN); the size guide number is determined by calculating the average particle size of a product granule in millimeters and multiplying by 100. Preferred SGN size range for golf courses is less than 100. Golf courses typically have minimal storage under cover, so fertilizer products must be supplied in bags or one (1) ton totes.

Most golf courses contract with fertilizer supply companies, such as Wilbur Ellis, to meet their fertilizer needs. Material Matters attempted to contact the fertilizer supply companies but were unable to connect with representatives from each of these facilities. If Fresno decides to move forward with thermal drying technology, it is strongly recommended to connect with fertilizer distribution companies to obtain greater penetration into the golf course market.

Golf courses showed a low to moderate interest in using a thermally dried biosolids product (Table 3.17). Of all products being considered, only thermally dried granules are suitable for the sod production and golf course markets. Interviewed golf courses showed specific interest in using a biosolids-based product if it would be more cost-effective than the conventional fertilizers they are currently using. Most fertilizers are expensive, costing hundreds of dollars per ton. However, the fertilizers are much more concentrated, so they can be applied at a much lower rate. Therefore, pricing of a biosolids product will also need to take additional labor costs associated with spreading the fertilizer into consideration. For golf courses to consider using biosolids-based product, it will need to be cost effective, have a low odor profile, and be available when needed.

Table 3.17 Turfgrass Production and Golf Course Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Not compatible with spreading equipment	Very Low
Class A/EQ Liquid	• Not compatible with spreading equipment	Very Low
Biochar	• Tight budget; need to be low / no cost • Demonstrations/research may be necessary to prove benefits • Low volume users	Low
Dried Granules	• Familiarity with Milorganite • Low odor and narrow SGN required • Bagging or supersacks required • Low volume user (<100 tons/golf course/yr.) • Connect with fertilizer distributor (i.e., Wilbur Ellis)	Low to Moderate
Compost	• Not compatible with spreading equipment	Very Low

3.5.2.4 Land Reclamation Markets

Disturbed land reclamation is the process of stabilizing the soil and reestablishing vegetation on land previously utilized for mining or on industrial sites/brownfields (drastically disturbed lands). In many cases, especially in the case of abandoned mines, the topsoil has been stripped and removed, and the remaining soil is highly erodible with little capacity to sustain vegetative growth over time. Biosolids have not yet been used for land reclamation in California; however, Class B cake and Class A/EQ composted biosolids have been successfully used for land reclamation in multiple states across the United States.

The California Association of Sanitary Agencies (CASA) has been working since 2007 to utilize biosolids in California to reclaim fire ravaged land. Recent increases in the frequency and severity of wildfires have created large portions of the California landscape –that suffer from extensive water quality impairment, increased risk of flooding and landslides, sparse native vegetation, and invasive plant proliferation. CASA is in the midst of developing a $200,000 targeted research project to demonstrate the benefits of using biosolids for fire-ravaged lands. To date, seven (7) utilities have donated $10,000 each, and the Water Research Foundation will match these funds. CASA submitted a preproposal for the project to WRF in April 2018. The project includes two fire-ravaged land sites – one in Northern California and one in southern California. Three biosolids products (Class B cake, thermally dried biosolids, and Lystek product) are included in the proposed projects. At present, the research project is in a holding pattern until they can find a viable site and additional funding. Table 3.18 shows the land reclamation market level of interest in biosolids products.

Table 3.18 Land Reclamation Market Level of Interest in Biosolids Products

Biosolids Product	Market Considerations	Level of Interest
Class A/EQ Cake	• Novel market in CA; CASA efforts 10+ years ongoing • Concern of promoting invasive species	Low
Class A/EQ Liquid	• Novel market in CA; CASA efforts 10+ years ongoing • Concern of promoting invasive species	Low
Biochar	• Established product used for reclamation plantings • Perception product is not 'native' • Concern of promoting invasive species	Low
Dried Granules	• Novel market in CA; CASA efforts 10+ years ongoing • Concern of promoting invasive species	Low
Compost	• Novel market in CA; CASA efforts 10+ years ongoing • Precedent using compost in Colorado • Concern of promoting invasive species	Low

3.6 Outside-the-Gate Cost Estimates

Based on the information gathered during the market assessment, Material Matters also estimated the annual outside-the-gate costs (and revenues) associated with each product (Table 3.19). Outside-the-gate costs include costs associated with marketing, transportation, and the final use of the biosolids product. Outside-the-gate costs do not account for any capital or operations and maintenance (O&M) costs associated with the biosolids processing equipment. Based on the limitations identified in the market assessment, management of Class B Cake, Class A/EQ Cake, and Class A/EQ liquid are best suited for management through a third-party contractor such as Synagro, Lystek, or Denali. The cost estimate assumes the high cost of the City's biosolids management program, as pricing is not anticipated to become any less costly. Additionally, the pricing provided assumes the product will be high quality, with low malodor potential. The estimated costs for biochar, thermally dried granules, and compost assume the City will be responsible for managing and marketing each product. Note, however, that the cost estimate for all products does not include any funding for research or demonstrations with the local customers or Universities. With these cost estimates, compost has the lowest outside the gate costs at a revenue of approximately $5,000 per year, and the Lystek product has the greatest outside the gate cost of $4.47 million per year.

Table 3.19 Land Reclamation Market Level of Interest in Biosolids Products

Product	Management Method	Total Revenue or Expense per WT	Tonnage	Annual Marketing Cost	Total Outside-the-Gate Costs or Revenues
Class B Biosolids	Third-Party	($34.00)	88,000	NA(1)	($2,992,000)
Class A/EQ Cake	Third-Party	($34.00)	46,000	NA(1)	($1,564,000)
Class A/EQ Liquid	Third-Party	($34.00)	131,400	NA(1)	($4,468,000)
Biochar	Self-Managed	$1.50	8,900	$100,000	($86,650)
Thermally Dried Granules	Self-Managed	$1.50	20,800	$100,000	($68,800)
Compost	Self-Managed	$1.50	69,700	$100,000	$4,550

Notes:
(1) Not Applicable

3.7 Findings and Recommendations

Material Matters conducted a biosolids market assessment for locally available markets for each of the products under consideration as a part of the Fresno-Clovis RWRF's Biosolids Master Plan. Products under consideration include: Class B anaerobically digested biosolids (baseline), Class A/EQ Cake produced via thermal hydrolysis, Class A/EQ liquid produced via post-digestion thermo-chemical hydrolysis, biochar produced via pyrolysis or gasification, Class A/EQ dried granule produced via thermal drying, and compost produced via composting.

The market assessment findings reveal Fresno's biosolids management program is cost-effective relative to biosolids management programs across California. The City's program has operated at a price of $26 to $28 per wet ton from 2013 through 2018, which is approximately two-thirds to half the price of most other biosolids management programs in California. Two (2) new contracts began in November 2018 at $31.86 and $33.85 per wet ton, and the City's biosolids management program continues to be less costly than the majority of other biosolids management programs in California.

The market assessment revealed that Class A/EQ compost is the biosolids product preferred by most local markets. This is because biosolids compost can be a direct substitute for other compost products (i.e., green waste compost and manure compost) that are commonly utilized by growers of food crops and by landscape supply companies in the region. While compost appears to be the most favored product, its use is limited in some markets due to standards set by an international food organization (Global GAP) and food companies that ban the use of biosolids products. As a result, the sale of biosolids compost is estimated to have net outside-the-gate (i.e., transportation and tipping fee) **revenue** of ~$5,000 per year.

In contrast, most interviewed customers were either unfamiliar with or previously used biochar and did not see benefits to warrant typical market price of $500+ per ton. While biochar is not well known, it appears there is an opportunity to develop the biochar market through partnership with local Universities and the Governor's Office of Planning and Research, which are engaged in multiple biochar research projects across the state. Due to the low volume produced and the marketing efforts, it is estimated biochar will initially **cost** the City ~$87,000 per year to market the product for beneficial use.

Thermally dried granules are also favorable for some specialty markets, such as golf courses. They too can be a low-cost substitute for growers that use granular fertilizer (note there is an increasing trend for many growers in the region to administer liquid fertilizer through drip irrigation). Estimated net outside-the-gate costs for granular fertilizer are ~$69,000 per year.

Most interviewed customers maintain a strong negative perception of Class A/EQ Cake and Class B Cake products due to history with biosolids being imported into the San Joaquin Valley from the Los Angeles area. Due to some of these challenges, it appears the most suitable management method for Class A/EQ Cake, Class B Cake, and Class A/EQ liquid is through a third-party vendor, which is estimated to have outside-the-gate management costs between $1.5 million and $4.7 million per year.

An overview of the biosolids market assessment is depicted in Table 3.20. No checkmarks indicate the market has a poor outlook because it meets at least two (2) of the following criteria: the level of interest is very low, the market can only accept a small percentage of the City's biosolids and has a very narrow range of acceptable biosolids characteristics due to market preferences or regulatory pressures. One checkmark indicates the market has a low interest level in the product, and it will require a significant effort to develop the market. Two checkmarks indicate the market is an established market, there is a moderate level of interest in using the product, and the market will require a moderate effort to develop the market, and the market can tolerate some variation in product quality. Three checkmarks indicate the market is an established market, and multiple entities showed a strong interest in using most or all the product. Note that no markets meet the three checkmark criteria.

While some markets do have a stronger interest in biosolids products than others, penetration into any local markets will require substantial marketing effort, which may include collaboration with the Fresno Farm Bureau and a partnership with Fresno State University to conduct demonstrations and trials. Distribution of any biosolids product will also require substantial public outreach and education to gain acceptance from the local community.

Table 3.20 Biosolids Market Assessment Summary

Product	Market						
	Food Crops	Feed and Fiber Crops	Rangeland	Energy	Landscape Supply/ Soil Blender	Golf Courses	Land Restoration
Class B Biosolids		✓	✓				
Class A/EQ Liquid	✓	✓	✓				✓
Class A/EQ Cake			✓				✓
Biochar	✓	✓	✓		✓	✓	✓
Thermally Dried Granules			✓	✓		✓	✓
Compost	✓	✓	✓		✓		

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Chapter 4

EVALUATION OF BIOSOLIDS MANAGEMENT ALTERNATIVES

4.1 Purpose

This chapter presents the biosolids management alternatives evaluation, including descriptions of the alternatives, the methodology used, and the results and recommendations. A list of known biosolids management alternatives was compiled based on the goals and objectives of this project. Biosolids management alternatives capable of stabilizing the solids received at the Regional Water Reclamation Facility (RWRF) and creating a beneficial product were evaluated.

As a first step, pass/fail initial screening criteria were used to eliminate alternatives deemed infeasible or impractical at this point in time. The remaining alternatives underwent a detailed evaluation based on financial (life cycle costs) and non-financial (technical, social, and environmental) criteria. The financial evaluation takes into account capital and operation and maintenance (O&M) costs presented as life cycle costs. The non-financial evaluation of the alternatives was performed by multiplying the criteria scores by the criteria weights which were both based on City of Fresno (City) input. The evaluations resulted in short- and long-term recommendations for biosolids management at the RWRF.

4.2 Initial Screening of Biosolids Management Alternatives

For the biosolids management alternatives evaluation, a comprehensive list of processes capable of achieving stabilization was compiled. Pass/fail initial screening criteria were used to eliminate alternatives deemed infeasible or impractical. The alternatives deemed viable were carried forward to the detailed evaluation. The following sections include descriptions of each alternative, and the methodology and results from the initial screening.

4.2.1 General Alternative Descriptions

4.2.1.1 Baseline: Mesophilic Anaerobic Digestion with Three New Digesters: Class B Cake

Mesophilic Anaerobic Digestion (MAD) is the most common sludge stabilization process in the United States. In this process, primary and thickened sludge are fed into a heated and mixed digester, where the sludge degrades in the absence of oxygen. MAD is operated at temperatures between 95 and 105 degrees Fahrenheit (°F), with a solids residence time (SRT) of 15 days or more.

The digestion process occurs in three stages:

- Hydrolysis: solubilization of particulate matter.
- Acidification: production of volatile acids.
- Methanogenesis: formation of methane gas.

During hydrolysis, the proteins, carbohydrates, lipids, and other complex organics that constitute sludge become soluble. During acidification, acetogenic bacteria convert the biodegradable organics into low molecular weight volatile fatty acids (VFAs). In the last stage, methanogenic bacteria convert the VFAs into methane and carbon dioxide gases. With MAD, these processes all occur within one reactor, even though both groups of bacteria, acetogens, and methanogens have considerably different optimal conditions for growth.

Anaerobic digestion is classified as either Class A or Class B, depending on the ability to meet time and temperature requirements for pathogen reduction (PR), per 40 CFR 503 federal biosolids regulations. To meet Class B PR requirements, the solids retention time (SRT) in MAD must be at least 15 days.

Anaerobic conditions in these digesters release ammonia from the solids into the liquid, which remains in the liquid stream during dewatering (centrate) and is returned to the plant's headworks. This ammonia recycle stream increases the load to the secondary treatment process, requiring additional energy input for treatment.

4.2.1.2 Baseline: Mesophilic Anaerobic Digestion with Process Optimization (Higher Percent Total Solids): Class B Cake

Chapter 1 identified several additions and modifications that could address the capacity constraints of the existing solids handling facilities. One recommendation is to increase the primary sludge (PS) and thickened waste activated sludge (TWAS) solids concentrations to minimize hydraulic loads on the digesters.

This alternative is primarily an operational modification, and only minimal new equipment may be required. The only expected capital expense would be to replace the PS and TWAS pumps to handle higher solids concentrations. The final product and end use (Class B cake) would not change from the current operation.

4.2.1.3 Baseline: Mesophilic Anaerobic Digestion with Recuperative Thickening: Class B Cake

Recuperative thickening, such as the Anaergia Omnivore process, is a modified version of the MAD process that thickens and recirculates the solids in the digester. This process increases the organic loading rate up to three times that of MAD, while achieving similar volatile solids reduction and biogas production.

MAD digesters are typically designed to maintain a hydraulic retention time (HRT) of 15 to 30 days and operated in a ‘flow in, flow out’ fashion, whereby microorganisms are constantly being removed from the tank. To allow sufficient time for methanogens to grow and avoid washout, the digesters are designed to be large enough to accommodate long HRTs.

Recuperative thickening, on the other hand, avoids losing active microbiology by returning a concentrated stream of digestate back to the digester. The thickening process is operated to provide the SRT required for the microbiology to complete the digestion process (15 to 30 days). With an internal solids return stream, the SRT is controlled separately from the HRT. Therefore, the required SRT can be achieved with a lower HRT. Additionally, the digester can handle organic loading rates up to three times higher because the concentrated microbiology remains active in the tank.

Recuperative thickening digesters maintain the digestate at 6 percent solids. To do this, the digestate is removed from the tank, thickened to 12 percent solids with a screw thickener and polymer feed system, and returned to the digester. Each recuperative thickening digester would be retrofitted with a screw thickener. To operate and maintain the screw thickener, a washwater connection and compressed air are needed. Pressate, which is similar to dewatering centrate, is returned to the headworks.

With the thicker digestate, positive displacement pumps are needed for all pumping applications, including sludge heating and recirculation. Special high-torque, low-speed mixers must also be installed in the digester (three per digester) to handle the higher solids concentration in the digesters.

The mixers are installed on guide rails so they can be lifted into a service box area, allowing them to be serviced without interrupting digester operations. To lift the mixers, the digesters would need structural modifications. These modifications would also require a digester condition assessment, scaffolding, shoring, and structural reinforcement.

The Omnivore system is an advanced, high solids approach to digestion. The current RWRF digester's gravity overflow system would likely need to be changed to accommodate the operating conditions of the higher solids digestate.

Converting digesters to the recuperative thickening process would still produce Class B cake.

4.2.1.4 Pre-Digestion Thermal Hydrolysis: Class A/EQ Cake

Pre-digestion thermal hydrolysis is a process (THP) that uses high temperature and pressure to break down cells and large organic molecules in the solids, making them more amenable for anaerobic digestion, and increasing their dewaterability.

The first step of pre-digestion THP is sludge dewatering. For this process, solids are sent to pre-THP centrifuges to increase the solids concentration up to 16 percent. Then, dewatered sludge is pumped into a series of reactors. Next, steam is injected into the reactors and held for 20 to 30 minutes at a temperature of 330ºF) and a pressure of 100-125 pounds per square inch (psi). The solids, now hydrolyzed, are sent to a flash tank, which operates at near atmospheric pressure.

The rapid change in temperature and pressure causes the steam to flash (i.e., a steam 'explosion'). The flashing breaks open the solids' cells, making them more accessible for digestion. Flashed steam is then recovered and recirculated to the reactors. After flashing, the hydrolyzed solids are cooled and diluted with plant water and are continuously fed into the digesters at roughly 10 percent solids.

With this process, the existing digesters can withstand a higher organic loading rate, and less digester volume is required due to the increased feed solids concentration. This process also improves dewaterability, producing a cake up to roughly 32 percent with belt filter presses (BFPs) or centrifuges. The final product volume is roughly one-third less than Baseline: MAD with Three New Digesters.

To add high-pressure steam, new boilers and increased staffing are required. Because steam operates at higher than 15 psi, two qualified boiler operators must be on-site at all times during operation, excluding maintenance.

Cambi provided the information for this alternative. With over 30 installations worldwide, Cambi is the most common pre-digestion THP.

The THP process followed by anaerobic digestion meets Class A PR requirements. Class A vector attraction reduction (VAR) requirements are met in the digestion process.

4.2.1.5 Post-Digestion Thermo-Chemical Hydrolysis (On-site): Class A/EQ Liquid Onsite

Post-digestion thermo-chemical hydrolysis is a process that uses a caustic chemical, low temperature, and high shear mixing to produce a liquid fertilizer. The process occurs after dewatering.

In this process, dewatered biosolids are diverted from the storage silos and fed into a storage hopper in a new building adjacent to the dewatering building. Solids concentrations to the storage hoppers should be between 16 and 18 percent, which is lower than the existing average cake. With the storage hoppers, the solids can be fed into the reactors at a constant rate using progressive cavity pumps.

The reactors are fed with low-pressure steam and caustic chemical, either potash (KOH) or caustic soda (NaOH). The steam would need to be around 10 psi, which is below the 15 psi threshold requiring qualified boiler operators onsite. A mechanical blade in the reactor mixes and shears the solids. The reactors operate for 30 minutes at 175°F, with a pH between 9.5 and 10.

The pH, temperature and mixing conditions hydrolyze and shear the solids. The result is a homogenized pumpable liquid product with a solids concentration up to 16 percent.

Lystek provided the information on the post-digestion thermo-chemical process and preliminarily agreed to market, haul, and distribute the product (referred to as LysteGro).

40 CFR Part 503 Subpart D specifies that to meet the Class A Exceptional Quality (EQ) standards, process VAR must occur after or at the same time as PR. In general, the Lystek process does not meet Class A/EQ standards because VAR (through volatile solids reduction in anaerobic digestion) occurs prior to PR (through time and temperature in the thermo-chemical hydrolysis reactor). To meet the requirement of PR occurring at the same time or before VAR, the Lystek process has been approved in California to utilize one of two VAR options. The facility must either test the material in an anaerobic digestion bench-scale unit and demonstrate less than 17 percent volatile solids reduction (Option 2), or inject the product within eight hours after discharge from the PR process (Option 9). Lystek has been meeting Class A using Option 2 consistently at the Fairfield-Suisun Wastewater Treatment Plant. If, for any reason, neither of these options can be met, then the product would be classified as Class B.

Lystek has obtained certifications for their product in the state of California and Solano County, and is actively seeking certification in other California counties. The product is currently certified as a licensed fertilizer by the California Department of Food and Agriculture (CDFA). In Solano County, the product is managed as a fertilizer rather than a biosolids product.

For the purposes of this master plan, it was assumed that Lystek would achieve Class A certification using VAR Option 2, which would allow land application of the product in Fresno County.

4.2.1.6 Post-Digestion Thermo-chemical Hydrolysis (Off-site): Class A/EQ Liquid

During this project, the City was notified of a potential partnership between Lystek and the Selma-Kingsburg-Fowler County Sanitation District (SKFCSD). Lystek is in the early stages of understanding the market in the area and determining the viability of constructing a regional thermo-chemical hydrolysis facility at SKF, located approximately 25 miles from the RWRF. The

City would be able to produce a sub-Class B biosolids cake, then pay a tipping fee to have the solids hauled to the off-site facility.

4.2.1.7 Thermal Drying: Dried Pellets or Granules

Thermal drying uses thermal energy to evaporate moisture from digested, dewatered biosolids, resulting in a Class A product. The two common drying processes are direct (convective) and indirect (conductive) drying.

Direct drying typically occurs in a rotary kiln or fluidized bed dryer. A fuel source, such as natural gas or biogas, heats oil or other media pumped into a heat exchanger. Heat is then transferred to the fluidizing air in contact with the biosolids, causing evaporation.

Indirect dryers separate the biosolids from the heating media, which is typically oil or steam. A fuel source powers a boiler or heat exchanger, which heats the media, in turn, heating and drying the biosolids fed into the drying chamber. As the biosolids move through the machine, moisture from the biosolids evaporates.

Both processes require treating the dryer air for water vapor, odor, and VOCs. The direct drying method requires more treatment because the air comes in direct contact with the biosolids. Ultimately, the dryers produce a dried product in the form of a pellet or granule, depending on the type of dryer, with a solids concentration between 80 and 90 percent.

4.2.1.8 Plasma-arc Gasification: Biochar

Plasma-arc gasification, or plasma arc-assisted oxidation, is a thermal conversion alternative that occurs after dewatering. It is an emerging technology, with no commercially operating installations for wastewater solids.

The technology uses a plasma torch at the end of a rotary kiln that can heat, dry, and oxidize sludge. With this technology, the electrical current passes through the combustion gas and ionizes it until an arc of light called plasma, similar to lightning, is created. The torch creates enough energy to preheat the incoming sludge and combustion air.

The plasma-arc gasification process operates at a temperature between 600 and 700 degrees Celsius (ºC) (1,112 to 1,292 degrees Fahrenheit [ºF]). Feed solids must have a minimum heating value of 9,500 British thermal unit per pound (Btu/lb) and 20 percent solids concentration. After being preheated, dewatered sludge and oxidation air are fed into the rotary kiln, where they are dried in the presence of the plasma torch at the opposite end. In the kiln, biochar accumulates and acts as a heating media for the incoming material. As it builds up, the biochar is extracted and hauled to a landfill or possibly beneficially used. The exhaust air is conveyed to the baghouse filter, and carbon is injected upstream of the filter to remove mercury. A tray scrubber and wet electrostatic precipitator then remove the particulate matter (ash), and the air is condensed to remove moisture. Finally, the clean air is discharged to the atmosphere.

Plasma-arc gasification is similar to incineration alternatives, such as fluidized bed gasification, except it does not require auxiliary fuel to start or sustain operation. Additional energy is provided through the electrodes.

4.2.1.9 Thermal Drying and Fluidized Bed Gasification: Biochar

The fluidized bed gasification process converts biosolids into biochar and syngas in an oxygen-deprived environment and controlled temperature. Dewatered biosolids are sent to thermal dryers, which heat the biosolids and remove most of the moisture. The dried biosolids are then conveyed to the gasifier.

Under oxygen-starved conditions, the gasifier temperature is increased to roughly 1,500 F using natural gas. A controlled amount of oxygen is then fed through media to fluidize the bed and mix in the feed solids. To adjust the pH, chemical is added.

Through gasification, the biosolids are converted into biochar and a combustible synthetic gas, or syngas. The syngas is typically returned to the thermal dryers upstream to reduce reliance on natural gas. Alternatively, syngas may have other opportunities for renewable energy production.

4.2.1.10 Thermal Drying and Pyrolysis: Biochar

Pyrolysis is an emerging technology with one wastewater application installation in the United States in the last year. The process is similar to the two gasification processes described above in that a controlled amount of heat is applied to dried sludge. Thermal dryers are needed following sludge dewatering and prior to pyrolysis to reduce moisture content of the cake to 10 percent solids, allowing the pyrolysis process to operate effectively. The difference from the gasification processes being considered for this alternatives evaluation is that pyrolysis operates in a completely anaerobic environment, resulting in little to no combustion. The 90 percent cake is subjected to high temperatures, up to 1,300ºF, without oxygen.

The incomplete combustion of the 90 percent cake produces a biochar and a pyrogas. For comparison, the energy content the biochar is between 4,500 and 9,000 Btu/lb and coal is between 8,000 and 12,000 Btu/lb. The pyrogas from pyrolysis is typically recycled to thermal dryers to reduce dependence on natural gas. The air pollution control system consists of equipment similar to a gasification process.

4.2.1.11 Covered Aerated Static Pile: Compost

Composting is a solids stabilization process whereby aerobic organisms decompose organic matter. Solids are combined with a bulking agent, commonly woody waste, at a one-to-one ratio by weight. The bulking agent raises the initial solids content of the mixture and provides a carbon source for the organisms and bulk porosity, which is important to maintain aerobic conditions.

The bulking agent could be woody waste from vineyards and orchards, or could be from the City's green waste collection program. Depending on the type and quality of bulking agent used, the City may need to purchase the material, receive it for free, or charge a tipping fee. Depending on the quality of the bulking agent, a wood chipper or grinder and other cleaning steps may be needed to process the material (reduce contamination to meet CalRecycle's limits for compost) before mixing with the biosolids.

Large mixers are used to ensure a well-mixed composition. Front-end loaders or conveyors then form composting piles.

Composting typically occurs over a two-phase, 42-day period to meet 40 CFR 503 regulations and produce Class A biosolids compost. High temperatures achieved during the microbial decomposition reduce pathogenic organisms in the solids. Even if a system upset in the RWRF anaerobic digestion process results in sub-Class B biosolids, the composting process can still produce Class A biosolids compost.

When composting is complete, the material is screened to retrieve a portion of the bulking agent that has not fully broken down (referred to as overs). The overs are returned to the front end to be composted again, and the final product is allowed to cure for several days. The resulting material, similar to humus, can be used as a soil amendment.

Compost is the most familiar product of those considered in this master plan and is therefore the most acceptable to the public at this time. In addition, when stabilized properly, biosolids compost lacks an objectionable odor or sludge-like appearance.

There are two types of composting processes that are typically operated in California: windrow and aerated static pile (ASP). With windrow composting, solids are formed into long, open-air piles that are manually aerated by overturning the piles frequently. With ASP composting, piles are formed over perforated pipes that use blowers to aerate the solids either positively (blowing air into the piles) or negatively (drawing air from the piles). Open composting can cause odor issues when the Sub-Class B or Class B solids are being further stabilized. To address this issue, composting installations are resorting to covered piles. Covered ASP composting uses a plastic barrier that reduces odors and emissions.

The most established packaged technology for covered biosolids composting in the U.S. is manufactured by the company GORE. Temperature and oxygen sensors monitor each pile, providing fine-tuned aeration control. The piles are formed on concrete pads, and the cover is attached to the rim wall around the pile's perimeter to create an enclosed system.

GORE's positive aeration process and cover allow the system to capture heat, odors, and volatile organic compounds (VOCs), while also providing passive treatment and reducing VOCs. Moisture condenses on the impermeable barrier, which then acts as a wet scrubber to the VOCs that volatize from the solids pile. The condensate collects as a leachate and passes through microorganisms present in the solids, which help to degrade the VOCs. The leachate collected from the piles is routed back to the headworks of the plant.

Since 2005, GORE has worked with the California Air Resources Board (CARB) to perform VOC emission reduction testing. Pilot and full scale testing has shown greater than 90 percent VOC emission reduction compared to open ASP composting.

Due to the land requirement to stockpile bulking agents and maintain piles, composting can be prohibitive for many sites. However, the City owns many acres of land surrounding the RWRF making it a viable alternative.

Because composting is a more passive solids handling process, it requires less mechanical equipment maintenance than other alternatives. However, significant labor is required to frequently move material.

4.2.2 Initial Screening Methodology

For the initial screening step, a list of four criteria were used and must be met for the alternative to be considered further. These criteria were introduced in Workshop No. 5 and later approved by the City. Table 4.1 lists the initial screening evaluation criteria and their descriptions.

Table 4.1 Initial Screening Evaluation Criteria

Criteria	Description
Proven Technology	The technology has at least one installation in at least one WWTP in the United States or Canada, with at least one year of successful operation receiving solids and/or biosolids in the last ten years.
Ability to Meet Existing Regulations	The alternative can comply with existing air emissions and biosolids-related regulations.
Redundancy/Reliability	The alternative provides redundancy (additional units) if one unit is down, and reliability so operations can remain in service.
Beneficial Use of Biosolids	The alternative generates a biosolids product that has a marketable beneficial use.

4.2.3 Initial Screening Results

Table 4.2 provides the results of the initial screening evaluation.

Table 4.2 Results of Initial Screening Evaluation

Process	Proven Technology	Meet Existing Regulations	Reliability/ Redundancy	Beneficial Use of Biosolids
Baseline: Mesophilic Anaerobic Digestion with 3 New Digesters	✓	✓	✓	✓
Process Optimization	✓	✓	✓	✓
Recuperative Thickening	✓	✓	✓	✓
Thermal Hydrolysis (Pre-Digestion)	✓	✓	✓	✓
Thermal Hydrolysis (Post-Digestion)	✓	✓	✓	✓
Plasma Arc Gasification		✓		✓
Fluidized Bed Gasification		✓		✓
Thermal Drying with Pyrolysis(1)	~(1)	✓	~(1)	✓
Thermal Drying	✓	✓	✓	✓
Composting	✓	✓	✓	✓

Notes: Pass: ✓ Fail: Blank

(1) One current pyrolysis installation has been operational since summer 2018, and the first full year of successful operation is expected to be met summer 2019. Therefore, pyrolysis was considered for further evaluation.

The two gasification alternatives have no successful installations in North America, meaning their reliability is unknown. As a result, they were not evaluated further. The following alternatives were carried forward to undergo detailed evaluation and are described in the following section:

- Baseline: MAD with 3 New Digesters.
- Baseline: MAD with Process Optimization (Higher % TS [percent total solids]).

- Baseline: MAD with Recuperative Thickening.
- Pre-Digestion Thermal Hydrolysis.
- Post-Digestion Thermo-Chemical Hydrolysis Onsite.
- Post-Digestion Thermo-Chemical Hydrolysis Offsite.
- Thermal Drying.
- Thermal Drying and Pyrolysis.
- Covered Aerated Static Pile Composting.

4.3 Detailed Evaluation of Viable Biosolids Management Alternatives

4.3.1 General Assumptions and Basis for Alternatives Sizing

In Chapter 1, average daily data from 2013 through 2017 were analyzed for each solids handling process area. Average and maximum flows and total solids TS and volatile solids (VS) loads were calculated for PS, TWAS, and anaerobically digestible material (ADM). To obtain per capita loading rates, loads were divided by the service area population and then extrapolated to 2040 based on population projections from the City's 2014 General Plan.

Table 4.3 summarizes the projected solids. Refer to Chapter 1 for more detailed descriptions of the process used to analyze the data and project solids production values.
The following findings and general assumptions were used for consistent evaluation and comparison of the alternatives:

1. Chapter 1 identified that the anaerobic digesters would be overloaded and unable to produce Class B biosolids by 2024. To size each alternative, the projected solids as described in Chapter 1 and summarized above were used. For each alternative, we assumed that construction would begin at the same time and would be able to stabilize biosolids before the existing digesters became overloaded. Although several alternatives could be constructed and expanded in phases as the solids loading increases, the analysis assumed that full capacity at build-out conditions (i.e., based on 2040 projected solids) would be constructed by 2024.
2. Although the City has a goal to diversify biosolids management, each technology was sized to handle the entire volume of biosolids for even comparison.
3. We assumed that all biogas produced would be used to produce Renewable Natural Gas (RNG) for pipeline injection, and that natural gas would be imported to supply process heating needs. The City has already invested in a biogas upgrading system, and is in the process of negotiating with PG&E on a pipeline injection project. We assumed that pipeline injection will be fully implemented by the time the recommendations from this biosolids master plan are implemented. Due to the low carbon and renewable fuel credits available for biogas to RNG, using the biogas as RNG is showing more financially beneficial at this time and natural gas is imported for process needs.
4. Throughout this master planning effort, we worked with manufacturers to obtain information and costs for a scope of supply for each technology. Each manufacturer provided a budgetary proposal representative of the technology. When the City chooses one of the alternatives, additional analysis can further explore the technology from competing manufacturers.

Table 4.3 Future Conditions (2040) – Solids Production

Parameter	Average Total Solids per capita (lb-TS/cap-day)	Average Total Solids Loading (lb- TS/day)	Average Percent Total Solids (percent)	Average Volatile Solids per capita (lb-VS/cap-day)	Average Volatile Solids Loading (lb-VS/day)	Average Percent Volatile Solids (percent)	Average Flow (mgd)	Maximum Daily Flow (mgd)	Ratio of Maximum Flow to Average Flow
Primary Sludge	0.23	198,000	4.2	0.19	159,000	3.4	0.57	0.75	1.32
Waste Activated Sludge	0.13	125,700	0.81	--(1)	--(1)	--(1)	1.86	2.28	1.22
Thickened WAS	0.15	124,000	4.4	0.12	102,000	3.5	0.35	0.44	1.27
ADM	0.037	31,300	7.7	0.034	29,000	7.1	0.049	0.060	1.24
Digester Feed	0.42	353,300	4.6	0.34	290,000	3.8	1.00	1.33	1.33
Dewatering Feed	0.20	173,000	2.1	0.13	106,000	1.3	1.00	1.24	1.24
Dewatered Cake	0.19	167,500	21	--(1)	--(1)	--(1)	0.096	0.13	1.33

Notes:
(1) Information needed for projecting this value was not available.

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4.3.2 Site-Specific Considerations

4.3.2.1 Baseline: Mesophilic Anaerobic Digestion with 3 New Digesters: Class B Cake

This alternative involves construction of three new large digesters. Three new large digesters are needed to meet 15-day SRT at the 2040 95 percent peak flow, with digester 1 or 2 used as storage, and one large digester out of service. In 2006, Digester 13 and a new control building were constructed, with plans for building three additional digesters in the future. The control building was designed to accommodate the equipment needed for three additional digesters. Based on solids projections, Digesters 14, 15, and 16 would need to be constructed by 2024, 2032, and 2038, respectively. However, to compare the alternatives evenly, it was assumed that all three digesters would be constructed in 2024. A volatile solids reduction (VSR) of 62.8 percent was used based on an average of the historical data.

Figure 4.1 shows a process schematic and Figure 4.2 shows a site layout for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

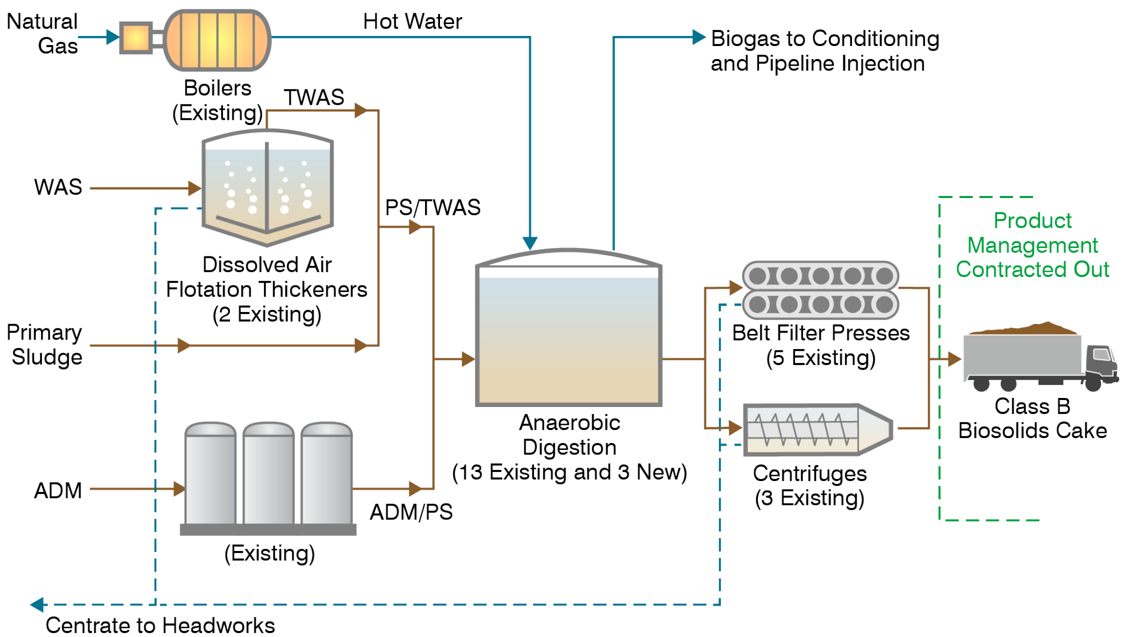

Figure 4.1 Baseline: Mesophilic Anaerobic Digestion with Three New Digesters Process Schematic

Figure 4.2 Baseline: Mesophilic Anaerobic Digestion with Three New Digesters Site Layout

4.3.2.2 Baseline: Mesophilic Anaerobic Digestion with Process Optimization (Higher %TS): Class B Cake

Mass balance calculations show that a slight increase in PS and TWAS solids concentration from 4.2 and 4.4 percent to 4.6 and 6 percent, respectively, would defer the need for new digesters until 2040.

Higher PS concentrations might be achieved by maintaining a deeper sludge blanket in the primary clarifiers, changing pumping frequency, utilizing inline automation to target a solids concentration and tying pump controls in accordingly, and/or using chemically enhanced primary treatment (CEPT). The TWAS solids concentration might be increased by optimizing DAFT operations including polymer selection and dosage, changing mechanism speed, and confirming that ancillary systems to the DAFT (e.g., air saturation system) are performing to specifications. To determine the achievable solids concentrations, plant staff would need to modify operations and monitor the effects.

The more the solids concentration to the digester can be increased, the more the hydraulic loading can be decreased. This operational optimization can significantly defer the need for new digester construction while still achieving and maintaining Class B requirements.

Plant staff expressed issues with pumping TWAS at concentrations greater than five percent. During optimization, TWAS and PS pumps should be closely monitored to ensure adequate pumping capacity. Both sets of PS and TWAS pumps may also need to be replaced to achieve higher solids concentrations.

Figure 4.3 shows a process schematic for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

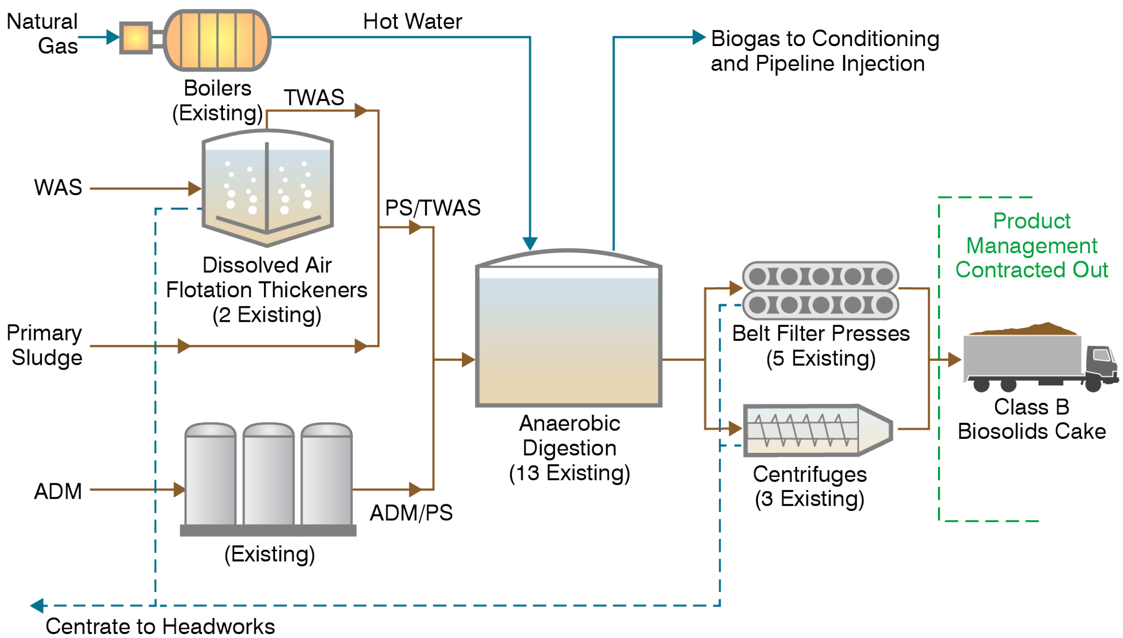

Figure 4.3 Baseline: MAD with Process Optimization (Higher %TS) Process Schematic

4.3.2.3 Baseline: Mesophilic Anaerobic Digestion with Recuperative Thickening: Class B Cake

Modifying four larger digesters, such as Digesters 9-12, to perform the recuperative thickening process would provide sufficient capacity to handle the expected increase in solids loads through 2040 without needing to construct new digesters. The recuperative thickening digesters would require three high-solids mixers per digester. Installing the mixers would require structural modifications to the digesters to accommodate the mixer service box and larger penetrations through the digester. Two new sludge screw thickeners are needed for the four recuperative thickening digesters. Based on the increased solids loads, three or four existing MAD digesters could be removed from service. Removing these digesters from service would provide redundancy and backup during an emergency, as well as extend the life span of the digesters and related equipment.

Mixing high solids digestate with the thinner MAD digestate may require changes to the sludge transfer pumps and mixers in the downstream holding Digesters 1 and 2. To minimize impacts to downstream mechanical equipment, alternative piping configurations for integrating recuperative thickening digesters with the rest of the plant should be explored during preliminary design, if this alternative is selected.

Pre-thickening is an alternative configuration that could be used instead of recuperative thickening to increase the thickness of the sludge fed to anaerobic digestion. This alternative configuration should be explored in more detail if recuperative thickening is selected. Pre-thickening would require changes to all digesters that would be fed the thicker material if thickened beyond five to six percent solids.

Figure 4.4 shows a process schematic and Figure 4.5 shows a site layout for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

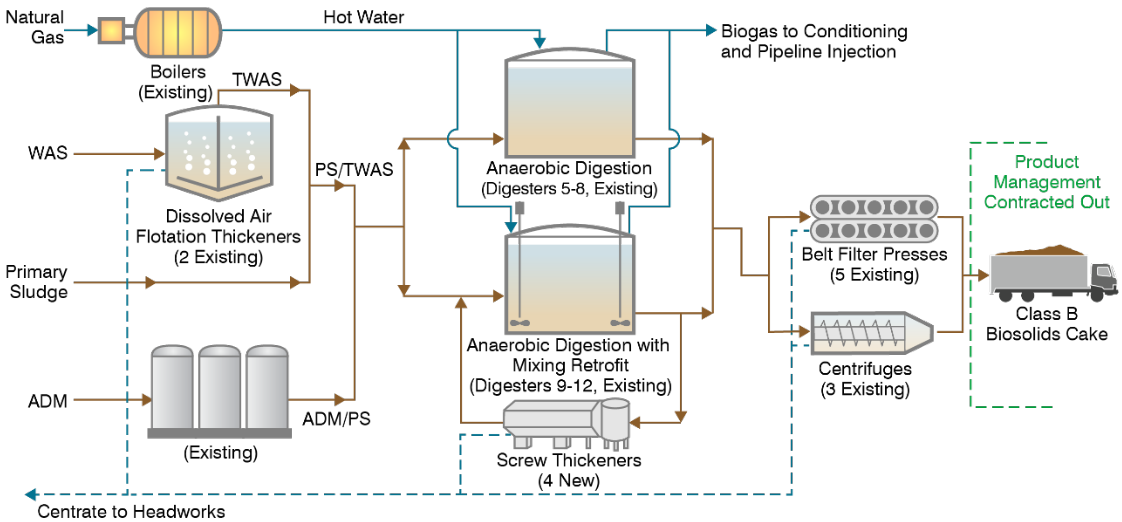

Figure 4.4 Baseline: MAD with Recuperative Thickening Process Schematic

Figure 4.5 Baseline: MAD with Recuperative Thickening Site Layout

4.3.2.4 Pre-Digestion Thermal Hydrolysis: Class A/EQ Cake

This alternative would involve installing three THP trains and the ancillary equipment associated with this process, which includes pre-THP centrifuges, sludge silos, cake pumps, steam boilers, and cooling heat exchangers. It requires construction of two new structures to house pre-dewatering centrifuges and new boilers and electrical equipment. Three large skid-mounted THP trains would be able to handle the projected solids loads and provide redundancy during maintenance or equipment failure.

Primary sludge and WAS would be dewatered to 16.5 percent TS prior to THP. The WAS thickening using dissolved air floatation (DAF) would no longer be needed, so this process would be decommissioned. Thermal hydrolysis uses steam at 125 psi, which is above the 15 psi threshold, and would require two facility engineers on site any time the boiler is operating.

The digesters would be fed at 10 percent TS. Due to the higher sludge thickness fed to anaerobic digestion, six of the existing digesters can be taken out of service to reduce O&M costs. Only Digesters 8-13 would be needed. The THP meets Class A/EQ PR and VAR requirements. As a result, the digesters would not need to maintain a 15-day SRT. A higher VSR of 65 percent is expected with THP, compared to the baseline of 62.8 percent.

Thermal hydrolysis increases the dewaterability of sludge, so only the BFPs would be used to reduce O&M costs and would produce a cake at 32 percent TS. The centrifuges could be maintained as backup dewatering equipment. The Class A cake produced would be a higher quality than the existing Class B solids. However, a market assessment showed little benefit in producing Class A cake over Class B cake. A similar biosolids hauling and disposal contract would still be needed, and the end use unit cost would not improve significantly unless future contract costs differ between Class A and Class B.

Figure 4.6 shows a process schematic and Figure 4.7 shows a site layout for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

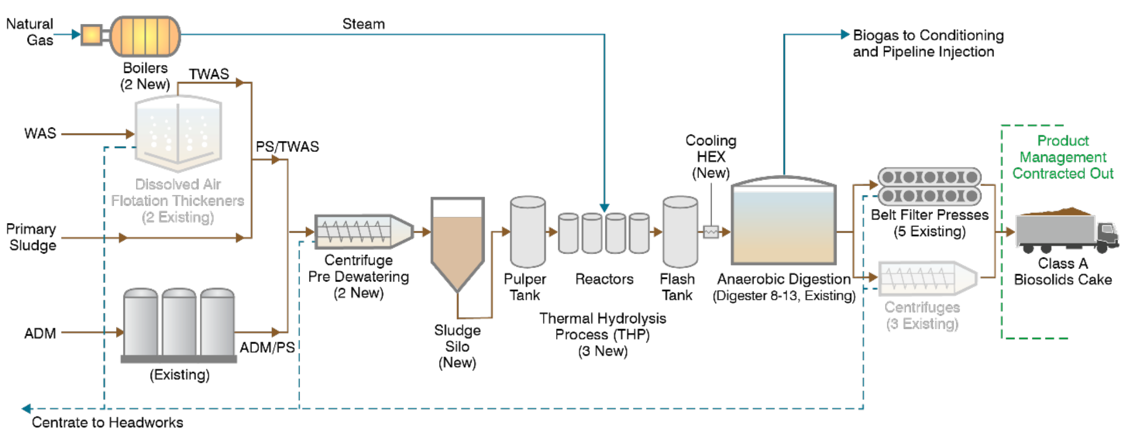

Figure 4.6 Pre-Digestion Thermal Hydrolysis Process Schematic

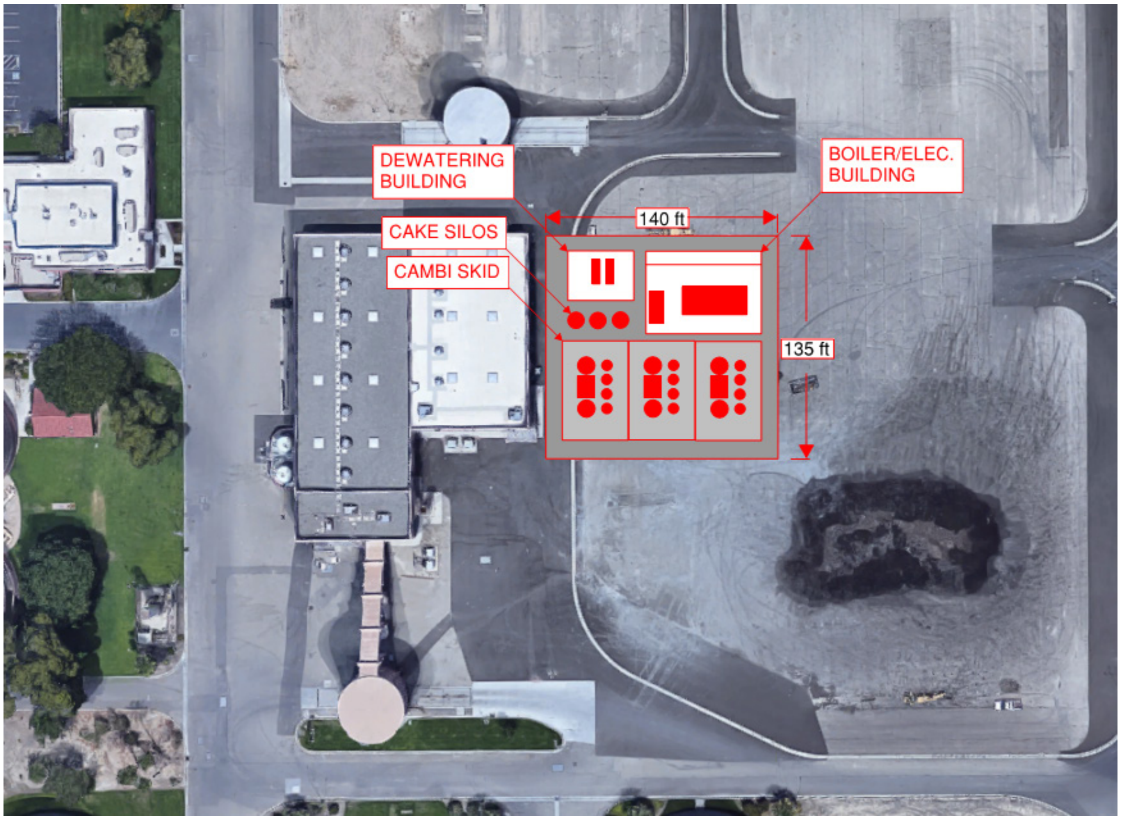

Figure 4.7 Pre-Digestion Thermal Hydrolysis Site Layout

4.3.2.5 Post-Digestion Thermo-Chemical Hydrolysis (On-site): Class A/EQ Liquid Onsite

The proposed configuration would require a new building to house the five treatment reactors, chemical storage and feed system, and electrical equipment. After the thermo-chemical hydrolysis process, the product is pumped from a new equipment building to on-site lined and covered lagoons for storage until it is hauled off-site. The manufacturer recommends having storage reservoirs with a minimum capacity of one-third of the annual production to account for weather events and crop rotation. Based on the 2040 solids projections, storage requirements would be around 52 acre-feet. The reservoir will need truck-loading pumps to fill 25-ton tankers.

This alternative does not include expansion of anaerobic digestion because the thermo-chemical hydrolysis process meets PR requirements. Thus, a 15-day SRT would not be needed in anaerobic digestion upstream. A lower VSR of 60 percent was assumed due to the lower SRT digestion.

Figure 4.8 shows a process schematic and Figures 4.9 and 4.10 show a site layout for this alternative. Alternative product storage sites closer to the process facility can be evaluated during preliminary design to avoid pumping high solids product long distances. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

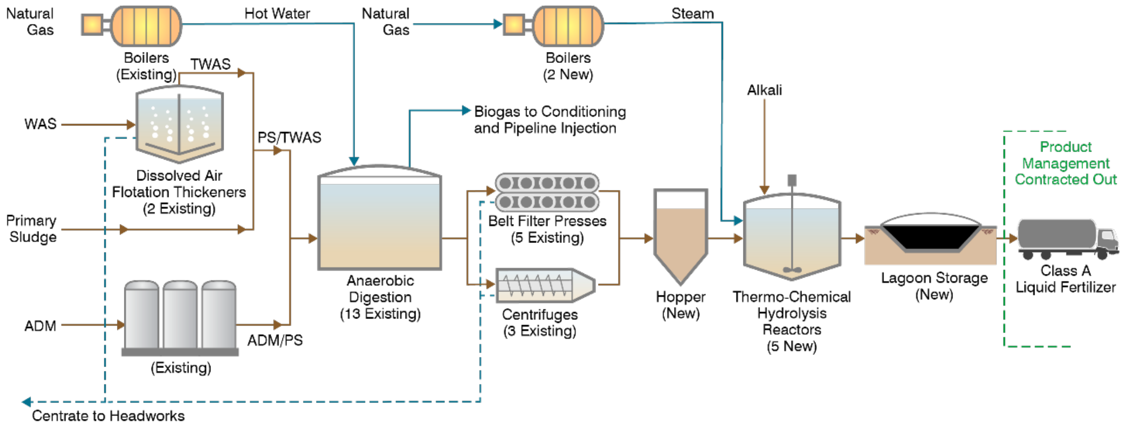

Figure 4.8 Post-Digestion Thermo-Chemical Hydrolysis – Onsite

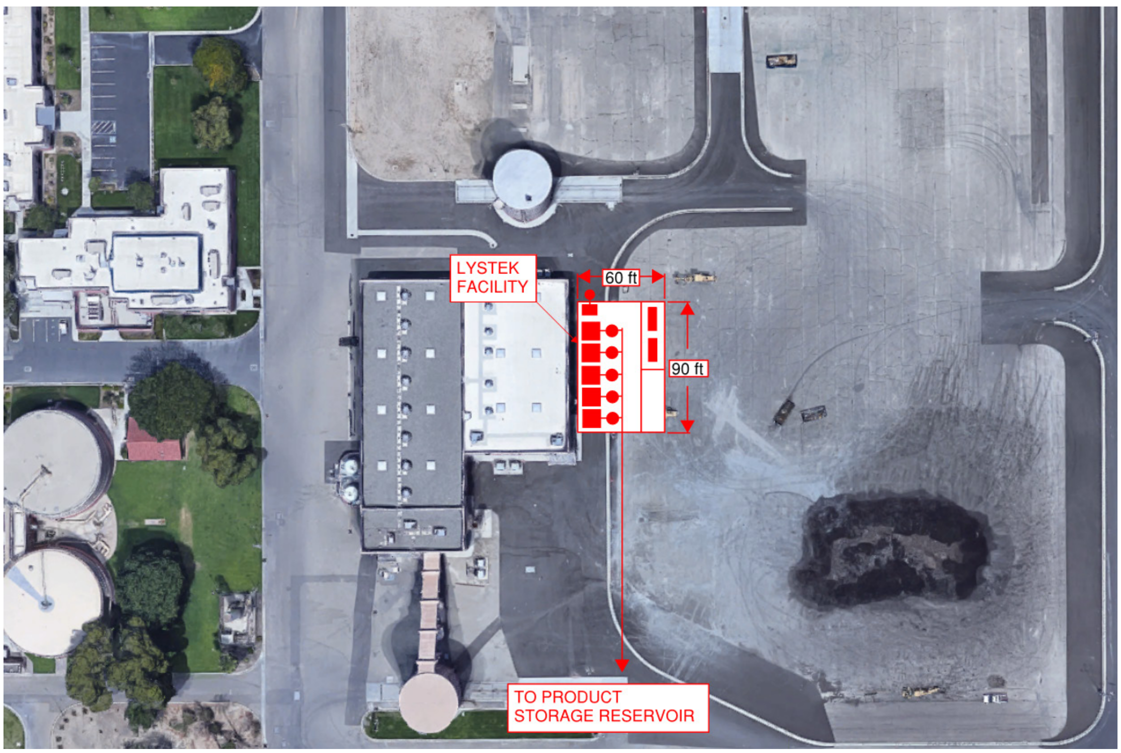

Figure 4.9 Post-Digestion Thermo-Chemical Hydrolysis – Onsite Site Layout

Figure 4 10 Post-Digestion Thermo-Chemical Hydrolysis – Onsite Site Layout

4.3.2.6 Post-Digestion Thermo-Chemical Hydrolysis (Off-site): Class A/EQ Liquid

For this alternative, we assumed the City would not require capital improvements. Instead, we assumed the City and Lystek would negotiate a long-term contract to haul the City's sub-Class B biosolids to the regional Lystek facility to be processed into Lystek-owned licensed fertilizer (or LysteGro). Lystek would charge the City a tipping fee to cover their capital and O&M costs.

Similar to the on-site thermo-chemical hydrolysis option, the 15-day SRT is not required in anaerobic digestion, and a lower VSR of 60 percent was assumed. The City would need to negotiate a contract to reduce potential product handling risk. If the offsite facility is out of service, it is recommended that the contract specify that the third party would need to provide an alternative outlet for sub-Class B biosolids.

Figure 4.11 shows a process schematic for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

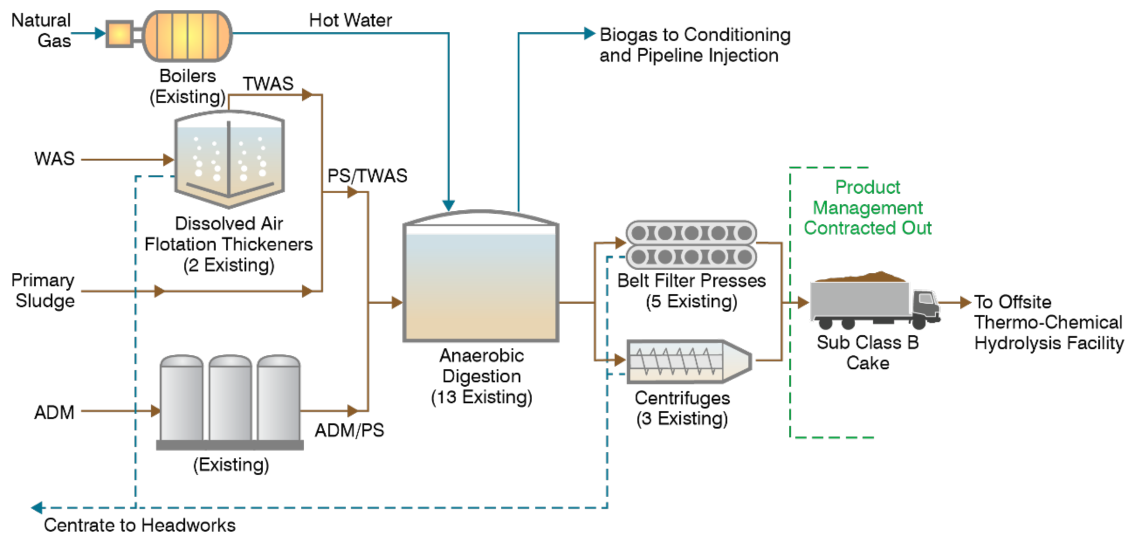

Figure 4.11 Post-Digestion Thermo-Chemical Hydrolysis – Offsite Process Schematic

4.3.2.7 Thermal Drying: Dried Product

This alternative involves installing two rotary drum dryers and the associated ancillary equipment for solids and product handling, and emissions and odor control. A fully redundant two train dryer configuration is proposed to be able to handle the 2040 projected solids loads. A new building would be needed to house the dryer trains, electrical equipment, chemical containment, and odor control equipment. Each process train includes a product storage silo and truck load-out station. The rotary drum dryer produces the highest quality end-product, compared to other dryer technologies.

The lower the moisture content of the input solids, the less energy required to operate the thermal drying process. Therefore, the City would benefit by operating centrifuges prior to thermal drying to create a dryer solid. Historically, the City's centrifuges have dried biosolids to 24 percent, compared to 18 percent for the BFPs.

The drying process meets the Class A PR requirements, so the 15-day SRT would not be needed in anaerobic digestion. A lower VSR of 60 percent was assumed to account for the lower SRT digestion.

Figure 4.12 shows a process schematic and Figure 4.13 shows a site layout for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

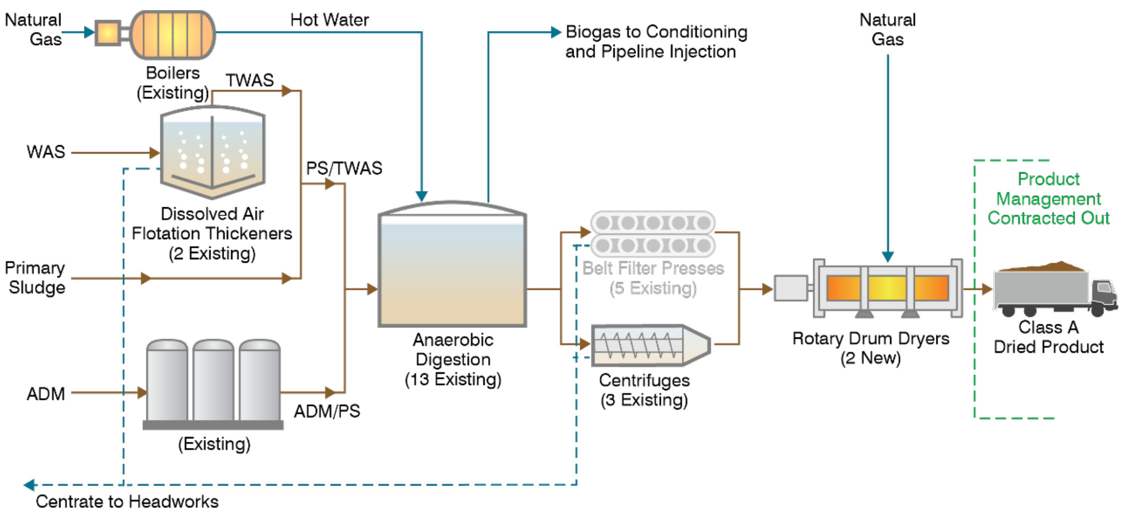

Figure 4.12 Thermal Drying Process Schematic

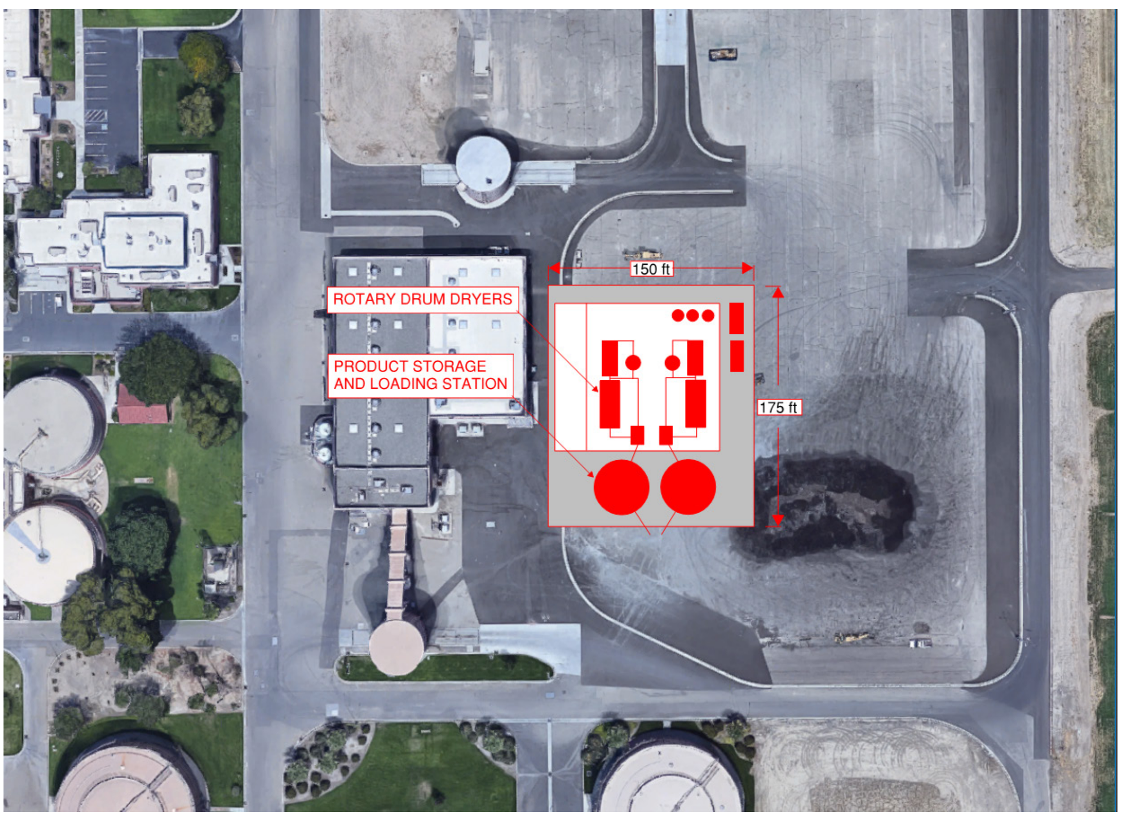

Figure 4.13 Thermal Drying Site Layout

4.3.2.8 Thermal Drying and Pyrolysis: Biochar

Similarly to the thermal drying process, the thermal drying and pyrolysis alternative would benefit by utilizing centrifuges to achieve dewatering, rather than belt filter presses. The pyrolysis system proposed requires eight belt dryers. After the belt dryers increase solids concentration to roughly 90 percent, the pyrolysis units operate to create pyrogas and biochar. The pyrogas is recycled to reduce heat input needed to operate the belt dryers. Twelve pyrolysis skids are needed to handle the projected solids loads. The equipment skid includes the pyrolysis unit and an odor control process. Although the dryer or pyrolysis skids do not need to be inside a building, the skids should be located on a new concrete equipment pad. The proposal includes two product storage silos and a truck load-out station.

The drying process meets the Class A PR requirement, so the 15-day SRT would not be needed in anaerobic digestion. A lower VSR of 60 percent was assumed to account for the lower SRT digestion.

Figure 4.14 shows a process schematic and Figure 4.15 shows a site layout for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

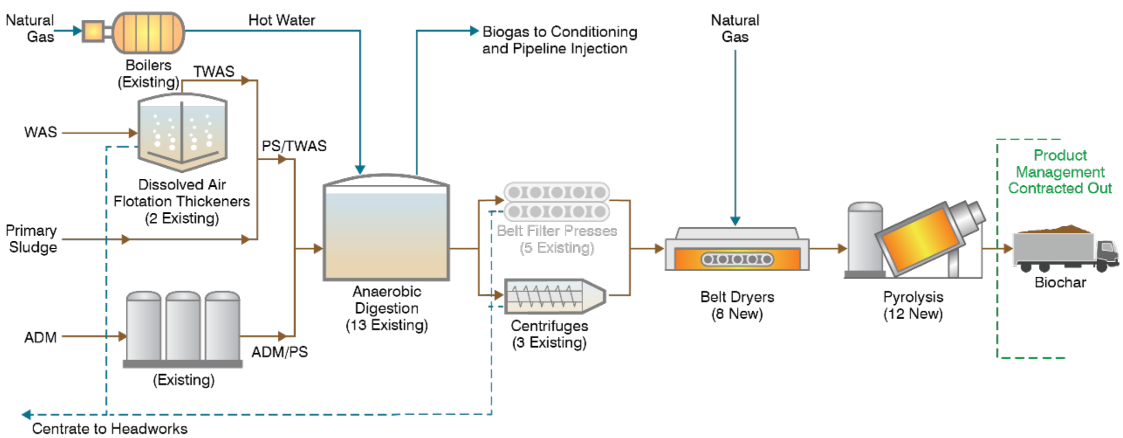

Figure 4.14 Thermal Drying and Pyrolysis Process Schematic

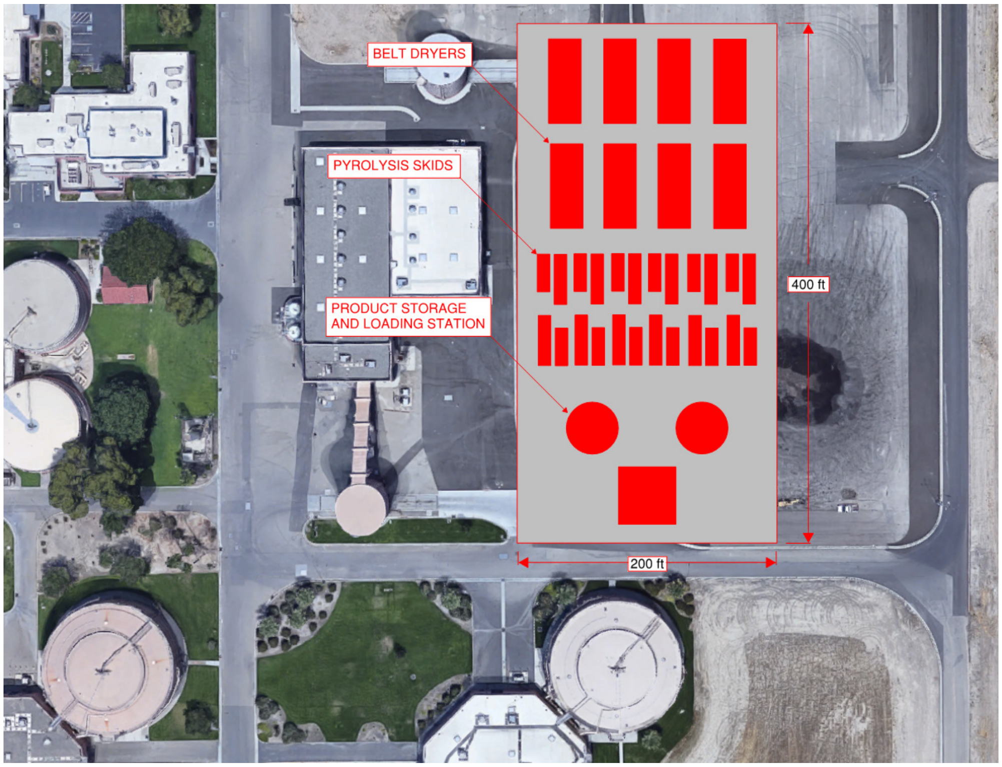

Figure 4.15 Thermal Drying and Pyrolysis Site Layout

4.3.2.9 Covered Aerated Static Pile: Compost

The compost facility proposed at the RWRF would require over 20 acres of land. The facility would include 64 covered bunkers, split between two phases. A new mixing and receiving pad would be needed to prepare the biosolids and bulking agent to be formed into piles. Two large mixers are proposed to ensure a well-mixed composition. Front-end loaders or conveyors then form composting piles. After processing, industrial screens separate the material into fines and overs. The fines are the finished compost. The overs are returned to the receiving station to be composted and reduce the amount of bulking agent needed. An area for compost storage is provided.

The composting process meets the Class A PR requirement, so the 15-day SRT would not be needed in anaerobic digestion. A lower VSR of 60 percent was assumed to account for the lower SRT digestion.

Figure 4.16 shows a process schematic and Figures 4.17 and 4.18 show a site layout for this alternative. Appendix A shows the results from the mass and energy balance calculations for 2040 annual average conditions.

If the City pursues an on-site composting facility, they can decide whether to enter into a public-private partnership to construct and operate the facility, issue a design-build-operate delivery method, or use existing staff to operate the new facility. There are advantages and disadvantages associated with each of these options. Owning and operating the compost facility would provide the highest control over the composting process and product quality, but would require hiring and training additional staff. Although GORE provides design assistance and operation training services, they do not provide contract operators.

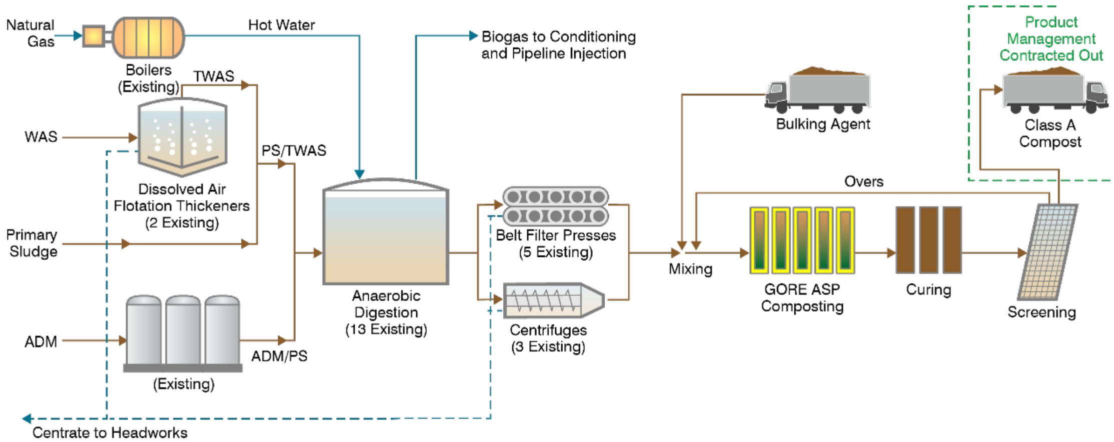

Figure 4.16 Covered Aerated Static Pile (ASP) Compost Process Schematic

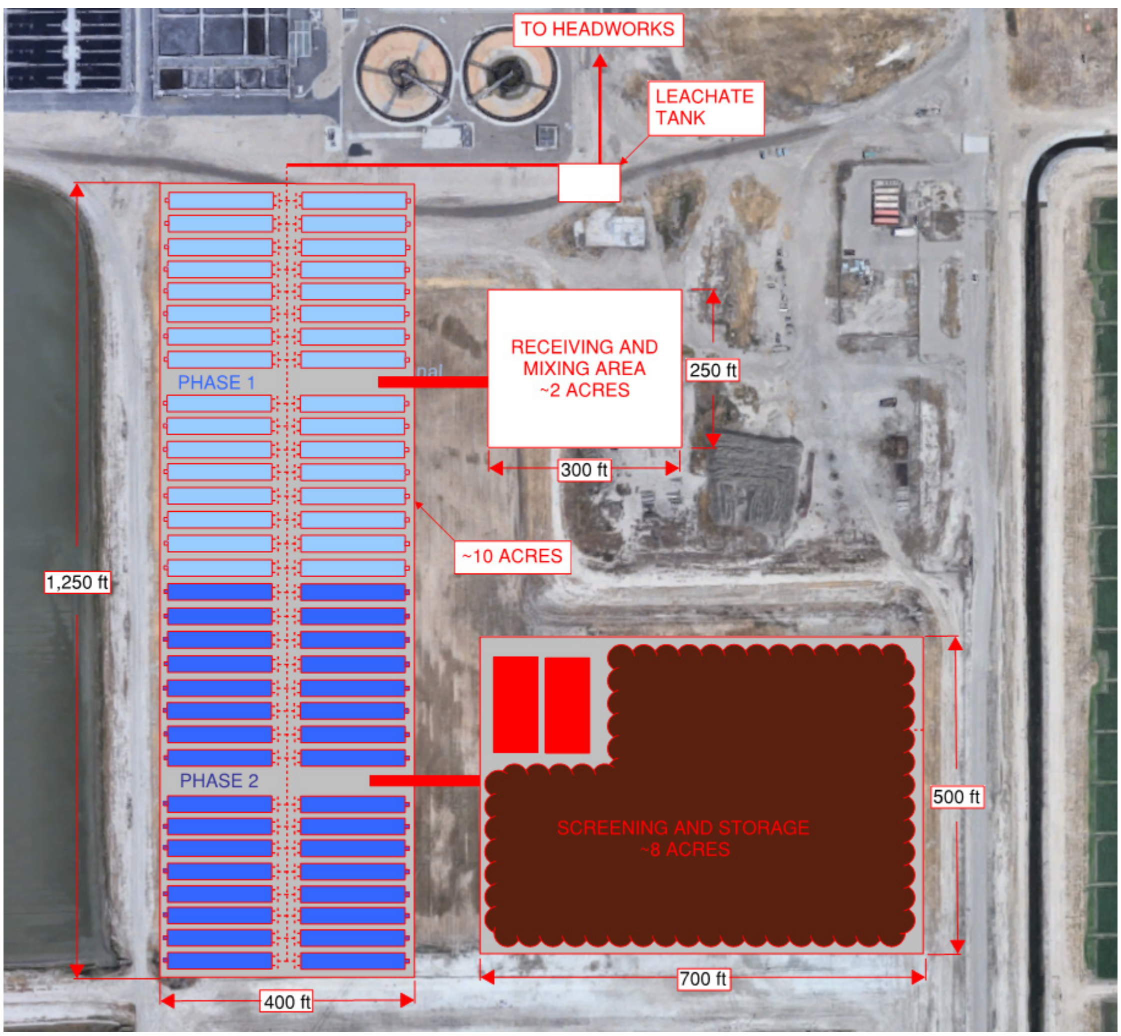

Figure 4.17 Covered ASP Compost Site Layout

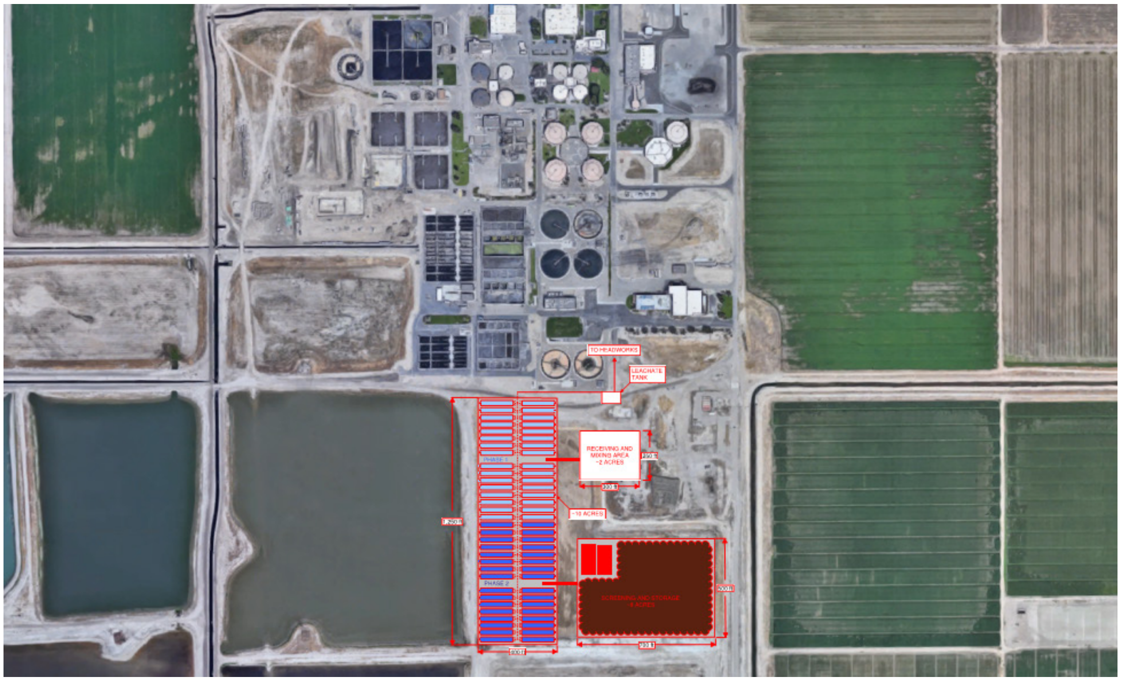

Figure 4.18 Covered Aerated Static Pile (ASP) Compost Site Layout

4.3.3 Non-Financial Evaluation Methodology

After the initial screening, a list of ten detailed, non-financial criteria were developed to further analyze and compare the alternatives. This list is presented in Table 4.4. The non-financial evaluation criteria were categorized as technical, social, and environmental. These criteria were introduced in Workshop No. 5 and later refined and approved by the City.

4.3.3.1 Non-Financial Criteria Evaluation Sensitivity Analysis

A sensitivity analysis was performed to test the robustness of the results to changes in criteria weights. Each criterion weight was increased and the remaining criteria weights were decreased by an amount proportional to their original weights. Updated weighted scores were then calculated and the resulting rankings were compared to original rankings. A more detailed description of the sensitivity analysis is described in Section 4.3.4.3.

Table 4.4 Detailed Evaluation Criteria

Category	Criteria	Considerations
Technical	Established Technology / Reliability	• How many installations does the technology have in the United States, Canada, and worldwide? • How many years of proven reliable operation does it have?
	Simplicity / Ease of O&M	• Is staff already familiar with the process, or will it require substantial staff training? • Will the alternative require hiring specialized staff? • Will O&M labor hours increase significantly? • Is additional monitoring required for regulatory compliance? • Can staff perform maintenance, or must it be contracted out? • Will the alternative require a third-party operator? • Is the technology serviceable in the United States, or does it require parts from outside the country? • Will a third party manage or market the product?
	Impacts on Facility Infrastructure / Footprint	• Will the technology require additional plant infrastructure, such as further expansion of the electrical substation? • Does the alternative avoid stranding assets before the end of their useful life? • What is the alternative's footprint?
	Ability to Implement / Permit	• How difficult will it be to integrate the technology with existing equipment? • How difficult will it be to continue operating the existing processes during construction? • How long will it take to implement, including permitting?
	Process Impacts and Risks	• Will the alternative affect mainstream treatment (e.g., by increasing sidestream nutrient loads)? • Will the alternative adversely affect water reuse? • What impacts occur if the process fails?
Social	Ability to Continue / Expand ADM	• Will the alternative allow the City to continue providing a service to local industries through their ADM program and potentially expand it?
	Community Acceptability	• Does the alternative introduce a source of odors, noise, and/or other emissions? • Will the alternative increase or decrease local truck traffic? • Does the alternative produce a product that the local community can use?
Environmental	Maximize Biosolids Beneficial Use	• Does the alternative produce a more marketable biosolids product than the existing Class B biosolids product?
	Minimize Volume of Residuals	• Does the alternative reduce the volume of biosolids?
	Minimize Greenhouse Gas Emissions	• Does the alternative increase or decrease GHG emissions relative to existing operations? This criterion accounts for the energy and chemical use of the process, fuel use for transport, and product carbon sequestration and fertilizer offsets.

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4.3.4 Non-Financial Criteria Evaluation Results

The non-financial criteria evaluation involved the following steps:

1. Develop a list of criteria and weights based on their relative importance.
2. Score each alternative based on their performance relative to each criteria.
3. Multiply criteria weights by scores to determine total scores for each alternative.
4. Perform a sensitivity analysis to evaluate the robustness of the results.

4.3.4.1 Criteria Weighting

The pairwise comparison process was used to determine the relative importance (weights) of each evaluation criterion. The process determines the weights based on comparisons of each criterion with the others. During a workshop facilitated by Carollo, City staff reached a consensus as they compared each criterion with another, assigning a value from a scale ranging between one and five, with a score of one meaning the criteria are equally important and five meaning a criterion is much more important or 1/5 meaning a criterion is much less important. The score for each criterion was normalized to the total to determine each criterion's relative weight. Table 4.5 shows the results from the pairwise comparison process. A number greater than one in the white cells indicates the criterion in that row is more important than the criterion in that column, whereas a fraction indicates the criterion in the column is more important. The grey cells are repeat comparisons and automatically calculate the inverse of the similar comparison. Appendix B includes a handout that describes the pairwise comparison process and shows an example. This handout was provided to City staff during the workshop.

4.3.4.2 Alternative Scoring

Carollo scored each alternative between one and five for each evaluation criterion. For example, MAD is a widely used technology through the United States, so the Baseline: Mesophilic Anaerobic Digestion with Three New Digesters alternative received a score of five for the Established Technology criterion. Whereas, pyrolysis and recuperative thickening each only have one installation at a WWTP so they received a score of two. City staff later confirmed the scores. Table 4.6 shows the scores for each evaluation criterion (and category) by alternative. The detailed reasoning for each score is documented and included in Appendix C. Appendix D and E show background information and calculated greenhouse gas (GHG) emissions, which were used to support the scoring of the alternatives.

The scores from Table 4.5 were then multiplied by the weighted criteria from the pairwise ranking process to determine the final weighted scores for the alternatives. Figure 4.19 shows the alternatives' weighted score, summarized by the evaluation criteria.

The results of the weighted scores show that Baseline MAD with Three New Digesters is the highest ranked alternative, followed by Post-Digestion Thermo-Chemical Hydrolysis – Offsite, Composting, and Baseline Process Optimization.

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Table 4.5 Pairwise Comparison Results

Criteria	Established Technology / Reliability	Simplicity / Ease of O&M	Impacts on Facility Infrastructure / Footprint	Ability to Construct / Implement / Permit	Process Impacts and Risks	Ability to Continue / Expand ADM Program	Community Acceptability	Maximize Biosolids Beneficial Use	Minimize Volume of Residuals	Minimize GHG Emissions	Score	Relative Weights (percent)
Established Technology / Reliability	1	3.00	3.00	0.33	0.20	1.00	3.00	2.00	3.00	1.00	17.5	11.1
Simplicity / Ease of O&M	0.33	1	3.00	0.33	0.33	1.00	3.00	2.00	3.00	1.00	15.0	9.5
Impacts on Facility Infrastructure / Footprint	0.33	0.33	1	0.33	0.20	0.33	1.00	0.33	0.33	0.33	4.5	2.9
Ability to Construct / Implement / Permit	3.00	3.00	3.00	1	0.33	3.00	5.00	3.00	3.00	3.00	27.3	17.3
Process Impacts and Risks	5.00	3.00	5.00	3.00	1	5.00	5.00	3.00	5.00	4.00	39.0	24.6
Ability to Continue / Expand ADM Program	1.00	1.00	3.00	0.33	0.20	1	3.00	0.33	1.00	1.00	11.9	7.5
Community Acceptability	0.33	0.33	1.00	0.20	0.20	0.33	1	0.33	0.33	1.00	5.1	3.2
Maximize Biosolids Beneficial Use	0.50	0.50	3.00	0.33	0.33	3.00	3.00	1	3.00	1.00	15.7	9.9
Minimize Volume of Residuals	0.33	0.33	3.00	0.33	0.20	1.00	3.00	0.33	1	0.33	9.9	6.2
Minimize GHG Emissions	1.00	1.00	3.00	0.33	0.25	1.00	1.00	1.00	3.00	1	12.6	7.9
Total											**158**	**100**

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Table 4.6 Alternative Scores by Evaluation Criteria

Evaluation Criteria	Weight (percent)	Baseline: Mesophilic Anaerobic Digestion (MAD) with 3 New Digesters	Baseline: MAD with Process Optimization (Higher %TS)	Baseline: MAD with Recuperative Thickening	Pre-Digestion Thermal Hydrolysis	Post-Digestion Thermo-Chemical Hydrolysis - Onsite	Post-Digestion Thermo-Chemical Hydrolysis - Offsite	Thermal Drying & Pyrolysis	Thermal Drying	Covered Aerated Static Pile (ASP) Compost
Technical		24	24	18	11	17	23	13	19	18
Established Technology/ Reliability	11	5	5	2	4	3	3	2	5	5
Simplicity/ Ease of O&M	9	5	5	4	2	3	5	2	3	3
Impacts on facility infrastructure/ Footprint	3	4	5	4	1	3	5	2	3	1
Ability to construct/ Implement / Permit	17	5	5	4	2	4	5	3	4	4
Process impacts & risks	25	5	4	4	2	4	5	4	4	5
Social		5	5	7	8	5	6	7	7	8
Ability to continue/ expand ADM program	7	3	3	5	5	3	3	3	3	3
Community acceptability	3	2	2	2	3	2	3	4	4	5
Environmental		10	10	10	10	8	10	10	10	11
Maximize biosolids beneficial use	10	2	2	2	3	3	2	3	4	5
Minimize volume of residuals	6	3	3	3	4	2	3	5	5	1
Minimize GHG Emissions	8	5	5	5	3	3	5	2	1	5
Total Weighted Normalized Score		39	39	35	29	30	39	30	36	37
		4.30	4.09	3.61	2.75	3.32	4.14	3.09	3.74	4.12
		86%	82%	72%	55%	66%	83%	62%	75%	82%

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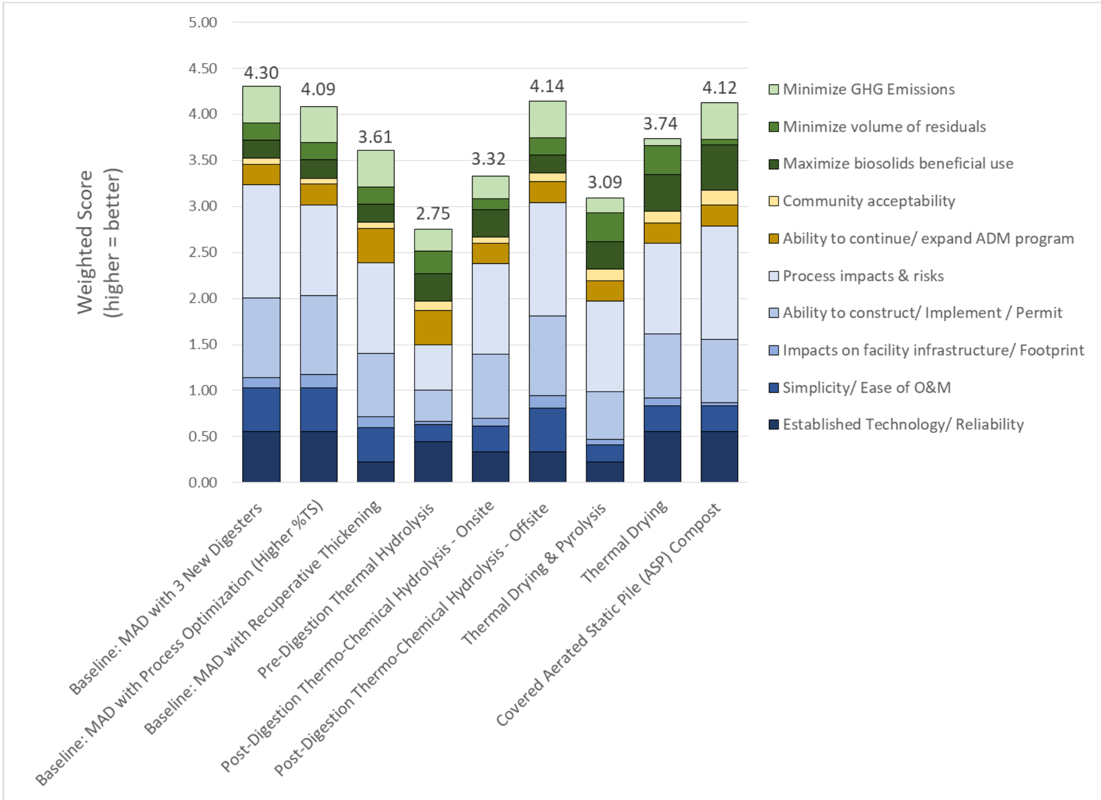

Figure 4.19 Weighted Non-Financial Criteria Evaluation Results

4.3.4.3 Sensitivity Analysis

Figure 4.20 shows an example of the sensitivity analysis. In the example, the criterion, Established Technology / Reliability, was increased by 100 percent, raising it from a weight of 11 percent to 22 percent. The other weights decreased proportionally. The overall scores for the alternatives were modified based on the new weights. With the new scores from each iteration of the sensitivity analysis, Baseline MAD with Three New Digesters was the highest ranking alternative for all tests. Compost and baseline process optimization alternatives became more favorable and offsite thermo-chemical hydrolysis became less favorable. The ranking of other alternatives remained unchanged.

The findings from the sensitivity analysis showed that the highest-ranking alternative, Baseline: MAD with Three New Digesters, is not sensitive to changes. The criterion weight for Maximize Biosolids Beneficial Use would have to be increased by over 50 percent before MAD is no longer the highest-ranking alternative. Other criteria weights would need to be changed by much greater amounts before MAD is no longer the highest-ranking alternative. Therefore, the results of the criteria weighting are robust in determining the highest ranked alternative.

Established Technology / Reliability	100%

	Weights	
Evaluation Criteria	original	modified
Established Technology / Reliability	11.1%	22.1%
Simplicity / Ease of O&M	9.5%	8.3%
Impacts on Facility Infrastructure / Footprint	2.9%	2.5%
Ability to Construct / Implement / Permit	17.3%	15.1%
Process Impacts and Risks	24.6%	21.6%
Ability to Continue / Expand ADM Program	7.5%	6.6%
Community Acceptability	3.2%	2.8%
Maximize Biosolids Beneficial Use	9.9%	8.7%
Minimize Volume of Residuals	6.2%	5.5%
Minimize GHG Emissions	7.9%	7.0%
	100%	100%

	Rank	
Alternatives	original	modified
Baseline: MAD with 3 New Digesters	9	9
Covered Aerated Static Pile (ASP) Compost	7	8
Baseline: MAD with Process Optimization (Higher %TS)	6	7
Post-Digestion Thermo-Chemical Hydrolysis - Offsite	8	6
Thermal Drying	5	5
Baseline: MAD with Recuperative Thickening	4	4
Post-Digestion Thermo-Chemical Hydrolysis - Onsite	3	3
Thermal Drying & Pyrolysis	2	2
Pre-Digestion Thermal Hydrolysis	1	1

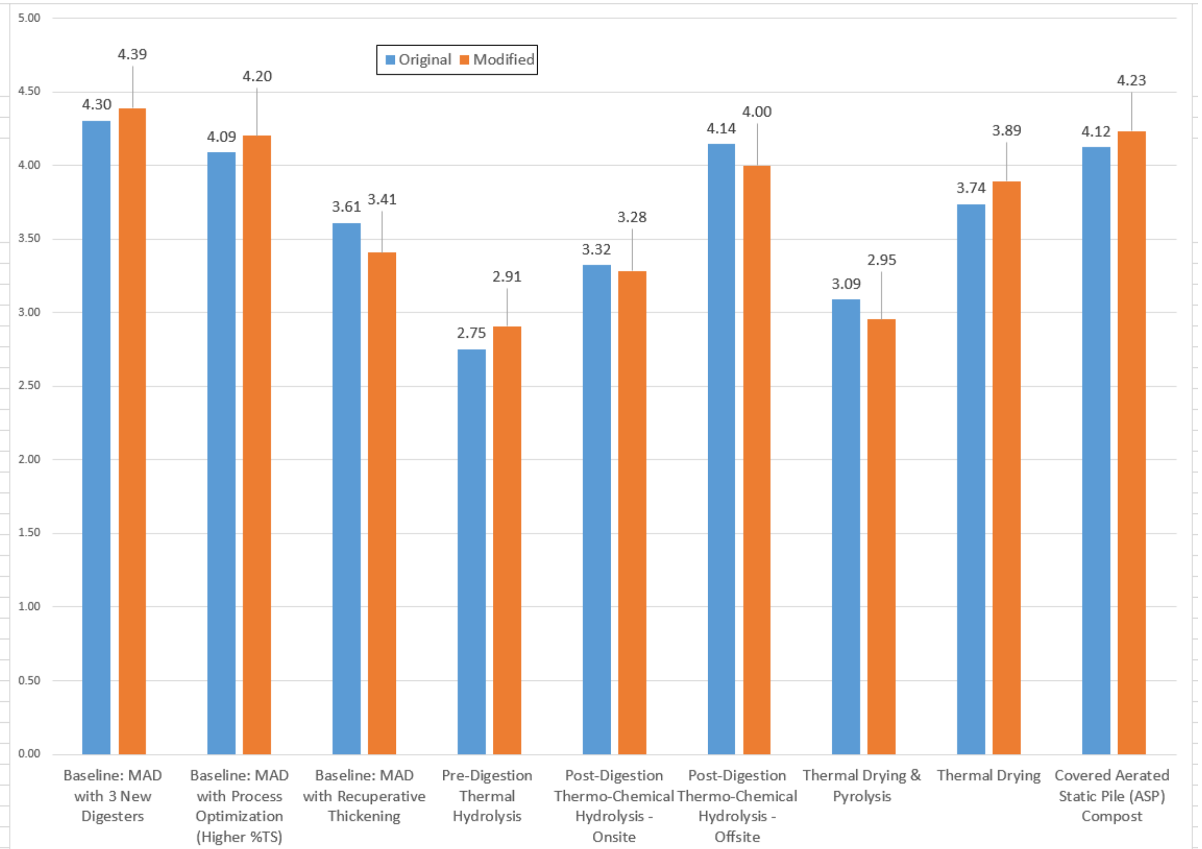

Figure 4.20 Example Sensitivity Analysis Results: Increasing Established Technology/Reliability Weight by 100 Percent

The second and third ranked alternatives, Post-Digestion Thermo-Chemical Hydrolysis – Offsite and Composting, are more sensitive to changes in criteria weighting. Increasing Established Technology / Reliability or Maximize Biosolids Beneficial Use criteria weights by just 10 percent made Composting the second highest ranked alternative and moved offsite thermo-chemical hydrolysis down to the third ranked alternative. Similarly, decreasing Simplicity / Ease of O&M or Ability to Construct / Implement / Permit criteria weighting by 10 percent made Composting the second ranked alternative and offsite thermo-chemical hydrolysis to third ranked. This indicates that second and third ranked alternatives have a very similar overall score and are more sensitive to changes in criteria weighting. Although slightly less sensitive to changes in criteria weighting, the fourth ranked alternative, Baseline: MAD with Process Optimization had an overall score within two percent of the second and third ranked alternatives.

4.3.5 Financial Criteria Evaluation Methodology

Life-cycle costs for each alternative were estimated using a present-worth analysis for capital and O&M costs. The following sections describe the process for projecting future capital, O&M, and present-worth costs.

4.3.5.1 Capital Costs

Capital costs represent the total value of completing a new project, including design, bidding, and construction.

The Association for the Advancement of Cost Engineering International (AACE International) defines five classes of cost estimates, with Class 1 being the most accurate. For this project, cost estimates are Class 5, which are used for planning level and concept screening purposes and have expected accuracy ranges between -50 and +100 percent.

Due to inflation, construction costs historically escalate over time. The standard indicator that tracks these changes in construction prices is the Engineering News-Record (ENR) Construction Cost Index (CCI). The CCI tracks construction markets in 20 cities throughout the United States and publishes monthly indices indicating relative market performance.

To determine the escalation to future construction costs, the historical percent change in the 20 city average CCI was determined, as shown in Table 4.7. The ten-year average (2009-2018) serves as the basis for escalating construction costs.

Table 4.7 ENR 20-City Construction Cost Index

Year	Annual Average 20-City CCI(1)	Percent Change from Previous Year
2008	8,311	--
2009	8,570	3.1
2010	8,804	2.7
2011	9,070	3.0
2012	9,308	2.6
2013	9,547	2.6
2014	9,807	2.7
2015	10,035	2.3
2016	10,338	3.0

Year	Annual Average 20-City CCI(1)	Percent Change from Previous Year
2017	10,737	3.9
2018	11,062	3.0
5-Year Average		**3.0**
10-Year Average		**2.9**

Notes:
(1) Data obtained from the Engineering News-Record 20 City Construction Cost Index.

Carollo worked with manufacturers of the various biosolids management technologies to develop capital cost estimates. For these cost estimates, manufacturers typically provide equipment and materials costs. Depending on the scope of their budgetary quote, percent allowances for work, such as equipment installation and electrical, instrumentation, and controls (EI&C) are added. Some alternatives require additional infrastructure or equipment beyond the manufacturer's scope of work, such as buildings for new equipment or product storage infrastructure. The manufacturer's quote, percent allowances, and additional infrastructure, if applicable, are summed to obtain the direct cost.

The estimated construction cost is the combination of direct and indirect costs. Indirect costs include contingency, contractor overhead and profit, sales tax, etc.

The total estimated project cost includes the construction cost plus engineering, legal, administrative, and construction management.

Table 4.8 breaks down the basis for estimating capital project costs.

Table 4.8 Basis for Estimating Total Project Cost

Cost Factor	Applied To	Factor (percent)
Equipment Installation	Equipment Cost	30
Electrical, Instrumentation, and Controls	New Structures and Equipment	15
Miscellaneous Process Piping	New Structures and Equipment	15
		Total Direct Cost (TDC)
Contingency	TDC	30
General Conditions (Mobilization, Permits, Bonds/Insurance, etc.)	TDC + Contingency	10
Sales Tax	50 percent of TDC	7.975
General Contractor Overhead and Profit	TDC + Contingency + Sales Tax + General Conditions	10
		Construction Cost
Design, Legal, and Administration Fees	Construction Cost	15
Construction Management	Construction Cost	10
		Total Project Cost

4.3.5.2 Operation and Maintenance Costs

The O&M costs were estimated from information received from manufacturers, assumptions for typical O&M, and unit costs specific to the RWRF. These costs were broken down by the following categories:

- Equipment energy (electricity).
- Heating demand (natural gas).
- Chemical consumption (polymer and caustic).
- Operation (labor).
- Maintenance (labor and parts).
- Hauling and disposal.

Electricity usages for most alternatives were based on the manufacturer's estimated power use factor (kWh/ton processed). Natural gas usages were estimated using a heat transfer and mass balance equation.

Chemical dose, labor operations, and maintenance requirements were provided in the budgetary proposals. Table 4.9 presents the City's O&M unit costs.

Table 4.9 Operation and Maintenance Unit Costs

Item	Estimated Cost	Basis
Electricity	$0.117/kilowatt-hour	2013 – 2017 average
Natural Gas	$1.26/therm	June 2018
Polymer	$10.20/gallon	2013 – 2015 average
Caustic	$0.30/lb	Provided by Univar Solutions
Labor	$40.58/hour	Wastewater treatment plant specialist FY 2019 salary, including benefits
Maintenance	2% of budgetary proposal, unless noted otherwise	Typical
Biosolids Hauling and Disposal	Varies	See below

Biosolids product end use costs, which include the costs for hauling and land application of biosolids, vary by type of biosolids product produced. End use unit costs were based on findings from the market assessment and are presented in Table 4.10. For the alternatives that produce biochar, granules, or compost, the City could sell the final product for a marginal revenue. For alternatives that produce a marketable product (thermal drying, pyrolysis, and compost), an annual O&M cost of $100,000 was included for marketing based on recommendations provided in Chapter 3.

The US Bureau of Labor Statistics publishes the monthly Consumer Price Index (CPI), which is 'a measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services.' Due to inflation, the relative costs of goods and services are steadily rising. To determine the inflation rate for O&M costs, the CPI's annual percent change was compared with the ten-year average, as shown in Table 4.11. The ten-year average was used as the basis for calculating the inflation rate for O&M costs.

Table 4.10 Biosolids Product End Use Unit Costs

Item	Estimated Cost
Class B Biosolids	$34.00
Class A Biosolids	$34.00
Class A Liquid Fertilizer	$24.00
Unclassified, Lystek-owned	$10.00
Biochar	-$1.50(1)
Granule	-$5.00(1)
Class A Compost	-$1.50(1)

Notes:
(1) Negative cost indicates a revenue stream for the City.

Table 4.11 Consumer Price Index (CPI)

Year	Annual Average Index Value(1)	Percent Change from Previous Year
2008	215.3	--
2009	214.5	-0.4
2010	218.1	1.6
2011	224.9	3.2
2012	229.6	2.1
2013	233.0	1.5
2014	236.7	1.6
2015	237.0	0.1
2016	240.0	1.3
2017	245.1	2.1
2018	251.1	2.4
5-Year Average		**1.5**
10-Year Average		**1.6**

Notes:
(1) Data obtained from the US Department of Labor Bureau of Labor Statistics

4.3.5.3 Net Present Value

The net present value or present-worth cost represents the value of the total cash flow occurring over the lifetime of the project in current dollars, including both capital and O&M costs. A discount rate of four (4) percent was used to bring future costs back to present value. The basis for selecting a discount rate depended on the expected rate the City can secure funding for future projects.

4.3.5.4 Sensitivity Analysis

A financial sensitivity analysis was performed on two cost parameters, the biosolids end-use cost and the composting bulking agent unit cost. The end-use cost is likely to change in the future given the low cost the RWRF currently has negotiated. The bulking agent cost is not known until further market analysis is completed. The results of the financial sensitivity analysis are presented below.

4.3.6 Financial Criteria Evaluation Results

Capital costs not provided in budgetary quotes were estimated using the Carollo Cost Estimating System, a database tool used to estimate costs from rough quantity take-offs and unit costs. The mid-point of construction was assumed to be 2023, with alternatives coming online in 2024 when the existing digesters would become overloaded. All costs are in 2019 dollars. Appendix F shows the summary of estimated capital costs for the alternatives.

The capital cost for constructing new digesters was calculated based on the scope of work from previous RWRF digester construction. Capital costs for the process optimization alternative includes only the cost to replace PS and TWAS pumps. Table 4.12 summarizes the scope of capital improvements for the alternatives and Figure 4.21 shows the capital cost for each alternative.

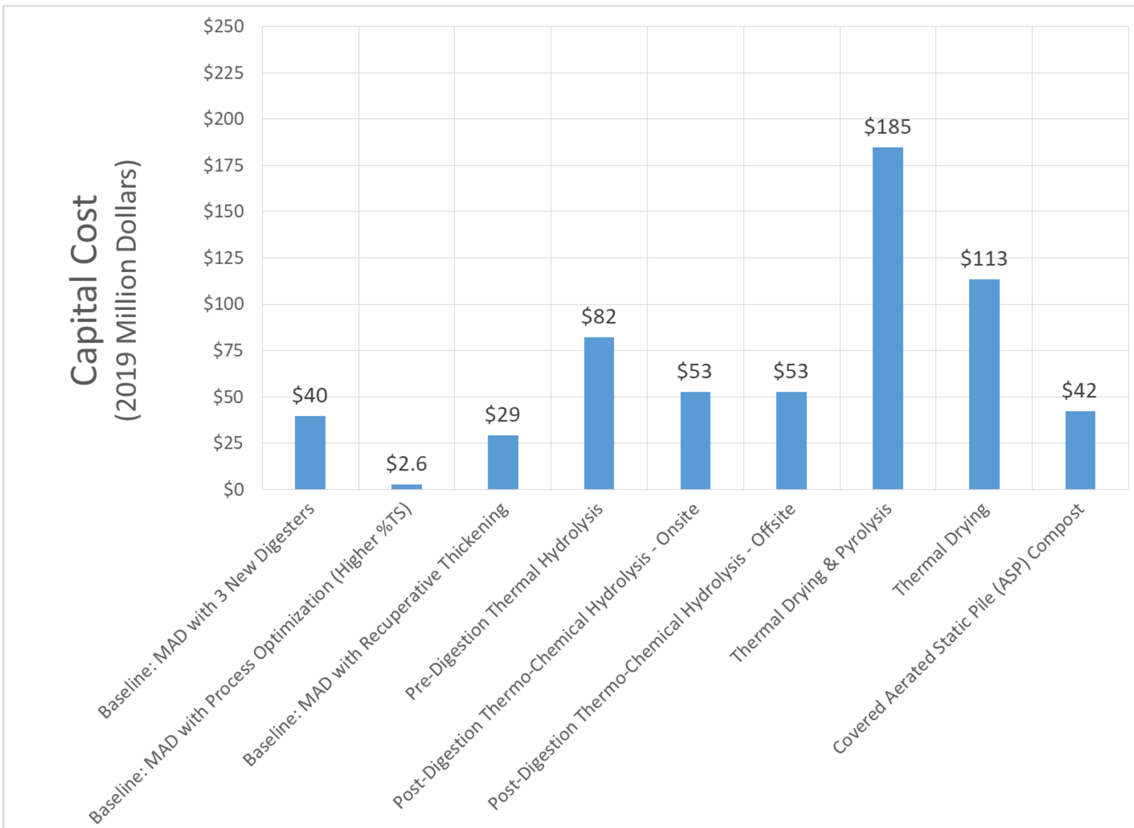

Figure 4.21 Capital Costs of Alternatives in Millions of 2019 Dollars

Figure 4.22 summarizes the annual O&M costs for each alternative. Mass and energy balances, included in Appendix A, were calculated to determine loads to process areas, end-product volumes, and associated power costs. Appendix G shows the detailed breakdown of O&M costs.

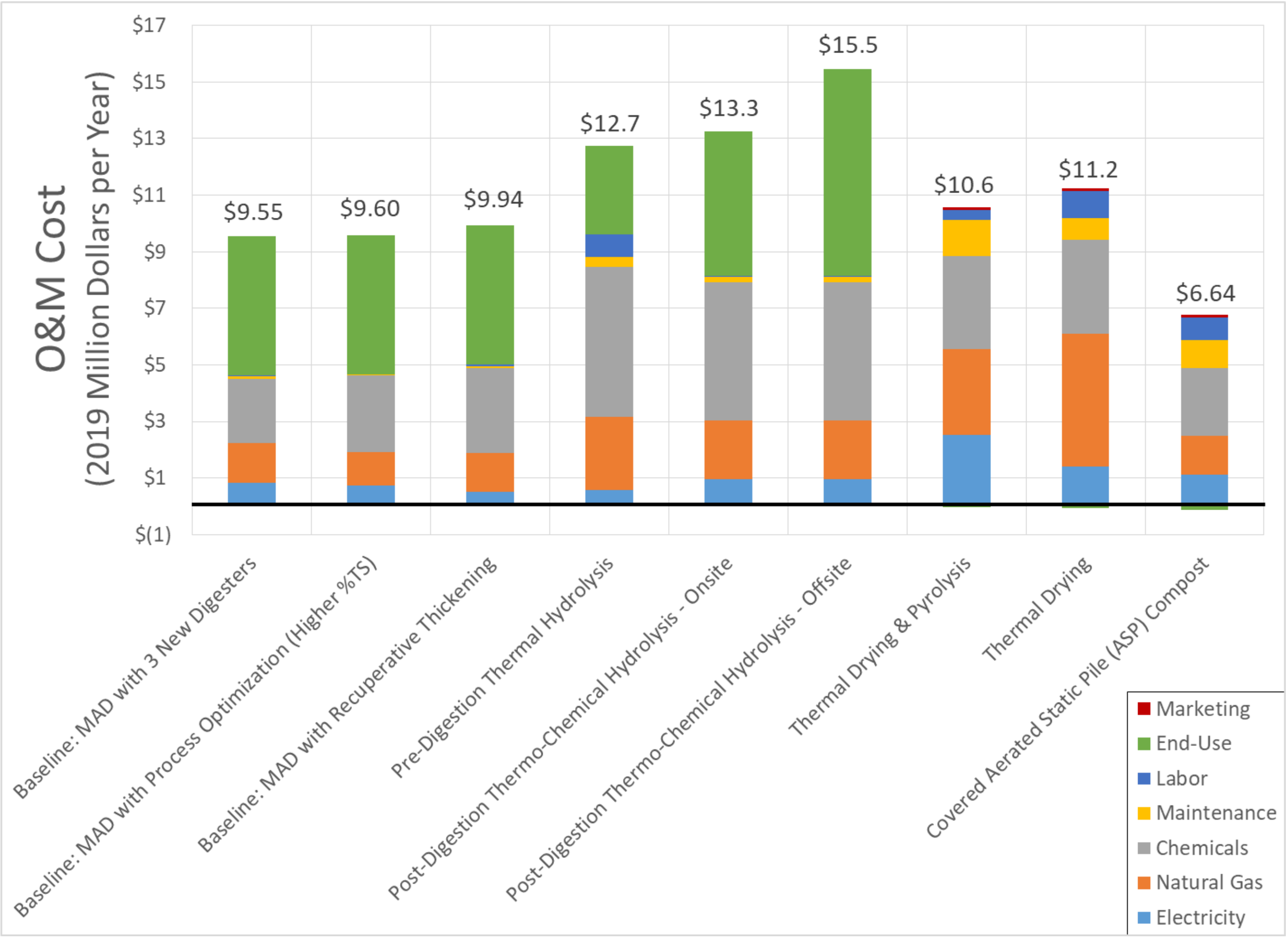

Figure 4.22 Operations and Maintenance Costs of Alternatives in Millions of 2019 Dollars per Year

Table 4.12 Proposed Capital Improvements by Alternative

Alternative	Thickening	Pre-Digestion	Digestion	Dewatering	Post-Digestion
Baseline: Mesophilic Anaerobic Digestion (MAD) with Three New Digesters			Three new 1.88 MG, 105' diameter concrete dome cover digesters. Solids handling processes operate similar to existing.		
Baseline: MAD with Process Optimization (Higher %TS)	Optimize Primary Clarifiers and DAFT to achieve thicker solids. Twelve new primary sludge pumps, six new TWAS pumps, to handle thicker solids.		Digesters operate at a thicker solids concentration, deferring need for new digesters.		
Baseline: MAD with Recuperative Thickening			Converts digesters 9 through 12 to the recuperative thickening process. Includes 12 mixers and service boxes (three per digester) and four sludge screw thickeners (one per digester). Structural reinforcement needed for mixer modifications. Increased digester capacity allows other digesters to be taken out of service.		
Pre-Digestion Thermal Hydrolysis	Process allows DAFT thickeners to be taken out of service.	Two centrifuges, one boiler, three pre-digestion skids each equipped with one pulper tank, four reactors, one flash tank, one sludge storage hopper, feed pumps, and a new equipment building	Increased digester capacity allows several digesters to be taken out of service. Digesters operate at a thicker solids concentration and can achieve greater volatile solids reduction	Dewatering feed is thicker, cake is thicker, and cake volume decreases. Only operate belt filter presses to reduce power and polymer usage.	
Post-Digestion Thermo-Chemical Hydrolysis - Onsite					Five biosolids storage hoppers, five reactors, feed pumps, caustic chemical storage, two boilers, loadout station, product storage reservoir, new equipment building
Post-Digestion Thermo-Chemical Hydrolysis - Offsite	**N/A**				
Thermal Drying				Only operate centrifuges to achieve higher solids concentration feed to post-digestion process.	Two-train rotary drum dryers, equipment building
Thermal Drying & Pyrolysis				Only operate centrifuges to achieve higher solids concentration feed to post-digestion process.	Eight belt dryers, twelve pyrolysis skids, two product storage tanks, loadout station
Covered Aerated Static Pile (ASP) Compost					Receiving structure, four industrial mixers, two screens, 64 bunkers (includes cover, blower, and leachate collection), end-product storage pad, leachate tank and pumps

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For the off-site Lystek option, a new facility would need to be constructed at the SKF. Lystek did not provide a tipping fee estimate. Instead, we assumed that the tipping fee would cover the portion of the construction costs and O&M costs corresponding to the portion of solids coming from the RWRF, and that these costs would be similar to those incurred to build and operate a facility at the RWRF. Given this, the same capital and O&M costs were used for the on-site and off-site Lystek options, except the off-site Lystek option includes an additional hauling and disposal fee to transport biosolids from the RWRF to SKF.

Life cycle costs, presented in Figure 4.23, are the sum of capital costs and O&M costs from 2024 through 2040.

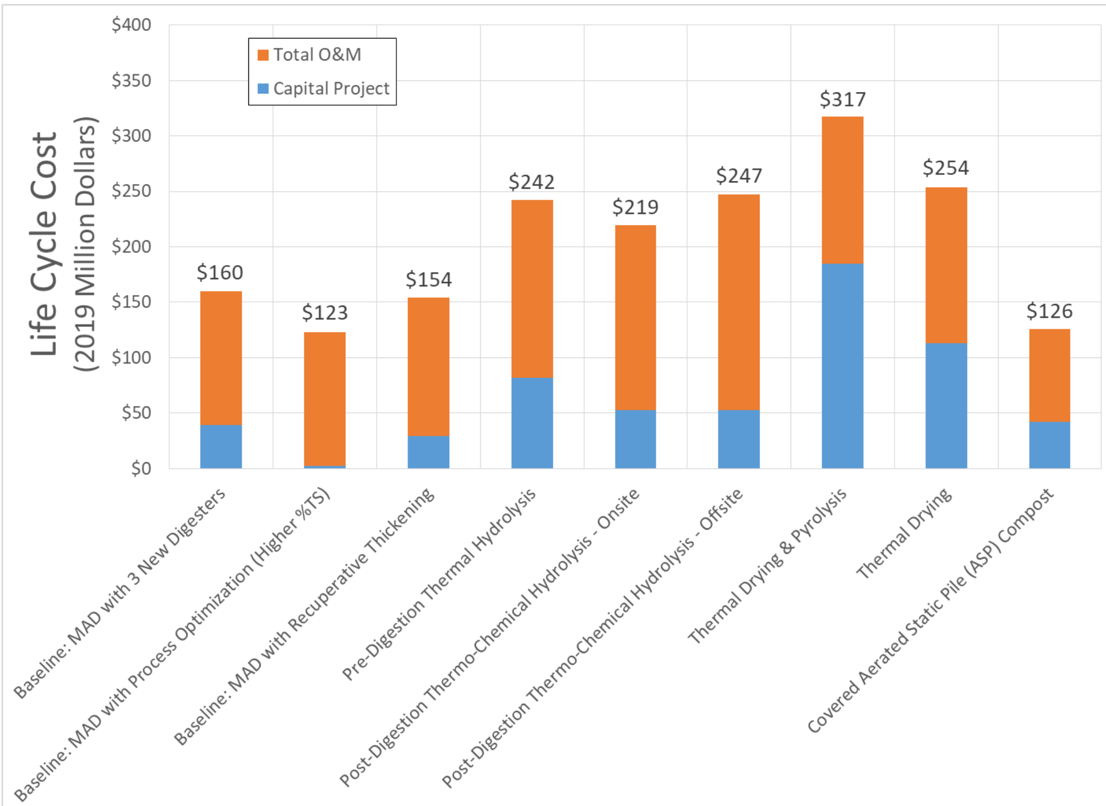


Figure 4.23 Life Cycle Costs of Alternatives in Millions of 2019 Dollars

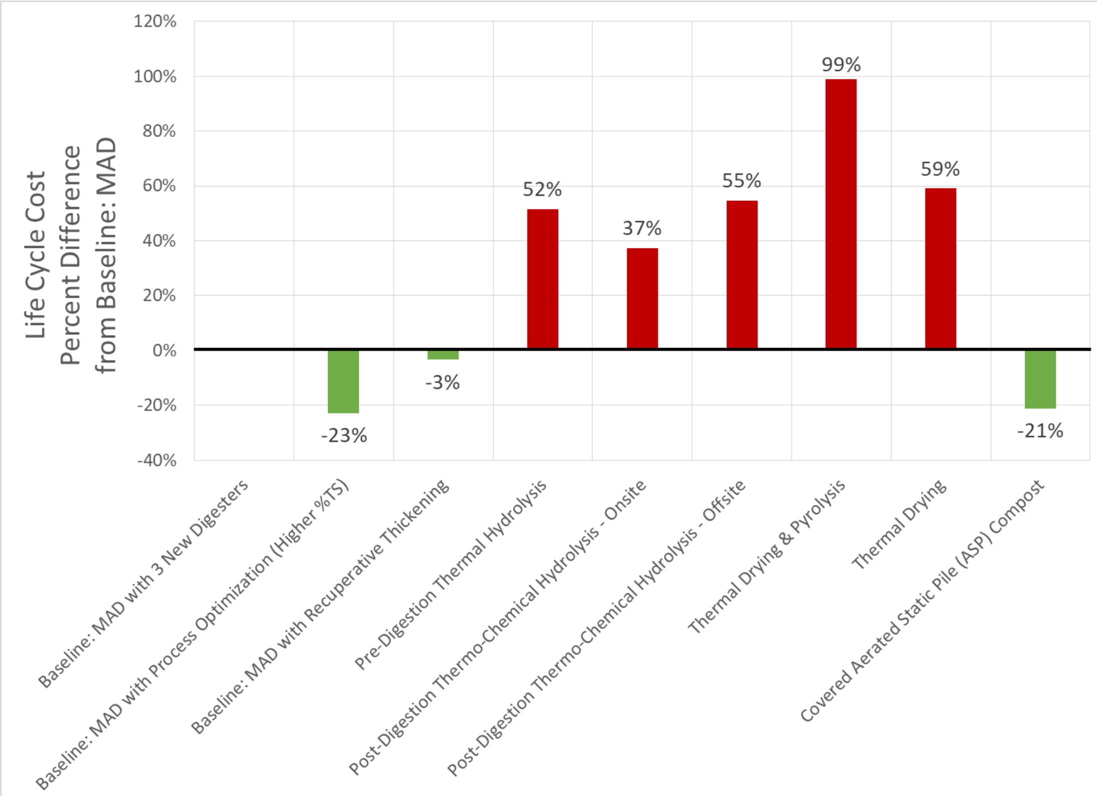


Figure 4.24 Percent Difference in Life Cycle Cost from Baseline (MAD with Three New Digesters)

Figure 4.24 shows the difference in life cycle costs for the alternatives compared to Baseline MAD with Three New Digesters. Compared to the Baseline MAD with Three New Digesters alternative, process optimization and composting show a cost savings of 23 and 21 percent, respectively. Recuperative thickening is roughly the same cost as Baseline MAD with Three New Digesters. All other alternatives are significantly more expensive, with costs 37 to 99 percent higher than Baseline MAD with Three New Digesters.

4.3.6.1 Sensitivity Analysis

The results of the market analysis indicated that the RWRF has a very favorable hauling and disposal unit cost, up to $33.85 per ton. Typical hauling and disposal costs throughout California range from $45 to $55 per ton. Given the below average hauling and disposal costs, it is likely that the price point will continue to increase steadily in the future. A sensitivity analysis was performed on the hauling and disposal costs to confirm the robustness of the project alternative life cycle costs. Figure 4.25 shows the life cycle costs when the hauling and disposal cost is doubled from the current value of $34/ton to $68/ton. Note that only four alternatives, the three Baseline MAD alternatives and Pre-Digestion Thermal Hydrolysis process, are impacted by varying hauling and disposal costs. The other alternatives produce a different end-product, subject to different or no hauling and disposal mechanisms. When hauling costs increase, more expensive alternatives, such as thermal hydrolysis, become more cost competitive, while composting is much cheaper than all other alternatives.

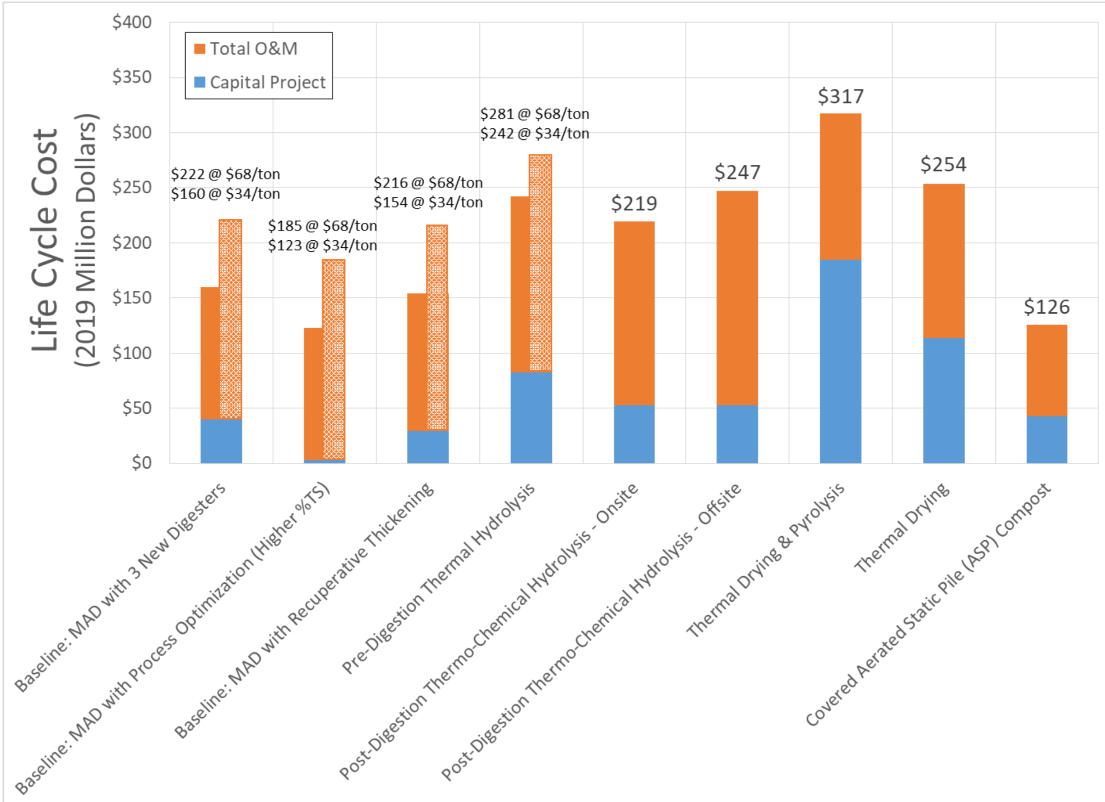


Figure 4.25 Life Cycle Cost for End-Use Costs of $68/ton (2x Current)

Another analysis was completed to look at how much the hauling and disposal cost would need to increase before the alternatives with the lowest life cycle costs, Baseline MAD with Process Optimization and Composting, have the same life cycle cost. Hauling and disposal costs would only need to increase by less than 5 percent, from $34/ton to roughly $35.50/ton, for the composting alternative to have the lowest life cycle cost.

One of the assumptions made to complete the financial analysis was that pre-ground bulking agent, used to supplement the composting process, would be received on-site for free, which is the case at other composting facilities. There is a chance the City will be charged a tipping fee to receive pre-ground agricultural woody waste, likely between $0 and $10 per ton. Figure 4.26 shows the impact to the life cycle cost if the City had to pay $10 or $20 per ton of bulking agent. Having to pay $10/ton versus $0 for bulking agent (and similarly $20/ton vs. $10/ton) increases the annual O&M cost by just over $1M, and the life cycle cost by $13.4M. Under a worst case scenario, having to pay $20/ton for bulking agent, increases the life cycle cost of composting to $152M, which is still a lower life cycle cost than the Baseline: MAD with Three New Digesters alternative, and second only to the process optimization alternative. Regardless of the bulking agent market, compost is still a cost-competitive alternative. An additional assessment should be completed on the bulking agent market to better understand specific drivers to agricultural woody waste hauling and identify potential costs and how they relate to the operation of a composting facility.

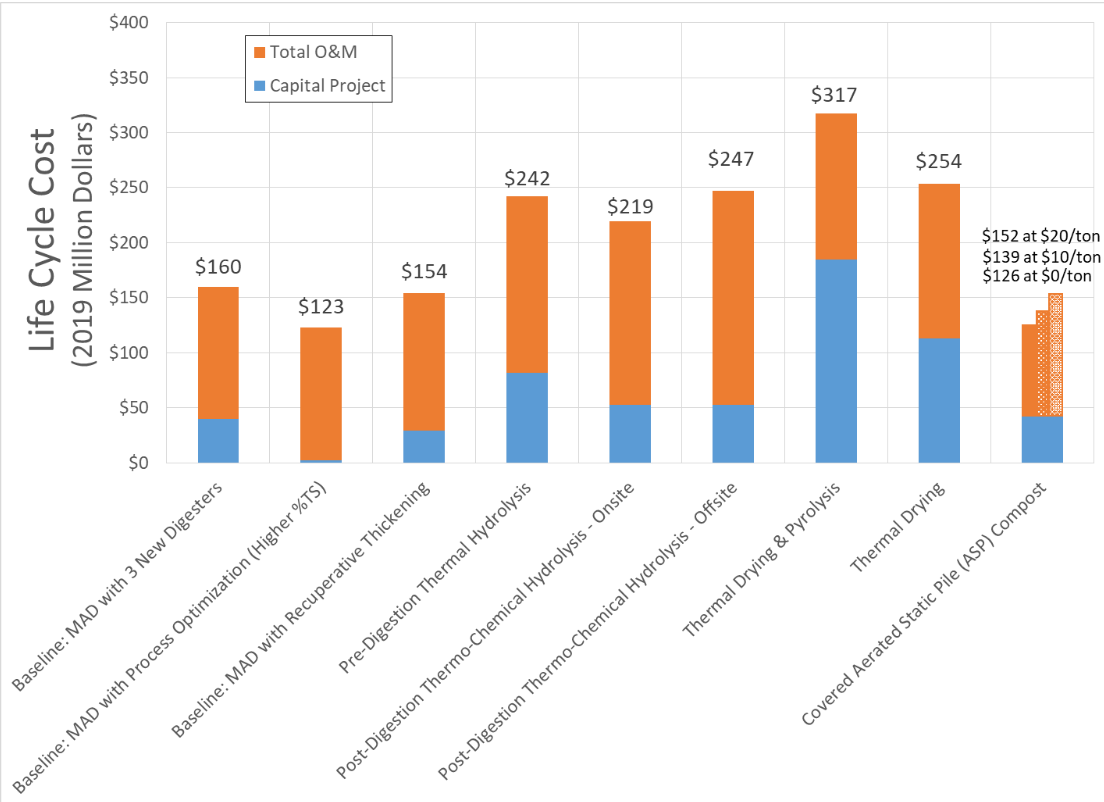
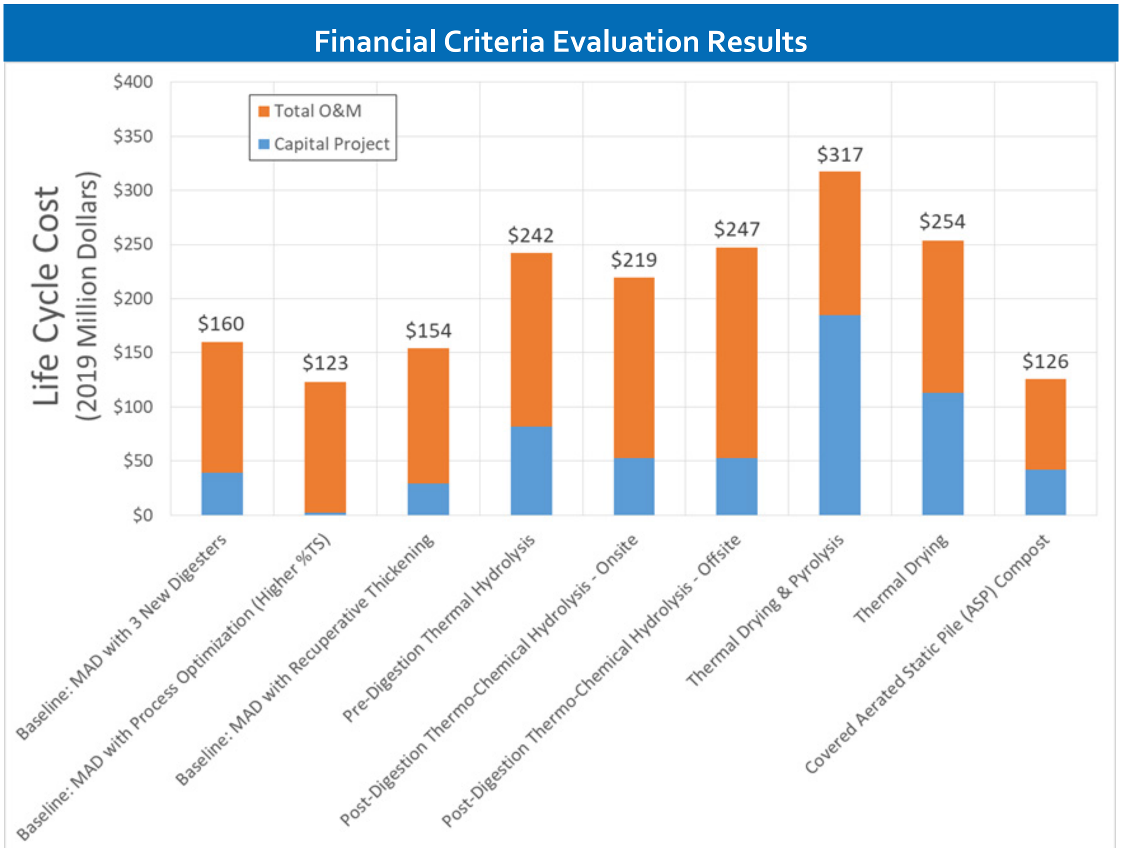


Figure 4.26 Sensitivity of Life Cycle Costs to Increased Cost of Bulking Agent for Compost

4.4 Findings

Figures 4.27 and 4.28 summarize the findings of the financial and non-financial criteria evaluation.

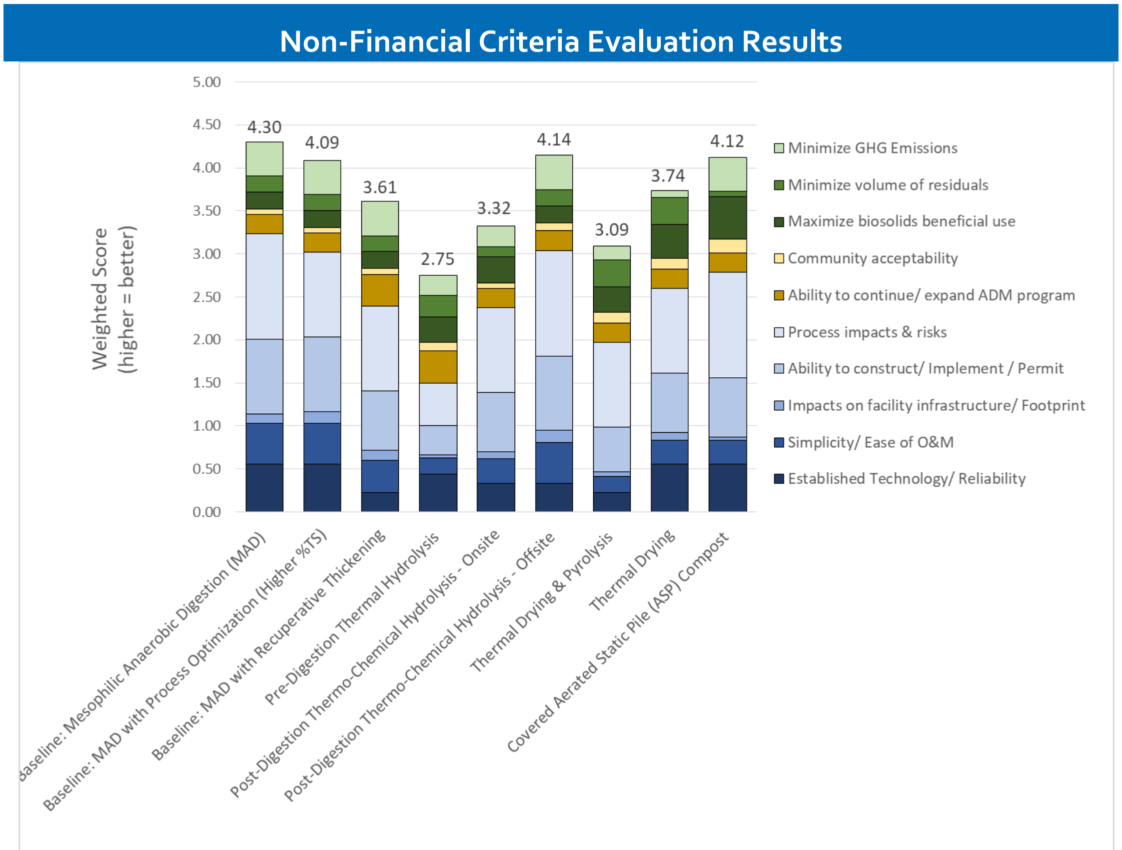


Most cost-effective alternatives:

1. Baseline: MAD with Process Optimization (-23 percent)*
2. Covered ASP Composting (-21 percent)*
3. Baseline: MAD with Recuperative Thickening (-3 percent)*
4. Baseline: MAD

**Percentage differences provided are relative to Baseline: MAD.*

Figure 4.27 Summary of Findings from Financial Criteria Evaluations



Highest scoring alternatives:

1. Baseline: MAD (4.30)
2. Thermo-chemical Hydrolysis Offsite (4.14)
3. Covered ASP Composting (4.12)
4. Baseline: MAD with Process Optimization (4.09)

Figure 4.28 Summary of Findings from Non-Financial Criteria Evaluations

The results from the financial and non-financial evaluations largely reinforce each other. The most cost-effective alternatives are Covered ASP Composting and Baseline MAD with Process Optimization followed by Baseline MAD with Three New Digesters, then Baseline MAD with Recuperative Thickening. The highest scoring alternatives from the non-financial evaluation are Baseline MAD with Three New Digesters followed by Post-digestion Thermo-Chemical Hydrolysis – Offsite, Covered ASP Composting, and Baseline MAD with Process Optimization.

Baseline MAD with Process Optimization (higher %TS) is estimated to have a 23 percent lower life cycle cost compared to Baseline MAD with Three New Digesters because it defers the cost of three additional large digesters. It also scored high on the non-financial evaluation because it does not introduce a new process, only requires minor modifications, and has little impact on other solids handling processes.

Covered ASP Composting is estimated to have a 21 percent lower life cycle cost compared to Baseline MAD with Three New Digesters largely because the City would no longer have to pay hauling and disposal costs. Additionally, it scored highly on the non-financial evaluation because it is a relatively simple process, has little to no impact on upstream processes, and produces the most marketable biosolids product. It requires several acres of land because of the longer period it takes to stabilize biosolids. However, this is likely not a concern because the City owns plenty of land around the RWRF.

Baseline MAD with Recuperative Thickening was found to have a similar cost to Baseline MAD with Three New Digesters. However, according to the results of the non-financial evaluation, it is less favorable than digestion due to the increased operational complexity of recuperative thickening. The City may also consider building new digesters with recuperative thickening, which would be easier to construct than retrofitting existing digesters.

Post-Digestion Thermo-Chemical Hydrolysis (Offsite) is estimated to have a 55 percent higher life cycle cost compared to Baseline MAD with Three New Digesters. However, it scored highly in the non-financial evaluation because it is the only alternative where the City is not responsible for the treatment process. This allows the City to limit potential process impacts or any constructability issues, which are the two highest weighted criteria. However, the City could explore opportunities for public-private partnerships for other alternatives as well, including composting, thermal drying, or pyrolysis. That approach would likely result in a better score on the non-financial evaluation for those processes as well.

4.5 Recommendations

Based on the findings of the financial and non-financial criteria evaluation of the biosolids management alternatives considered for this Master Plan and described in this Chapter, Figure 4.29 summarizes Carollo's recommendations for the RWRF in the near- and long-term. The recommendations reflect the need to address the near-term capacity limitation of the existing digesters, as well as the City's desire to incorporate diversification of operations and biosolids products in the long-term.

Near-term: Process Optimization	Long-term: Examine Composting On-site
• Consider replacing PS and TWAS pumps to handle higher solids concentrations. • Investigate solids thickness achievable through optimization of primary clarifier and DAFT operations. • If increased thickness is not achievable, further evaluate costs of building new digesters or retrofitting existing digesters with recuperative thickening.	• Determine desired portion of biosolids product to be composted to determine basis for facility sizing (e.g., produce 50% Class B cake and 50% Class A Compost). • Evaluate whether the City wants to own and operate a compost facility or lease the land and contract the operations. Consider benefits and risks of each option. • Further examine compost and bulking-aging markets.

Figure 4.29 RWRF Biosolids Master Plan Near- and Long-Term Recommendations

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Chapter 5

IMPLEMENTATION PLAN

5.1 Introduction

The implementation plan provides a detailed breakdown of project phasing and associated capital project costs for the recommended near- and long-term solids handling improvements. Two pathways are presented, as summarized in Figure 5.1, a Class B pathway based on continuing the Baseline MAD alternative, and a Class A pathway based on the Composting alternative. Process Optimization and the construction of Digester No. 14 are included in both pathways to provide capacity through year 2032, when additional biosolids handling capacity will be needed. While Process Optimization is included as a near-term project, the implementation plan assumes a worst-case scenario (i.e., no solids concentration improvements can be achieved through process optimization) to develop conservative life cycle cost estimates.

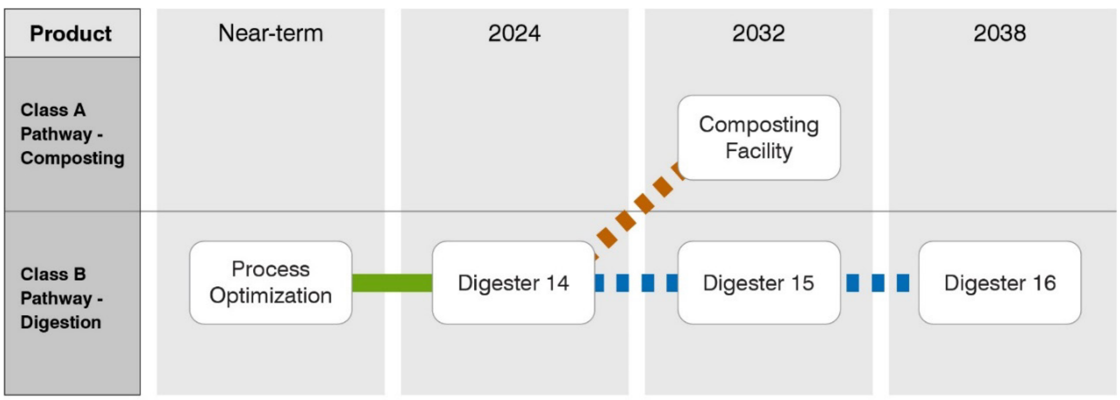

Figure 5.1 Implementation Plan for Class A and Class B Pathways

The City needs to decide which pathway it will carry forward by 2028, at which point the City needs to begin the procurement and preliminary design of the selected alternative in order to maintain the same level of service to customers. By then, the City will have additional information to make an informed decision including understanding the effectiveness of the process optimization, as well as a better understanding of the compost market. Additionally, the City should also consider the impact of potential regulatory and financial drivers on the decision between the two pathways, which is summarized in Section 5.6 of this report.

Figures 5.2 and 5.3 present the detailed implementation plan (schedule for planning through construction services and capital costs, followed by the site map) for the Class B pathway, and Figures 5.4 and 5.5 show the same for the Class A pathway. Project schedules are broken down by quarter and estimated duration of project phases are provided. Estimated project costs are comprised of procurement, preliminary design, final design, bidding and award, construction, and project closeout.

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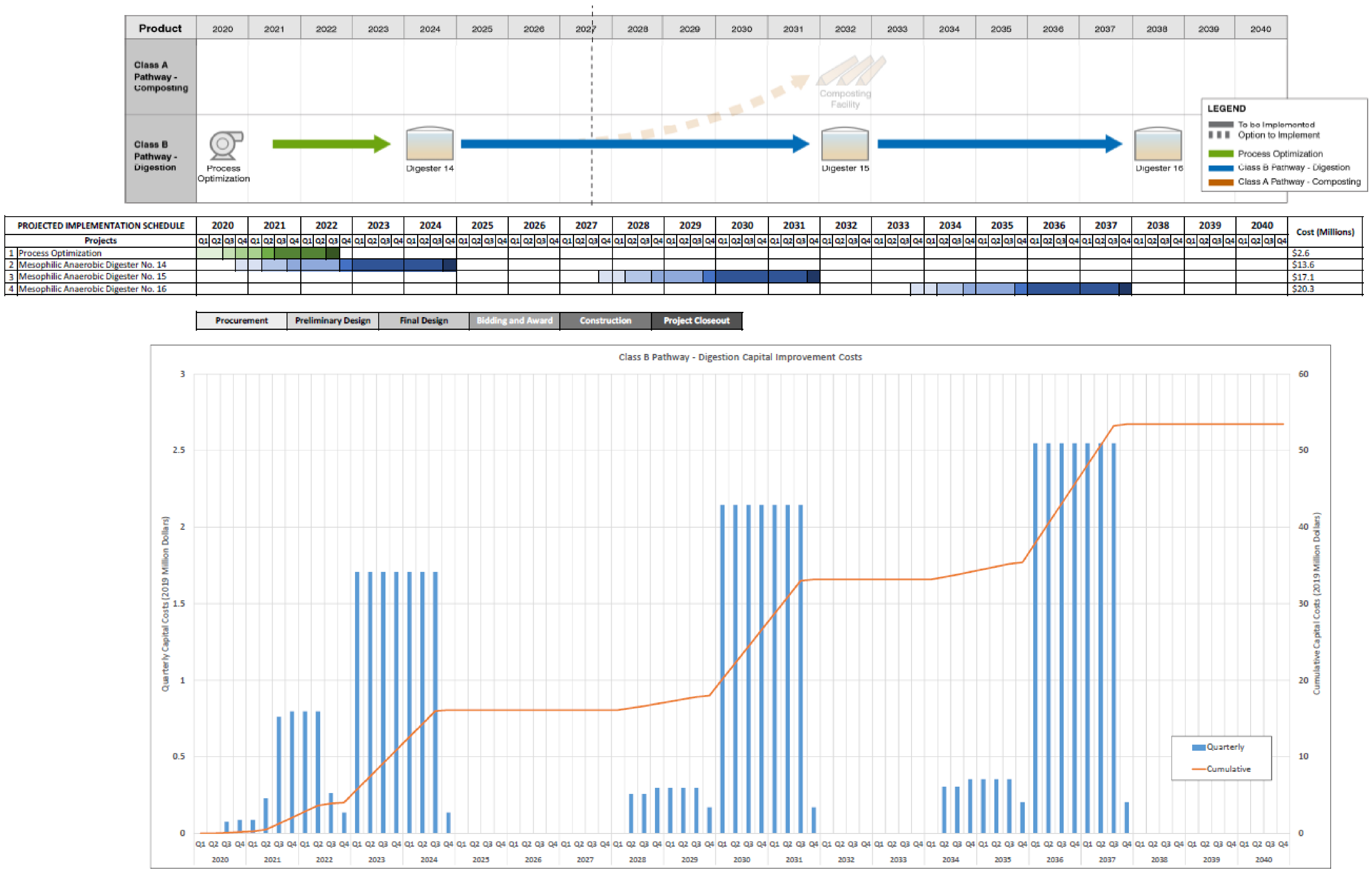

Figure 5.2 Implementation Schedule and Estimated Project Costs by Phase – Class B Pathway: Mesophilic Anaerobic Digestion

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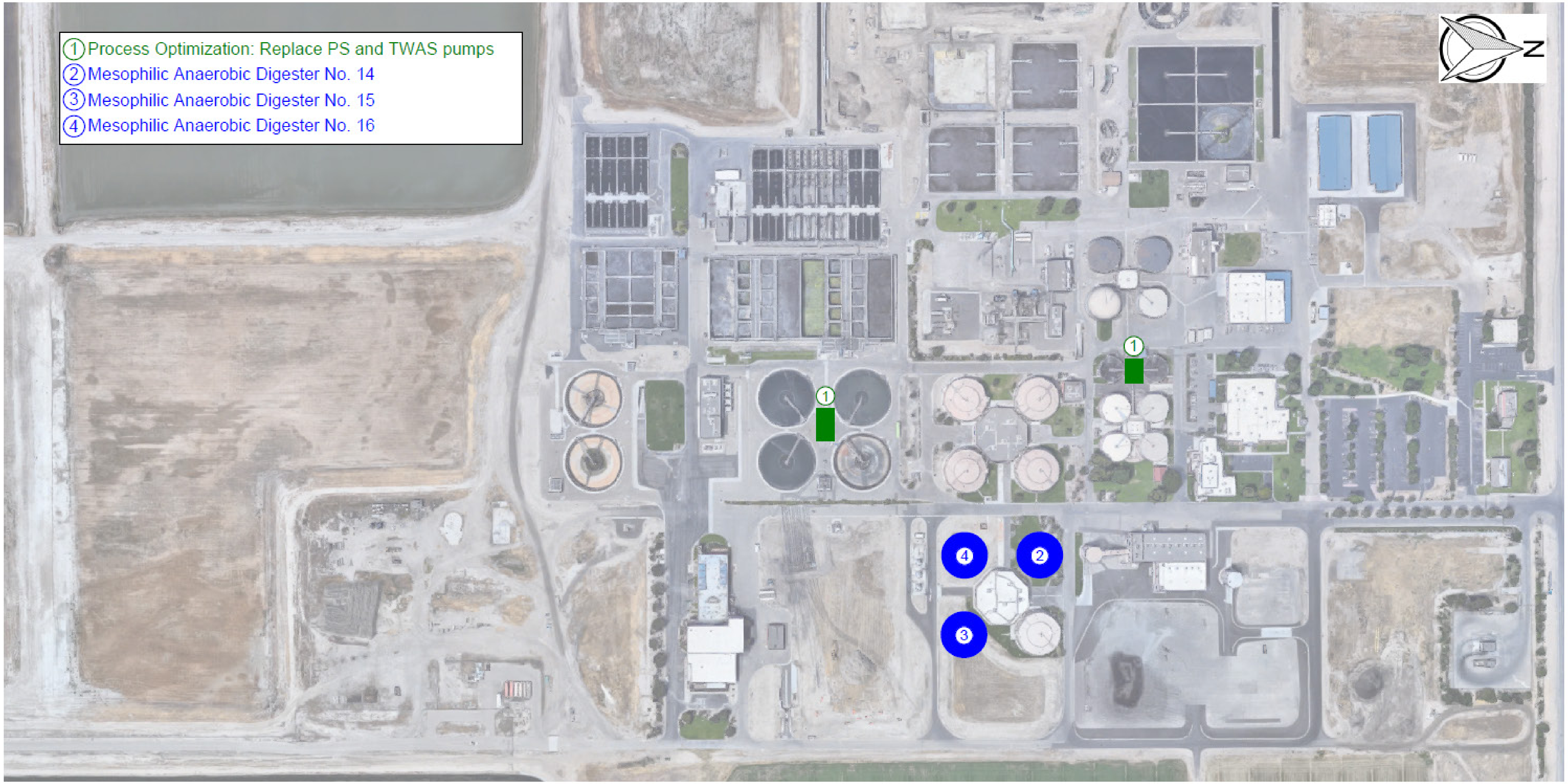

Figure 5.3 Implementation Site Plan – Class B Pathway: Mesophilic Anaerobic Digestion

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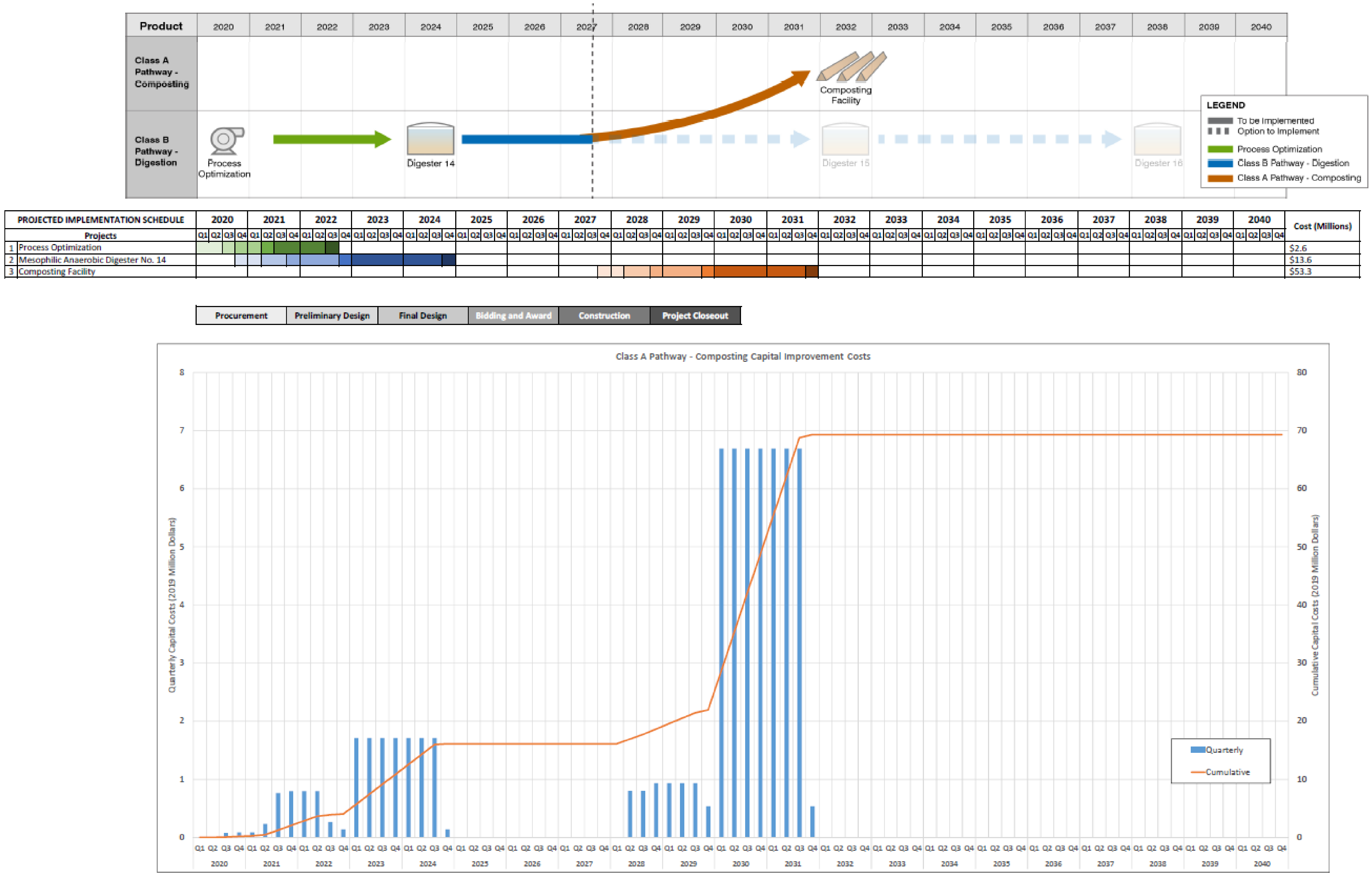

Figure 5.4 Implementation Schedule and Estimated Project Costs by Phase- Class A Pathway: Composting

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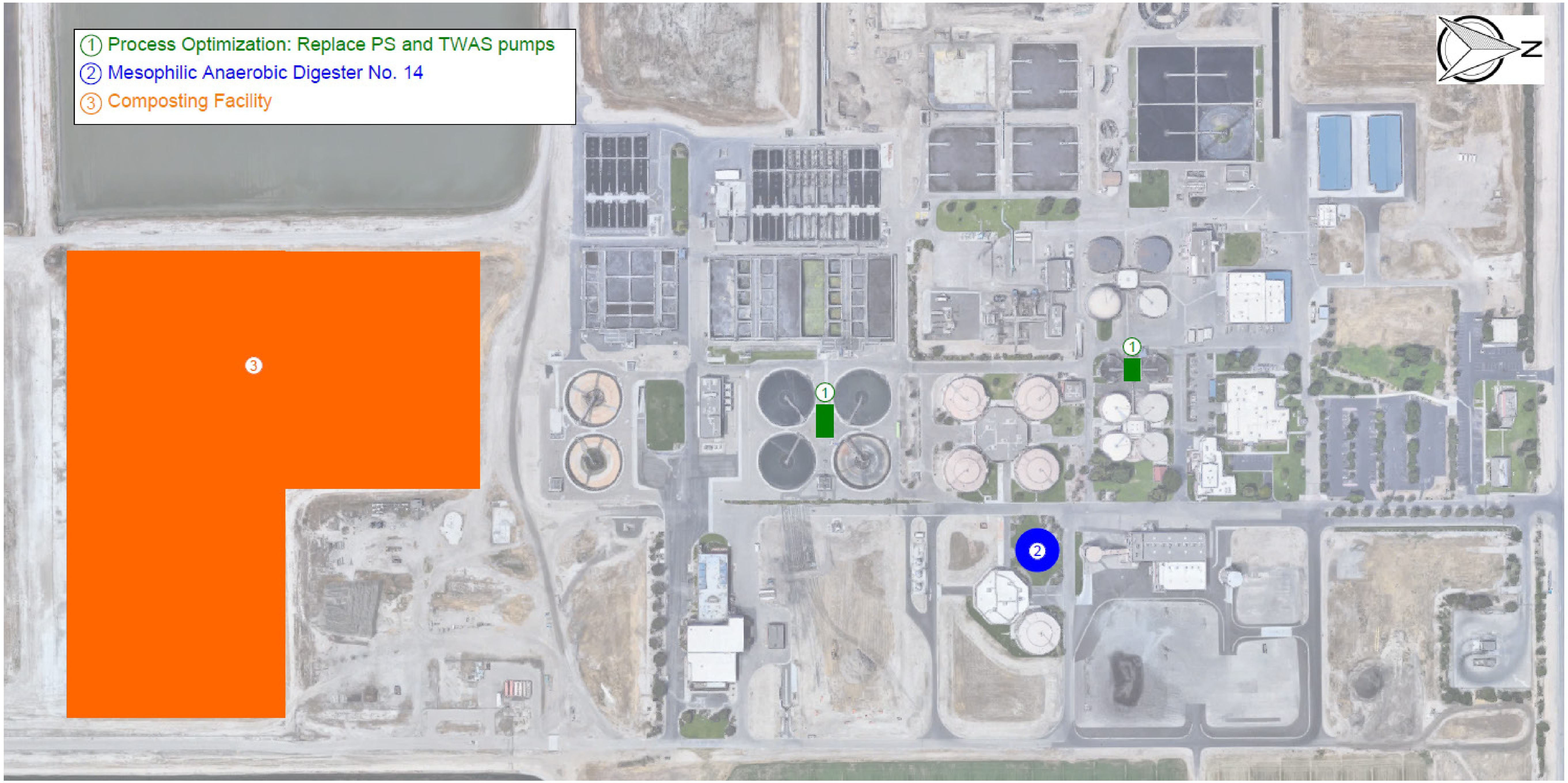

Figure 5.5 Implementation Site Plan – Class A Pathway: Composting

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Table 5.1 provides the breakdown of estimated project costs distributed evenly over the project phases. As detailed in Section 4.3.5.1, Design, Legal, and Administration Fees are estimated to be 15 percent of the total project cost, while Construction Management is estimated to be 10 percent, for a total of 25 percent of the total project costs. The remainder of the total project cost is construction cost, and is expended during the construction phase of the project.

Table 5.1 Estimated Project Costs Broken Down into Project Phases

Project Phase	City	Designer	Construction Management	Total
Procurement	--	--	--	--
Preliminary Design	1%	2%	--	**3%**
Final Design	1%	6%	--	**7%**
Bidding and Award	1%	--	--	**1%**
Construction	2%	2%	9%	**13%**
Project Closeout	--	--	1%	**1%**
Total	**5%**	**10%**	**10%**	**25%**

The estimated total project costs are consistent with those provided in Section 4.3.6 with the only difference being the escalation to mid-point. While the implementation plan provides a timeline for new construction, the evaluation of alternatives assumed all projects would be constructed by 2024 in order to compare alternatives equally. Therefore, both alternatives will show higher project costs than previously presented due to the later construction date considered in the implementation plan.

The following sections describe each recommended improvement and future pathway

5.2 Process Optimization

The more the solids concentration to the digester can be increased, the more the hydraulic loading can be decreased. This operational optimization can significantly defer the need for new digester construction while still achieving and maintaining Class B requirements.

Higher primary sludge (PS) concentrations might be achieved by maintaining a deeper sludge blanket in the primary clarifiers, changing pumping frequency, utilizing inline automation to target a solids concentration and tying in pump controls accordingly, and/or using chemically enhanced primary treatment (CEPT). The thickened waste activated sludge (TWAS) solids concentration might be increased by optimizing DAFT operations including polymer selection and dosage, changing mechanism speed, and confirming that ancillary systems to the DAFT (e.g., air saturation system) are performing to their specifications. To determine the achievable solids concentrations, plant staff would need to modify operations and monitor the effects.

Plant staff stated their concerns with pumping TWAS at concentrations greater than five percent. During optimization, TWAS and PS pumps should be closely monitored to ensure adequate pumping capacity is maintained. Both sets of PS and TWAS pumps may also need to be replaced to reliably pump thickened solids at higher concentrations.

The process optimization project assumes replacement of twelve PS and six TWAS pumps at an estimated project cost of $2.6M. Operational modifications noted above to produce thicker solids can be implemented as soon as practical for the City to determine the extent of achievable process improvements. Pump replacement, if necessary, will require design and subsequent construction.

5.3 Digester No. 14

If process optimization significantly improves solids handling operations (i.e., increases digestion capacity across the existing digester volume), digester construction may be deferred several years. However, the implementation plan conservatively assumes process optimization does not improve digestion capacity, and Digester No. 14 would need to be constructed by 2024.

Digester No. 13 and its control building were constructed as part of the Organics Upgrade project in 2007. The control building was constructed with space to accommodate future Digester No.'s 14, 15, and 16. Digester No. 14 would be similar in design to Digester No. 13, with a 105-foot diameter and 1.88 million gallon capacity. Digester No. 14 would be located on the northwest corner of the digester control building.

The total project cost for constructing Digester No. 14 by 2024 is estimated at approximately $13.6M.

5.4 Class B Pathway: Mesophilic Anaerobic Digestion

Under the Class B pathway, it is assumed the City continues expanding mesophilic anaerobic digestion capacity and producing Class B cake. Assuming no solids concentration improvements can be achieved through process optimization, the City would then need to build Digester No. 15 by 2032 and Digester No. 16 by 2038 to maintain a minimum 15-day average SRT to maintain regulatory compliance. The total project cost for constructing Digester No. 15 and Digester No. 16 is approximately $17.1 and $20.3M, respectively.

5.5 Class A Pathway: Composting

The alternatives analysis identified composting as the highest ranked alternative, producing a Class A product, with a high score in the non-financial evaluation, and a roughly 20 percent lower life-cycle cost compared to Baseline MAD with three new digesters. The capital cost for constructing a composting facility is comparable to the cost of constructing three new mesophilic anaerobic digesters with equal solids handling capacities. However, the annual operation and maintenance (O&M) costs for a composting facility are roughly 30% lower than the O&M for new digesters, largely because of the cost associated with biosolids end-use (hauling and tipping fee). The alternatives analysis assumed Class A compost could be marketed and sold for revenue at $1.50 per ton, whereas Class B cake is hauled and further processed at a current cost of $34/ton.

Under the Class A pathway, the City would build an on-site composting facility by 2032 to process 100 percent of the digested sludge. The equipment and facilities sized for the projected 2040 biosolids load include four industrial mixers, two screens, and 64 composting bunkers, each with their own dedicated ancillary equipment.

No additional anaerobic digestion capacity would be needed after the construction of Digester No. 14, since the City could achieve the Class A pathogen reduction requirement through the composting process. However, if the City wanted to diversify their product and have the ability to produce both Class B cake and Class A compost, then they would need to build both the composting facility and Digester No.'s 15 and 16, which would almost double the total project costs incurred through 2040.

The City should investigate the compost and bulking agent markets. This analysis assumes the City will be able to receive pre-ground agricultural woody waste for free. Further analysis is recommended to determine whether the City would need to pay a fee for pre-ground agricultural woody waste, or if they could charge a tipping fee for processing it.

The City investigated a potential partnership with the solid waste department to use green waste as the bulking agent for compost, but the solid waste department expressed a preference to compost green waste separate from biosolids at this point in time. Municipal green waste has higher contamination rates than agricultural waste, which would require increased labor for the removal of contaminants and may require additional mechanical equipment such as grinders and/or more screens.

The City can better understand the composting process and operation by visiting other similar composting facilities, such as the Mid Valley Disposal composting facility in Kerman. This facility uses the same recommended bunker system with GORE® covers that were included in this analysis.

A major decision related to the final implementation of a compost facility is deciding whether to fund and/or operate the compost facility with City resources or to engage with a third party to assist with compost facility funding and/or operations. The costs shown in Figure 5.4 assume the City owns and operates the new composting facility. In either case, the compost operation will be influenced by the party responsible for operating the facility and marketing the final compost product. While both options have been successfully implemented by utilities across the United States, each has its own set of benefits and considerations that should be understood and evaluated when determining the best management option specifically for the City.

The team has identified four major areas in which public operations will differ from a privately-operated facility, including management of daily compost activities, marketing efforts, potential for regionalization, and product quality (summarized in Table 5.2). Overall, a publicly operated facility will provide the City with more control over the composting effort, including processing, marketing, product quality, and pricing, whereas the privately-operated facility could allow for management of the facility by experienced composting experts.

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Table 5.2 Benefits and Considerations of Publicly vs. Privately Operating a Compost Facility

Parameter	Public Operation		Private Operation	
	Benefits	Consideration	Benefits	Considerations
Management of Daily Compost Activities Includes sourcing carbon-rich material, grinding woody waste, managing piles, and recordkeeping.	• Allows City to choose feedstocks, refine operation to meet City needs, and control product quality • Promotes synergy with public works and local agricultural community	• Will require City personnel training • Will take time to learn/optimize process • Additional full-time equivalent (FTE) employees may be required	• Private firm has experience with composting process • Shorter timeframe for process start-up & optimization • Fewer City FTEs required	• City will have less control over source of feedstocks & outlets • Private firm responsible for final product quality • Must gauge risk / reliability (facility failure, compliance, tipping fee increases, etc.) with private firm
Marketing Efforts Includes branding, market studies, website, social media, customer identification, etc.	• Positive association between City & compost product • City controls where and how product is distributed • Option to target low- or high-value markets • Potential use for City projects	• City resources or outside firm to brand / market program • City responsible for seasonal distribution • Potential to have surplus product during slow season	• Private firm assumes full responsibility for branding / marketing biosolids compost	• Private firm economics typically driven by reliance on tipping fees alone • Less incentive for private firm to market to higher value outlets
Biosolids Source(s) / Regionalization Includes option to accept Fresno biosolids only, or to also accept solids from other municipal water resource recovery facilities.	• City controls pursuit of regional options • Quality of material (i.e., stabilized or unstabilized) dictated by City • Responsible to operate facility to minimize potential for odors	• City responsible for managing sources other than Fresno • Site selection may present challenges from community	• Regionalization may result in reduced tipping fee for City (i.e., other sources share financial obligation)	• Incentive to accept biosolids / unstabilized solids from other treatment plants • Increased potential for nuisances associated with traffic and odors • Site selection & permitting may present challenges from community
Product Quality Related to level of product stability, including potential to generate odors.	• City controls source material, compost duration, and quality of final product quality to meet customer preferences • Less potential to produce malodor complaints	• City responsible for maintaining quality control	• Experience to meet targeted customer preferences / needs	• Economics may favor lower value outlets • Incentive to operate compost process to meet minimum requirements without proper curing • May result in poorly stabilized product

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5.6 Impact of Potential Regulatory and Financial Drivers

Table 5.3 highlights key, potential regulatory and financial drivers that may affect the City's decision between the two pathways, as well as the timing of proposed projects. Refer to Chapter 2 for a comprehensive assessment of current and future regulations that may impact biosolids management.

Table 5.3 Summary of Potential Regulatory and Financial Drivers and Associated Impacts

Regulatory and Financial Drivers	Likelihood	Potential Impact
Class B biosolids end-use cost increase, similar to other regions in California.	High	Class A compost becomes more favorable relative to MAD.
SB 1383 overturns Fresno county's ordinance banning Class B biosolids land application, reducing the hauling and land application cost of Class B biosolids.	Low	Class A compost becomes less favorable relative to MAD.
SB 1383 increases the market supply of organic wastes diverted from landfills, reducing the cost of pre-ground agricultural woody waste, and other compost amendments.	Medium	Class A compost becomes more favorable relative to MAD.
SB 1383 drives private composting and organic waste management companies to build more composting facilities in the area, resulting in increased potential for partnership, increased demand for compost amendments and increased supply of compost.	High	Potential for partnership with an off-site facility for composting the City's biosolids, as well as increased opportunities for partnership with private companies interested in owning and operating an on-site composting facility, make the Class A Pathway (Compost) more favorable. Increased demand for compost amendments could drive up the cost of pre-ground agricultural woody waste, and could also drive down the cost of compost, making the Compost pathway less favorable.
SB 1383 increases the market supply of organic wastes, providing an opportunity for Fresno to maximize their codigestion program and charge higher tipping fees.	High	Will increase O&M costs associated with ADM program. May need additional anaerobic digestion capacity sooner than expected. Additional capacity could be provided through process optimization or anaerobic digestion expansion.
PFOS/PFOA regulation or restrictions applicable to biosolids products and their use become more stringent.	Low	Stringent PFOS/PFOA regulations could significantly impede biosolids management options (e.g., land application). The current state of knowledge relative to biosolids (e.g., test methods for biosolids and proven technologies resulting in PFAS destruction in biosolids) is limited. Considerable applied research is necessary before proven mitigation measures are identified and recommended.
Regional to international pressures against food crops grown using biosolids products increase.	Medium	The market of Class A and Class B biosolids products for beneficial use on crops for human consumption may become more limited.

5.7 Conclusion

The results of the background information, regulatory review, market assessment, and alternatives evaluation performed as part of this Master Plan provided a basis for developing the implementation plan for the recommendations. Two alternatives (thus, two pathways) are shown for the RWRF biosolids handling through 2040. One option is to continue the existing practice of solids stabilization through mesophilic anaerobic digestion to achieve Class B cake. Alternatively, constructing a composting facility within the next ten years provides a means of producing a higher quality end-product (in addition to Class B product) with an estimated life cycle cost lower than the baseline. Regardless of the long-term alternative selected, short-term recommendations are described that include process optimization improvements and construction of Digester No. 14. The implementation plan provides total project costs, schedule, regulatory and financial drivers, and a discussion of additional considerations to facilitate the City's decision regarding the fate (long-term beneficial use) of their biosolids.

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Appendix 1-A

ADDITIONAL TABLES AND FIGURES

Table A.1 Capacity and Performance Assessment – Anaerobic Digestion

Parameter	VSLR ($lb/ft^3/d$)(1)	SRT (days)(1)	VA:Alk(1)	VSR (%)(1)	Meeting Operating Criteria?
Design Criteria	**≤0.12**	**≥15**	**≤0.10**	**≥50**(2)	
Digester 1	0.085	32	0.013	61	Yes
Digester 2	0.081	32	0.013	61	Yes
Digester 3	0.104	28	0.012	59	Yes
Digester 4	0.104	28	0.013	59	Yes
Digester 5	0.106	29	0.012	60	Yes
Digester 6	0.081	32	0.013	62	Yes
Digester 7	0.078	32	0.015	62	Yes
Digester 8	0.085	31	0.014	61	Yes
Digester 9	0.14	23	0.015	60	No
Digester 10	0.15	25	0.015	60	No
Digester 11	0.14	27	0.015	61	No
Digester 12	0.13	28	0.016	60	No
Digester 13	0.14	24	0.017	62	No
All non-ADM Digesters (No. 3-8)	0.093	30	NA	NA	
All ADM Digesters (No. 9-13)	0.14	25	NA	NA	
All Digesters	0.114	28	NA	NA	
Largest Digester Out of Service	0.110	22(4)	NA	NA	

Notes:
(1) Values calculated as average.
(2) While value was not found in design documents, a typical value for a blend of PS and TWAS is approximately 50%. A minimum of 38% is required under Part 503 for vector attraction reduction if that option is selected for biosolids management.
(3) Calculation assumes a proportional flow split among digesters based on operating volume.

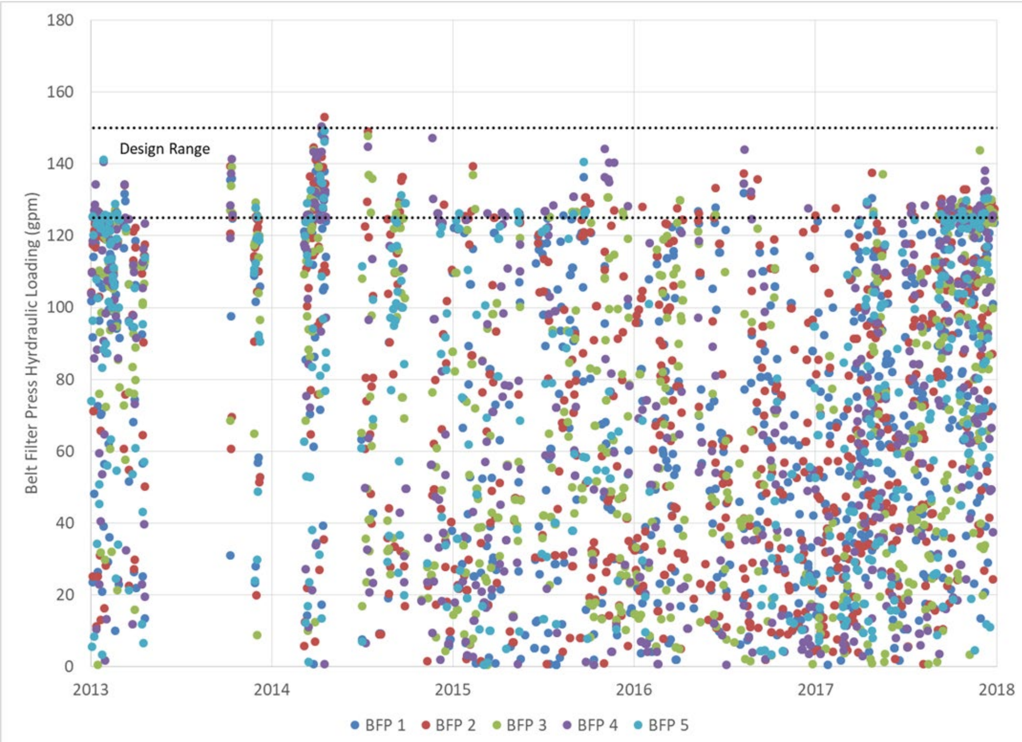

Figure A.1 Belt Filter Press Hydraulic Loading Rate (gpm)

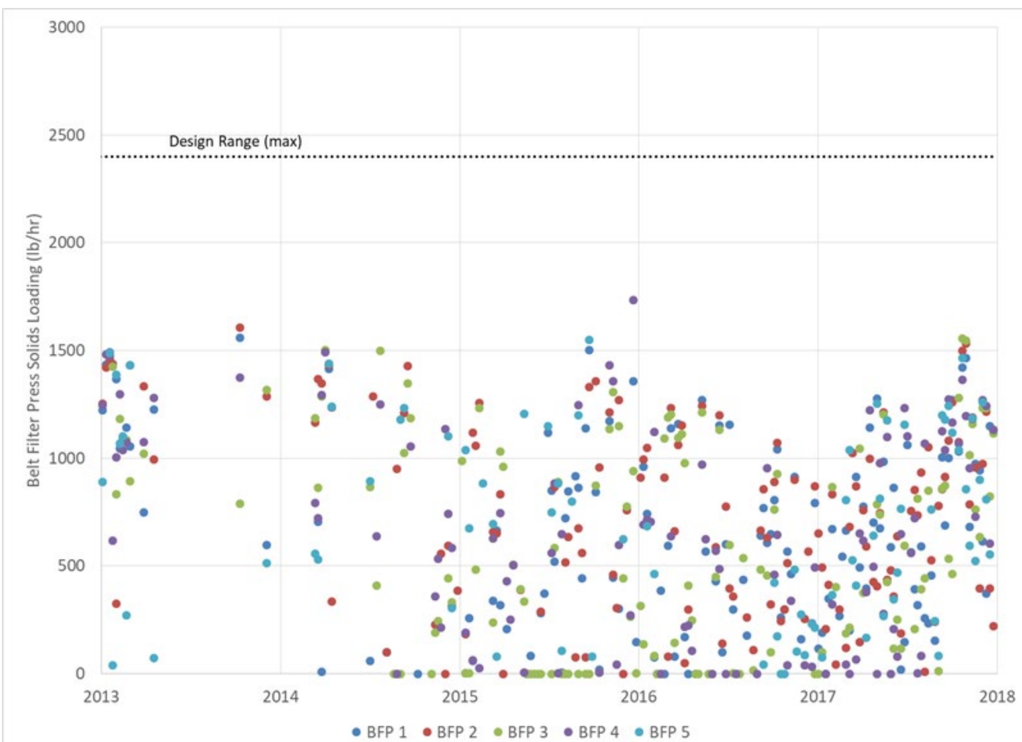

Figure A.2 Belt Filter Press Solids Loading Rate (lb/hr)

Figure A.3 Centrifuge Hydraulic Loading Rate (gpm)

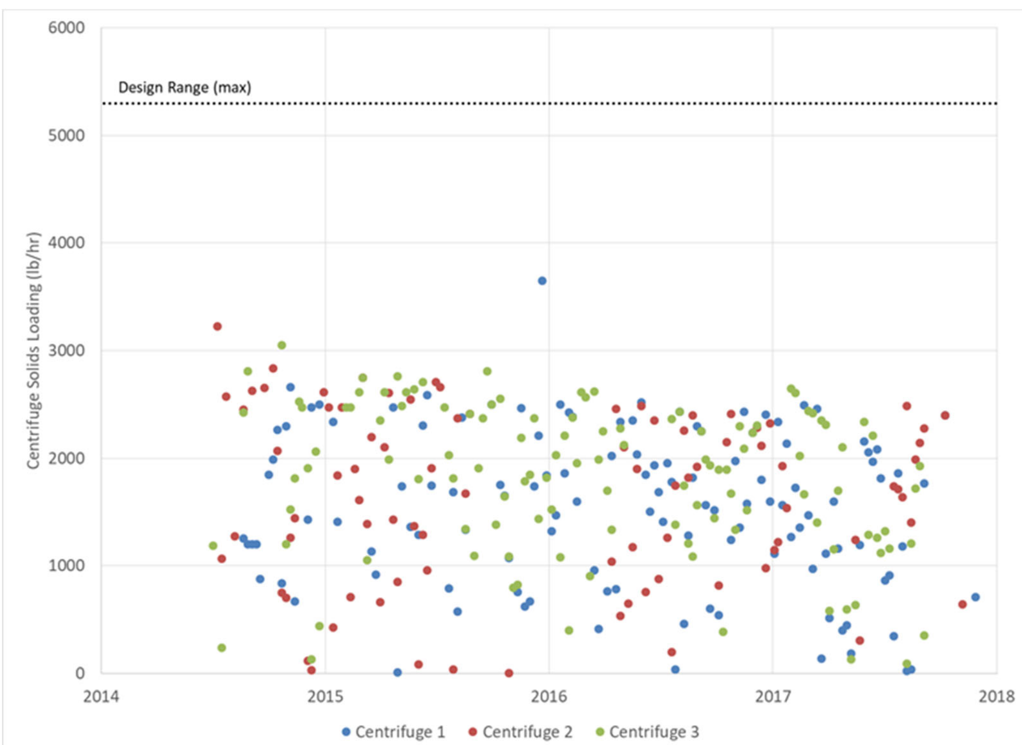

Figure A.4 Centrifuge Solids Loading Rate (lb/hr)

Appendix 1-B

DETAILED BIOSOLIDS HANDLING COSTS

	Process			Power						Labor				Equipment Maintenance	Chemical		Tipping		Hauling		TOTAL
				Electricity						Operations		Maintenance									
				$ 0.117 /kWh						$ 40.58 /hr		$ 40.58 /hr			$ 10.20 /gallon		$ (0.03) /gallon		$ 34.00 /ton		
	No. of Operating Units	No. of Standby Units	Motor Power (hp)	Total Motor Power (hp) Note 1	Operational % of Nameplate Note 2	Power input (kW)	Operation Time (hr/day)	Annual kWh	Annual Electricity Cost	Labor (hr/day)	Annual Labor Operations Cost	Labor (hrs/yr)	Annual Labor Maintenance Cost	Annual Equipment Maintenance Cost	gallons per day	Annual Chemical Cost	gallons per day	Annaul Tipping Revenue	tons per day	Annual Hauling Cost	O&M Cost ($/year)
Plant Wide																					
Air compressor	1	2	150	150	85%	95	12	416,754	$ 48,927												
Labor: Operations										39	$577,656										
Total									**$48,927**		**$577,656**		**$0**	**$0**		**$0**		**$0**		**$0**	**$626,583**
Sludge																					
Primary Clarifier Sludge Collector	3	3	1.5	4.5	85%	3	24	25,005	$ 2,936												
Primary Sludge Pumps	6	6	0	0	NA	-	24	-	$ -												
Primary Scum Pumps	1	3	0	0	NA	-	24	-	$ -												
Primary Scum Mixers	1	3	10	10	85%	6	4	9,261	$ 1,087												
Secondary Clarifier Drives (1-5)	5	0	1.5	7.5	85%	5	24	41,675	$ 4,893												
Secondary Sedimentation Basin Sludge Collector Drives (6-17)	24	0	1	24	85%	15	24	133,361	$ 15,657												
WAS Pumps (A-Side)	1	4	15	15	55%	6	24	54,178	$ 6,360												
WAS Pumps (B-Side)	1	2	20	20	68%	10	24	88,907	$ 10,438												
WAS Pumps (C-Side)	1	1	20	20	68%	10	24	88,907	$ 10,438												
WAS Pumps (MBR)	1	1	5	5	85%	3	10	11,576	$ 1,359												
Labor: Maintenance - Primary Sludge												820	$33,276								
Labor: Maintenance - Secondary Sludge												1700	$68,986								
Equipment Maintenance - Primary Sludge														$25,000							
Equipment Maintenance - Secondary Sludge														$70,000							
Total									**$53,167**		**$0**		**$102,262**	**$95,000**		**$0**		**$0**		**$0**	**$250,429**
Sludge Thickening																					
TWAS Float Pumps	2	4	15	30	64%	14	24	125,026	$ 14,678												
TWAS Sludge Pumps	1	2	10	10	85%	6	3.2	7,409	$ 870												
Pressurization Pumps	1	2	100	100	85%	63	24	555,672	$ 65,236												
Central Sludge Drive	1	1	5	5	26%	1	24	8,335	$ 979												
Electrical Room Heat Pump	1	0	10	10	85%	6	24	55,567	$ 6,524												
Miscellaneous Building Loads			10	10	85%	6	24	55,567	$ 6,524												
Labor: Maintenance												560	$22,725								
Equipment Maintenance														$15,500							
Chemical Costs															65	$241,995					
Total									**$94,809**		**$0**		**$22,725**	**$15,500**		**$241,995**		**$0**		**$0**	**$375,029**
ADM Receiving Station																					
Fill/Mix Pumps	3	0	7.5	22.5	85%	14	2.67	13,892	$ 1,631												
Rock Trap/Grinder	3	0	5	15	85%	10	0.89	3,087	$ 362												
Drain Pumps	2	0	20	40	85%	25	2.67	24,697	$ 2,899												
Labor: Maintenance																					
Equipment Maintenance																					
Tipping																	29,000	-$317,550			
Total									**$4,893**		**$0**		**$0**	**$0**		**$0**		**-$317,550**		**$0**	**-$312,657**
Anaerobic Digestion																					
Sludge Grinder (Digesters 1-8)	8	0	3	24	85%	15	24	133,361	$ 15,657												
Sludge Grinder (Digesters 9-13)	5	5	3	15	85%	10	24	83,351	$ 9,785												
Digester Mixing Pump (1-8)	8	0	40	320	85%	203	24	1,778,149	$ 208,755												
Digester Mixing Pump (9-13)	5	5	40	200	85%	127	24	1,111,343	$ 130,472												
Heated Sludge Recirculation Pump (1-4)	4	0	7.5	30	85%	19	24	166,701	$ 19,571												
Heated Sludge Recirculation Pump (5-8)	4	0	5	20	85%	13	24	111,134	$ 13,047												
Heated Sludge Recirculation Pump (9-13)	5	0	20	100	85%	63	24	555,672	$ 65,236												
Hot Water Circulation Pump (1-8)	8	0	3	24	85%	15	24	133,361	$ 15,657												
Hot Water Circulation Pump (9-13)	5	0	7.5	37.5	85%	24	24	208,377	$ 24,463												
Sludge Booster pumps	2	0	10	20	85%	13	24	111,134	$ 13,047												
Miscellaneous Building Loads			120	120	85%	76	24	666,806	$ 78,283												
Labor: Maintenance												1880	$76,290								
Equipment Maintenance														$70,000							
Total									**$593,972**		**$0**		**$76,290**	**$70,000**		**$0**		**$0**		**$0**	**$740,263**
Biogas																					
Boiler Feed Water Pump	1	1	10	10	85%	6	24	55,567	$ 6,524												
Blower Superflare	1	0	15	15	85%	10	24	83,351	$ 9,785												

	Process			Power Electricity						Labor Operations		Labor Maintenance		Equipment Maintenance	Chemical		Tipping		Hauling		TOTAL
				$ 0.117 /kWh						$ 40.58 /hr		$ 40.58 /hr			$ 10.20 /gallon		$ (0.03) /gallon		$ 34.00 /ton		
	No. of Operating Units	No. of Standby Units	Motor Power (hp)	Total Motor Power (hp) Note 1	Operational % of Nameplate Note 2	Power input (kW)	Operation Time (hr/day)	Annual kWh	Annual Electricity Cost	Labor (hr/day)	Annual Labor Operations Cost	Labor (hrs/yr)	Annual Labor Maintenance Cost	Annual Equipment Maintenance Cost	gallons per day	Annual Chemical Cost	gallons per day	Annual Tipping Revenue	tons per day	Annual Hauling Cost	O&M Cost ($/year)
Blower Temporary Flare	1	1	40	40	85%	25	24	222,269	$ 26,094												
Boiler Fan	1	0	10	10	85%	6	24	55,567	$ 6,524												
Digester Gas Booster for Boiler	1	0	10	10	85%	6	24	55,567	$ 6,524												
Miscellaneous Fans			40	40	85%	25	24	222,269	$ 26,094												
Labor: Maintenance																					
Equipment Maintenance																					
Total									**$81,545**		**$0**		**$0**	**$0**		**$0**		**$0**		**$0**	**$81,545**
Sludge Dewatering																					
Centrifuge																					
Main Drive	3	0	125	375	81%	226	10.5	866,066	$ 101,676												
Back Drive Hydraulic Unit	3	0	40	120	85%	76	10.5	291,728	$ 34,249												
Sludge Feed Pump	3	0	25	75	60%	33	10.5	127,631	$ 14,984												
Belt Filter Press																					
Press Belt Drive (Vertical)	5	0	3	15	26%	3	5.5	5,730	$ 673												
Press Belt Drive (Horizontal)	5	0	3	15	26%	3	5.5	5,730	$ 673												
Hydraulic Unit	5	0	1.5	7.5	85%	5	5.5	9,551	$ 1,121												
Sludge Feed Pump	5	0	25	125	30%	28	5.5	55,712	$ 6,541												
Polymer																					
Bulk Mixers	1	3	5	5	85%	3	0.33	382	$ 45												
Batch Mixers	1	1	5	5	85%	3	4	4,631	$ 544												
Feed Mixers	1	1	5	5	85%	3	4	4,631	$ 544												
Bulk Pump	1	3	5	5	85%	3	0.33	382	$ 45												
Mix Pump	1	1	3	3	85%	2	1.5	1,042	$ 122												
Feed Pump	8	0	3	24	21%	4	9	12,503	$ 1,468												
Slip Injection Pumps	2	3	3	6	17%	1	10.5	2,917	$ 342												
Sludge Transfer Pump	1	1	25	25	36%	7	1	2,431	$ 285												
Sludge Grinder	1	1	3	3	85%	2	1	695	$ 82												
Miscellaneous Building Loads			200	200	85%	127	24	1,111,343	$ 130,472												
Labor: Maintenance (includes Biosolids Storage Silos and Conveyors)												3750	$152,175								
Equipment Maintenance (includes Biosolids Storage Silos and Conveyors)														$240,000							
Chemical Costs															300	$1,116,900					
Total									**$293,864**		**$0**		**$152,175**	**$240,000**		**$1,116,900**		**$0**		**$0**	**$1,802,939**
Biosolids Storage and Hauling																					
Silo Screw Conveyor	2	0	20	40	85%	25	0.75	6,946	$ 815												
BFP Belt Conveyor	1	0	15	15	21%	2	24	20,838	$ 2,446												
BFP Silo Belt Conveyor	1	0	7.5	7.5	21%	1	24	10,419	$ 1,223												
Centrifuge Twin Screw Feeder	3	0	15	45	85%	29	10.5	109,398	$ 12,843												
Centrifuge Classifying Screw Conveyor	3	0	7.5	22.5	85%	14	10.5	54,699	$ 6,422												
Centrifuge Cake Pump	3	0	60	180	85%	114	10.5	437,591	$ 51,373												
Miscellaneous Silo Fans	4	0	5	20	85%	13	24	111,134	$ 13,047												
Labor: Maintenance																					
Equipment Maintenance																					
Biosolids Hauling																			245	$3,040,450	
Total									**$88,170**		**$0**		**$0**	**$0**		**$0**		**$0**		**$3,040,450**	**$3,128,620**
Total									**$1,259,348**		**$577,656**		**$353,452**	**$420,500**		**$1,358,895**		**-$317,550**		**$3,040,450**	**$6,692,751**

Notes:
1. Calculated by multiplying the number of operating units by the motor horse power.
2. Operational percent used to calculate energy consumption. All values reduced by 15% to account for motor oversizing.

Appendix 2-A

SAN JOAQUIN VALLEY AIR POLLUTION CONTROL DISTRICT PERMITS

FACILITY: C-535-0-3 **EXPIRATION DATE:** 01/31/2021

FACILITY-WIDE REQUIREMENTS

1. The owner or operator shall notify the District of any breakdown condition as soon as reasonably possible, but no later than one hour after its detection, unless the owner or operator demonstrates to the District's satisfaction that the longer reporting period was necessary. [District Rule 1100, 6.1; County Rules 110 (Fresno, Stanislaus, San Joaquin); 109 (Merced); 113 (Madera); and 111 (Kern, Tulare, Kings)] Federally Enforceable Through Title V Permit
2. The District shall be notified in writing within ten days following the correction of any breakdown condition. The breakdown notification shall include a description of the equipment malfunction or failure, the date and cause of the initial failure, the estimated emissions in excess of those allowed, and the methods utilized to restore normal operations. [District Rule 1100, 7.0; County Rules 110 (Fresno, Stanislaus, San Joaquin); 109 (Merced); 113 (Madera); and 111 (Kern, Tulare, Kings)] Federally Enforceable Through Title V Permit
3. The owner or operator of any stationary source operation that emits more than 25 tons per year of nitrogen oxides or reactive organic compounds, shall provide the District annually with a written statement in such form and at such time as the District prescribes, showing actual emissions of nitrogen oxides and reactive organic compounds from that source. [District Rule 1160, 5.0] Federally Enforceable Through Title V Permit
4. Any person building, altering or replacing any operation, article, machine, equipment, or other contrivance, the use of which may cause the issuance of air contaminants or the use of which may eliminate, reduce, or control the issuance of air contaminants, shall first obtain an Authority to Construct (ATC) from the District unless exempted by District Rule 2020 (12/20/07). [District Rule 2010, 3.0 and 4.0; and 2020] Federally Enforceable Through Title V Permit
5. The permittee must comply with all conditions of the permit including permit revisions originated by the District. All terms and conditions of a permit that are required pursuant to the Clean Air Act (CAA), including provisions to limit potential to emit, are enforceable by the EPA and Citizens under the CAA. Any permit noncompliance constitutes a violation of the CAA and the District Rules and Regulations, and is grounds for enforcement action, for permit termination, revocation, reopening and reissuance, or modification; or for denial of a permit renewal application. [District Rules 2070, 7.0; 2080; and 2520, 9.8.1 and 9.13.1] Federally Enforceable Through Title V Permit
6. A Permit to Operate or an Authority to Construct shall not be transferred unless a new application is filed with and approved by the District. [District Rule 2031] Federally Enforceable Through Title V Permit
7. Every application for a permit required under Rule 2010 (12/17/92) shall be filed in a manner and form prescribed by the District. [District Rule 2040] Federally Enforceable Through Title V Permit
8. The operator shall maintain records of required monitoring that include: 1) the date, place, and time of sampling or measurement; 2) the date(s) analyses were performed; 3) the company or entity that performed the analysis; 4) the analytical techniques or methods used; 5) the results of such analysis; and 6) the operating conditions at the time of sampling or measurement. [District Rule 2520, 9.4.1] Federally Enforceable Through Title V Permit
9. The operator shall retain records of all required monitoring data and support information for a period of at least 5 years from the date of the monitoring sample, measurement, or report. Support information includes copies of all reports required by the permit and, for continuous monitoring instrumentation, all calibration and maintenance records and all original strip-chart recordings. [District Rule 2520, 9.4.2] Federally Enforceable Through Title V Permit

FACILITY-WIDE REQUIREMENTS CONTINUE ON NEXT PAGE

10. The operator shall submit reports of any required monitoring at least every six months unless a different frequency is required by an applicable requirement. All instances of deviations from permit requirements must be clearly identified in such reports. [District Rule 2520, 9.5.1] Federally Enforceable Through Title V Permit

11. Deviations from permit conditions must be promptly reported, including deviations attributable to upset conditions, as defined in the permit. For the purpose of this condition, promptly means as soon as reasonably possible, but no later than 10 days after detection. The report shall include the probable cause of such deviations, and any corrective actions or preventive measures taken. All required reports must be certified by a responsible official consistent with section 10.0 of District Rule 2520 (6/21/01). [District Rules 2520, 9.5.2 and 1100, 7.0] Federally Enforceable Through Title V Permit

12. If for any reason a permit requirement or condition is being challenged for its constitutionality or validity by a court of competent jurisdiction, the outcome of such challenge shall not affect or invalidate the remainder of the conditions or requirements in that permit. [District Rule 2520, 9.7] Federally Enforceable Through Title V Permit

13. It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of the permit. [District Rule 2520, 9.8.2] Federally Enforceable Through Title V Permit

14. The permit may be modified, revoked, reopened and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance does not stay any permit condition. [District Rule 2520, 9.8.3] Federally Enforceable Through Title V Permit

15. The permit does not convey any property rights of any sort, or any exclusive privilege. [District Rule 2520, 9.8.4] Federally Enforceable Through Title V Permit

16. The Permittee shall furnish to the District, within a reasonable time, any information that the District may request in writing to determine whether cause exists for modifying, revoking and reissuing, or terminating the permit or to determine compliance with the permit. Upon request, the permittee shall also furnish to the District copies of records required to be kept by the permit or, for information claimed to be confidential, the permittee may furnish such records directly to EPA along with a claim of confidentiality. [District Rule 2520, 9.8.5] Federally Enforceable Through Title V Permit

17. The permittee shall pay annual permit fees and other applicable fees as prescribed in Regulation III of the District Rules and Regulations. [District Rule 2520, 9.9] Federally Enforceable Through Title V Permit

18. Upon presentation of appropriate credentials, a permittee shall allow an authorized representative of the District to enter the permittee's premises where a permitted source is located or emissions related activity is conducted, or where records must be kept under condition of the permit. [District Rule 2520, 9.13.2.1] Federally Enforceable Through Title V Permit

19. Upon presentation of appropriate credentials, a permittee shall allow an authorized representative of the District to have access to and copy, at reasonable times, any records that must be kept under the conditions of the permit. [District Rule 2520, 9.13.2.2] Federally Enforceable Through Title V Permit

20. Upon presentation of appropriate credentials, a permittee shall allow an authorized representative of the District to inspect at reasonable times any facilities, equipment, practices, or operations regulated or required under the permit. [District Rule 2520, 9.13.2.3] Federally Enforceable Through Title V Permit

21. Upon presentation of appropriate credentials, a permittee shall allow an authorized representative of the District to sample or monitor, at reasonable times, substances or parameters for the purpose of assuring compliance with the permit or applicable requirements. [District Rule 2520, 9.13.2.4] Federally Enforceable Through Title V Permit

22. No air contaminants shall be discharged into the atmosphere for a period or periods aggregating more than 3 minutes in any one hour which is as dark or darker than Ringelmann #1 or equivalent to 20% opacity and greater, unless specifically exempted by District Rule 4101 (02/17/05). If the equipment or operation is subject to a more stringent visible emission standard as prescribed in a permit condition, the more stringent visible emission limit shall supersede this condition. [District Rule 4101, and County Rules 401 (in all eight counties in the San Joaquin Valley)] Federally Enforceable Through Title V Permit

FACILITY-WIDE REQUIREMENTS CONTINUE ON NEXT PAGE

23. No person shall manufacture, blend, repackage, supply, sell, solicit or apply any architectural coating with a VOC content in excess of the corresponding limit specified in Table of Standards 1 effective until 12/30/10 or Table of Standards 2 effective on and after 1/1/11 of District Rule 4601 (12/17/09) for use or sale within the District. [District Rule 4601, 5.1] Federally Enforceable Through Title V Permit

24. All VOC-containing materials subject to Rule 4601 (12/17/09) shall be stored in closed containers when not in use. [District Rule 4601, 5.4] Federally Enforceable Through Title V Permit

25. The permittee shall comply with all the Labeling and Test Methods requirements outlined in Rule 4601 sections 6.1 and 6.3 (12/17/09). [District Rule 4601, 6.1 and 6.3] Federally Enforceable Through Title V Permit

26. With each report or document submitted under a permit requirement or a request for information by the District or EPA, the permittee shall include a certification of truth, accuracy, and completeness by a responsible official. [District Rule 2520, 9.13.1 and 10.0] Federally Enforceable Through Title V Permit

27. If the permittee performs maintenance on, or services, repairs, or disposes of appliances, the permittee shall comply with the standards for Recycling and Emissions Reduction pursuant to 40 CFR Part 82, Subpart F. [40 CFR 82 Subpart F] Federally Enforceable Through Title V Permit

28. If the permittee performs service on motor vehicles when this service involves the ozone-depleting refrigerant in the motor vehicle air conditioner (MVAC), the permittee shall comply with the standards for Servicing of Motor Vehicle Air Conditioners pursuant to all the applicable requirements as specified in 40 CFR Part 82, Subpart B. [40 CFR Part 82, Subpart B] Federally Enforceable Through Title V Permit

29. Disturbances of soil related to any construction, demolition, excavation, extraction, or other earthmoving activities shall comply with the requirements for fugitive dust control in District Rule 8021 unless specifically exempted under Section 4.0 of Rule 8021 (8/19/2004) or Rule 8011 (8/19/2004). [District Rules 8011 and 8021] Federally Enforceable Through Title V Permit

30. Outdoor handling, storage and transport of any bulk material which emits dust shall comply with the requirements of District Rule 8031, unless specifically exempted under Section 4.0 of Rule 8031 (8/19/2004) or Rule 8011 (8/19/2004). [District Rules 8011 and 8031] Federally Enforceable Through Title V Permit

31. An owner/operator shall prevent or cleanup any carryout or trackout in accordance with the requirements of District Rule 8041 Section 5.0, unless specifically exempted under Section 4.0 of Rule 8041 (8/19/2004) or Rule 8011 (8/19/2004). [District Rules 8011 and 8041] Federally Enforceable Through Title V Permit

32. Whenever open areas are disturbed, or vehicles are used in open areas, the facility shall comply with the requirements of Section 5.0 of District Rule 8051, unless specifically exempted under Section 4.0 of Rule 8051 (8/19/2004) or Rule 8011 (8/19/2004). [District Rules 8011 and 8051] Federally Enforceable Through Title V Permit

33. Any paved road or unpaved road shall comply with the requirements of District Rule 8061 unless specifically exempted under Section 4.0 of Rule 8061 (8/19/2004) or Rule 8011 (8/19/2004). [District Rules 8011 and 8061] Federally Enforceable Through Title V Permit

34. Any unpaved vehicle/equipment area that anticipates more than 50 Average annual daily Trips (AADT) shall comply with the requirements of Section 5.1.1 of District Rule 8071. Any unpaved vehicle/equipment area that anticipates more than 150 vehicle trips per day (VDT) shall comply with the requirements of Section 5.1.2 of District Rule 8071. On each day that 25 or more VDT with 3 or more axles will occur on an unpaved vehicle/equipment traffic area, the owner/operator shall comply with the requirements of Section 5.1.3 of District Rule 8071. On each day when a special event will result in 1,000 or more vehicles that will travel/park on an unpaved area, the owner/operator shall comply with the requirements of Section 5.1.4 of District Rule 8071. All sources shall comply with the requirements of Section 5.0 of District Rule 8071 unless specifically exempted under Section 4.0 of Rule 8071 (9/16/2004) or Rule 8011 (8/19/2004). [District Rules 8011 and 8071] Federally Enforceable Through Title V Permit

35. Any owner or operator of a demolition or renovation activity, as defined in 40 CFR 61.141, shall comply with the applicable inspection, notification, removal, and disposal procedures for asbestos containing materials as specified in 40 CFR 61.145 (Standard for Demolition and Renovation). [40 CFR 61 Subpart M] Federally Enforceable Through Title V Permit

FACILITY-WIDE REQUIREMENTS CONTINUE ON NEXT PAGE

36. The permittee shall submit certifications of compliance with the terms and standards contained in Title V permits, including emission limits, standards and work practices, to the District and the EPA annually (or more frequently as specified in an applicable requirement or as specified by the District). The certification shall include the identification of each permit term or condition, the compliance status, whether compliance was continuous or intermittent, the methods used for determining the compliance status, and any other facts required by the District to determine the compliance status of the source. [District Rule 2520, 9.16] Federally Enforceable Through Title V Permit

37. The permittee shall submit an application for Title V permit renewal to the District at least six months, but not greater than 18 months, prior to the permit expiration date. [District Rule 2520, 5.2] Federally Enforceable Through Title V Permit

38. When a term is not defined in a Title V permit condition, the definition in the rule cited as the origin and authority for the condition in a Title V permits shall apply. [District Rule 2520, 9.1.1] Federally Enforceable Through Title V Permit

39. Compliance with permit conditions in the Title V permit shall be deemed in compliance with the following outdated SIP requirements: Rule 401 (Madera, Fresno, Kern, Kings, San Joaquin, Stanislaus, Tulare and Merced), Rule 110 (Fresno, Stanislaus, San Joaquin), Rule 109 (Merced), Rule 113 (Madera), Rule 111 (Kern, Tulare, Kings), and Rule 202 (Fresno, Kern, Tulare, Kings, Madera, Stanislaus, Merced, San Joaquin). A permit shield is granted from these requirements. [District Rule 2520, 13.2] Federally Enforceable Through Title V Permit

40. Compliance with permit conditions in the Title V permit shall be deemed in compliance with the following applicable requirements: SJVUAPCD Rules 1100, sections 6.1 and 7.0 (12/17/92); 2010, sections 3.0 and 4.0 (12/17/92); 2031 (12/17/92); 2040 (12/17/92); 2070, section 7.0 (12/17/92); 2080 (12/17/92); 4101 (2/17/05); 4601 (12/17/09); 8021 (8/19/2004); 8031 (8/19/2004); 8041 (8/19/2004); 8051 (8/19/2004); 8061 (8/19/2004); and 8071 (9/16/2004). A permit shield is granted from these requirements. [District Rule 2520, 13.2] Federally Enforceable Through Title V Permit

41. No air contaminant shall be released into the atmosphere which causes a public nuisance. [District Rule 4102]

42. Should the facility, as defined in 40 CFR 68.3, become subject to Part 68, then the owner or operator shall submit a risk management plan (RMP) by the date specified in 40 CFR 68.10. The facility shall certify compliance as part of the annual certification as required by 40 CFR Part 70. [40 CFR Part 68] Federally Enforceable Through Title V Permit

43. The reporting periods for the Report of Required Monitoring and the Compliance Certification Report begin March 23 of every year, unless alternative dates are approved by the District Compliance Division. These reports are due within 30 days after the end of the reporting period. [District Rule 2520] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-6-17 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
16.7 MMBTU/HR CLEAVER-BROOKS MODEL CBI-700-400 DIGESTER GAS/NATURAL GAS-FIRED BOILER WITH AN ALZETA MODEL CSB167R ULTRA LOW NOX BURNER AND SULFATREAT DIGESTER GAS TREATMENT SYSTEM

PERMIT UNIT REQUIREMENTS

1. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District Rule 2201] Federally Enforceable Through Title V Permit
2. Particulate matter emissions shall not exceed 0.1 grain/dscf at operating conditions, nor 0.1 grain/dscf calculated to 12% CO2. [District Rules 4201 and 4301] Federally Enforceable Through Title V Permit
3. The boiler shall only be fired on the following fuels: 1) raw digester gas treated in the SulfaTreat system listed on this permit; 2) conditioned digester gas from the digester gas conditioning system under permit C-535-26; or 3) PUC-quality natural gas. [District Rules 2201 and 4320] Federally Enforceable Through Title V Permit
4. The exhaust stack shall vent vertically upward. The vertical exhaust flow shall not be impeded by a rain cap (flapper ok), roof overhang, or any other obstruction. [District Rule 4102]
5. Emissions from the boiler shall not exceed any of the following limits: 9 ppmvd NOx @ 3% O2 or 0.011 lb-NOx/MMBtu, 0.026 lb-SOx/MMBtu, 0.0048 lb-PM10/MMBtu, 100 ppmvd CO @ 3% O2 or 0.061 lb-CO/MMBtu, or 0.0055 lb-VOC/MMBtu. [District Rules 2201, 4305, 4306, and 4320] Federally Enforceable Through Title V Permit
6. The sulfur content of any fuel used by the boiler shall not exceed 5 grains/100 dscf of total sulfur (equivalent to 79.6 ppm as H2S). [District Rules 2201, 4320, and 4801] Federally Enforceable Through Title V Permit
7. When the unit is fired on digester gas fuel, daily testing of the digester gas is required so as to not exceed an average of 79.6 ppm as hydrogen sulfide (H2S). Corrections shall be made, and re-tested within three (3) hours in order to maintain average below 79.6 ppm. [District Rules 2201 and 2520] Federally Enforceable Through Title V Permit
8. The sulfur content of the digester gas fuel being fired in the unit shall be determined using ASTM D-1072, D-3031, D-4084, D3246, D-4810, or grab sample analysis by GC-FPD/TCD performed in the laboratory. [District Rules 2520 and 4320] Federally Enforceable Through Title V Permit
9. The boiler shall be equipped with an operational non-resettable, totalizing mass or volumetric flow meter on each fuel supply line. [District Rule 2201 and 40 CFR 60.48(c)(g)] Federally Enforceable Through Title V Permit
10. For each fuel type used, source testing to measure NOx and CO emissions from this unit shall be conducted at least once every twelve (12) months. After demonstrating compliance on two (2) consecutive annual source tests, the unit shall be tested not less than once every thirty-six (36) months. For each fuel type used, if the result of the 36-month source test demonstrates that the unit does not meet the applicable emission limits, the source testing frequency for that fuel type shall revert to at least once every twelve (12) months. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

11. Source testing shall not be required for a fuel not exceeding the following limits in any rolling 12-month period: 2,899,306 scf of raw digester gas; 1,741,397 scf of conditioned digester gas; or 1,670,000 scf of PUC-quality natural gas (calculated based on 100 hours of operation at full load and higher heating values of 576 Btu/scf, 959 Btu/scf, and 1,000 Btu/scf, respectively). Upon exceeding these fuel usage limits in any rolling 12-month period for a given fuel type, a source test shall be completed within 60 days, unless source testing for that fuel type has been completed within the last 12 or 36 months, as normally would be required. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

12. The permittee shall monitor and record the stack concentration of NOx, CO, and O2 at least once every month (in which a source test is not performed) using a portable emission monitor that meets District specifications. Monitoring shall not be required if the unit is not in operation, i.e. the unit need not be started solely to perform monitoring. Monitoring shall be performed within 5 days of restarting the unit unless monitoring has been performed within the last month. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

13. If either the NOx or CO concentrations corrected to 3% O2, as measured by the portable analyzer, exceed the allowable emissions concentration, the permittee shall return the emissions to within the acceptable range as soon as possible, but no longer than 1 hour of operation after detection. If the portable analyzer readings continue to exceed the allowable emissions concentration after 1 hour of operation after detection, the permittee shall notify the District within the following 1 hour and conduct a certified source test within 60 days of the first exceedance. In lieu of conducting a source test, the permittee may stipulate a violation has occurred, subject to enforcement action. The permittee must then correct the violation, show compliance has been re-established, and resume monitoring procedures. If the deviations are the result of a qualifying breakdown condition pursuant to Rule 1100, the permittee may fully comply with Rule 1100 in lieu of the performing the notification and testing required by this condition. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

14. All alternate monitoring parameter emission readings shall be taken with the unit operating either at conditions representative of normal operations or conditions specified in the Permit to Operate. The analyzer shall be calibrated, maintained, and operated in accordance with the manufacturer's specifications and recommendations or a protocol approved by the APCO. Emission readings taken shall be averaged over a 15 consecutive-minute period by either taking a cumulative 15 consecutive-minute sample reading or by taking at least five (5) readings, evenly spaced out over the 15 consecutive-minute period. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

15. The permittee shall maintain records of: (1) the date and time of NOx, CO, and O2 measurements, (2) the O2 concentration in percent and the measured NOx and CO concentrations corrected to 3% O2, (3) make and model of exhaust gas analyzer, (4) exhaust gas analyzer calibration records, and (5) a description of any corrective action taken to maintain the emissions within the acceptable range. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

16. All emissions measurements shall be made with the unit operating either at conditions representative of normal operations or conditions specified in the Permit to Operate. No determination of compliance shall be established within two hours after a continuous period in which fuel flow to the unit is shut off for 30 minutes or longer, or within 30 minutes after a re-ignition as defined in Section 3.0 of District Rule 4320. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

17. Sampling facilities for source testing shall be provided in accordance with the provisions of Rule 1081 (Source Sampling). [District Rule 1081] Federally Enforceable Through Title V Permit

18. The source test plan shall identify which basis (ppmv or lb/MMBtu) will be used to demonstrate compliance. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

19. The results of each source test shall be submitted to the District within 60 days thereafter. [District Rule 1081] Federally Enforceable Through Title V Permit

20. Source testing shall be conducted using the methods and procedures approved by the District. The District must be notified at least 30 days prior to any compliance source test, and a source test plan must be submitted for approval at least 15 days prior to testing. [District Rule 1081] Federally Enforceable Through Title V Permit

21. NOx emissions for source test purposes shall be determined using EPA Method 7E or ARB Method 100 on a ppmv basis, or EPA Method 19 on a heat input basis. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

22. CO emissions for source test purposes shall be determined using EPA Method 10 or ARB Method 100. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

23. Stack gas oxygen (O2) shall be determined using EPA Method 3 or 3A or ARB Method 100. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

24. For emissions source testing, the arithmetic average of three 30-consecutive-minute test runs shall apply. If two of three runs are above an applicable limit the test cannot be used to demonstrate compliance with an applicable limit. [District Rules 4305, 4306, and 4320] Federally Enforceable Through Title V Permit

25. Records of daily consumption of each fuel and daily sulfur testing results of digester gas fuel shall be maintained. [District Rules 1070 and 2520; and 40 CFR 60.48(c)(g)] Federally Enforceable Through Title V Permit

26. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rules 1070, 4305, 4306, and 4320; and 40 CFR 60.48(c)(i)] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-9-15 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
36.3 MMBTU/HR JOHN ZINK COMPANY WASTE GAS FLARE

PERMIT UNIT REQUIREMENTS

1. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District Rule 4102]
2. The flare shall be operated in a manner preventing the emission of noxious odors or other nuisances. [District Rule 4102]
3. Particulate matter emissions shall not exceed 0.1 gr/dscf in concentration at the point of discharge. [District Rule 4201] Federally Enforceable Through Title V Permit
4. The waste gas flare system shall be specifically designed for burning wastewater treatment plant digester gas, and alternate fuel may be used as pilot fuel. [District Rule 2201] Federally Enforceable Through Title V Permit
5. The flare shall be equipped and operated with a heat sensing device such as a thermocouple, ultraviolet beam sensor, infrared sensor, or an equivalent device, capable of continuously detecting at least one pilot flame. [District Rule 4311] Federally Enforceable Through Title V Permit
6. The flare system shall have continuous readout and recording of gas flow rate and stack temperature. [District Rule 2201] Federally Enforceable Through Title V Permit
7. Flare flue gas temperature shall be maintained to at least 1,400 øF and 0.6 seconds minimum residence time. [District Rule 2201] Federally Enforceable Through Title V Permit
8. Total volume of gaseous fuel flared shall not exceed 1,584,000 scf per day. [District Rule 2201] Federally Enforceable Through Title V Permit
9. A flame shall be present at all times in the flare whenever combustible gases are vented through the flare. [District Rule 4311] Federally Enforceable Through Title V Permit
10. The flare shall operate with a pilot flame present at all times when combustible gases are vented through the flare, except during purge periods for automatic-ignition equipped flares. [District Rule 4311] Federally Enforceable Through Title V Permit
11. Daily testing of digester gas is required so as to not exceed an average of 200 ppm as hydrogen sulfide (H2S). Corrections shall be made, and re-tested within 3 hours in order to maintain average below 200 ppm. [District Rule 2201] Federally Enforceable Through Title V Permit
12. Emissions shall not exceed any of the following limits: 0.18 lb PM10/hr, 1.8 lb SOx/hr, 2.2 lb NOx/hr, or 10.5 lb CO/hr. [District Rules 2201 and 4311] Federally Enforceable Through Title V Permit
13. VOC emissions shall not exceed 0.0027 lb-VOC/MMBtu. [District Rules 2201 and 4311] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

14. Total combined annual NOx emissions from the waste gas flare (C-535-9), the transportable diesel-fired IC engine powering an air compressor (C-535-24), and the transportable diesel-fired IC engine powering a pump (C-535-44) shall not exceed 19,272 pounds in any calendar year. [District Rule 2201] Federally Enforceable Through Title V Permit

15. Total combined annual NOx emissions from the waste gas flare (C-535-9), the transportable diesel-fired IC engine powering an air compressor (C-535-24), and the transportable diesel-fired IC engine powering a pump (C-535-44) shall be calculated as follows: Annual NOx Emissions (lbs/year) = [(33.0 lb/MMscf x Waste Gas Flare's Annual Fuel Combusted (MMscf/year)) + (1.13 lbs/hr x IC Engine Powering an Air Compressor Annual Hours of Operation (hrs/year)) + (0.51 lbs/hr x IC Engine Powering a Pump Annual Hours of Operation (hrs/year))]. [District Rule 2201] Federally Enforceable Through Title V Permit

16. Flaring is prohibited unless it is consistent with an approved flare minimization plan (FMP), pursuant to Section 6.5, and all commitments listed in that plan have been met. This standard does not apply if the APCO determines that the flaring is caused by an emergency as defined by Section 3.7 and is necessary to prevent an accident, hazard or release of vent gas directly to the atmosphere. [District Rule 4311] Federally Enforceable Through Title V Permit

17. Source testing to measure digester gas-combustion NOx and VOC emissions from this unit shall be conducted at least once every twelve (12) months. [District Rule 4311] Federally Enforceable Through Title V Permit

18. The results of each source test shall be submitted to the District within 45 days thereafter. [District Rule 4311] Federally Enforceable Through Title V Permit

19. Source testing shall be conducted using the methods and procedures approved by the District. The District must be notified at least 30 days prior to any compliance source test, and a source test plan must be submitted for approval at least 15 days prior to testing. [District Rules 1081 and 4311] Federally Enforceable Through Title V Permit

20. VOC emissions for source test purposes, measured and calculated as carbon, shall be determined by EPA Method 25, except when the outlet concentration must be below 50 ppm in order to meet the standard, in which case Method 25a may be used, and analysis of halogenated exempt compounds shall be analyzed by EPA Method 18 or ARB Method 422 "Determination of Volatile organic Compounds in Emission from Stationary Sources". [District Rule 4311] Federally Enforceable Through Title V Permit

21. NOx emissions for source test purposes, in pounds per million Btu, shall be determined by using EPA Method 19. [District Rule 4311] Federally Enforceable Through Title V Permit

22. NOx and O2 concentrations shall be determined by using EPA Method 3A, EPA Method 7E, or ARB 100. [District Rule 4311] Federally Enforceable Through Title V Permit

23. The operator of a flare subject to flare minimization plans pursuant to Section 5.8 of this rule shall notify the APCO of an unplanned flaring event within 24 hours after the start of the next business day or within 24 hours of their discovery, which ever occurs first. The notification shall include the flare source identification, the start date and time, and the end date and time. [District Rule 4311] Federally Enforceable Through Title V Permit

24. The operator of a flare subject to flare minimization plans pursuant to Section 5.8 shall submit an annual report to the APCO that summarizes all Reportable Flaring Events as defined in Section 3.0 that occurred during the previous 12 month period. The report shall be submitted within 30 days following the end of the twelve month period of the previous year. The report shall include, but is not limited to all of the following: the results of an investigation to determine the primary cause and contributing factors of the flaring event; any prevention measures considered or implemented to prevent recurrence together with a justification for rejecting any measures that were considered but not implemented; if appropriate, an explanation of why the flaring was an emergency and necessary to prevent accident, hazard or release of vent gas to the atmosphere, or where, due to a regulatory mandate to vent a flare, it cannot be recovered, treated and used as a fuel gas at the facility; and the date, time, and duration of the flaring event. [District Rule 4311] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

25. The operator of a flare subject to flare monitoring requirements pursuant to Section 5.10 shall submit an annual report to the APCO within 30 days following the end of each 12 month period. The report shall include the following: the total volumetric flow of vent gas in standard cubic feet for each day; if the flow monitor used pursuant to Section 5.10 measures molecular weight, the average molecular weight for each hour of each month; a flow verification report which shall include flow verification testing pursuant to Section 6.3.5. [District Rule 4311] Federally Enforceable Through Title V Permit

26. For purposes of the flow verification report required by Section 6.2.3.8, vent gas flow shall be determined using one or more of the following methods, or by any alternative method approved by the APCO, ARB, and EPA: EPA Methods 1 and 2; a verification method recommended by the manufacturer of the flow monitoring equipment installed pursuant to Section 5.10; tracer gas dilution or velocity; other flow monitors or process monitors that can provide comparison data on a vent stream that is being directed past the ultrasonic flow meter. [District Rule 4311] Federally Enforceable Through Title V Permit

27. The operator shall monitor and record the vent gas flow to the flare with a flow measuring device or other parameters as specified in the Permit to Operate. [District Rule 4311] Federally Enforceable Through Title V Permit

28. The sulfur content of gas being flared shall be determined using ASTM D-1072, D-3031, D-4084, D 3246, D-4810, or grab sample analysis by GC-FPD/TCD performed in the laboratory. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit

29. The flare shall be operated according to the manufacturer's specifications, a copy of which shall be maintained on site. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit

30. This flare shall be inspected annually while in operation for visible emissions. If visible emissions are observed, corrective action shall be taken. If excess emissions continue, a EPA Method 9 test shall be conducted within 72 hours. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit

31. Daily records of total gas flared shall be maintained. [District Rules 2201 and 2520, 9.3.2] Federally Enforceable Through Title V Permit

32. Records of flare maintenance, inspections and repair shall be maintained. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit

33. Records of daily sulfur testing results shall be maintained. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit

34. Permittee shall maintain the following records: a copy of the source testing result conducted pursuant to Section 6.4.2; a copy of the approved flare minimization plan pursuant to Section 6.5; a copy of annual reports submitted to the APCO pursuant to Section 6.2. [District Rule 4311] Federally Enforceable Through Title V Permit

35. Permittee shall maintain records of the following when the flare is used during an emergency: duration of flare operation, amount of gas burned, and the nature of the emergency situation. [District Rule 4311] Federally Enforceable Through Title V Permit

36. Records of the total annual NOx emissions from units C-535-9, -24 and -44 shall be maintained and updated monthly. [District Rule 1070] Federally Enforceable Through Title V Permit

37. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rules 1070 and 4311] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-10-3 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
2518 BHP CATERPILLAR MODEL 3516 DIESEL-FIRED EMERGENCY STANDBY IC ENGINE POWERING A 1750 KW ELECTRICAL GENERATOR

PERMIT UNIT REQUIREMENTS

1. Sulfur compound emissions shall not exceed 0.2% by volume, 2000 ppmv, on a dry basis averaged over 15 consecutive minutes. [District Rule 4801 and Fresno County Rule 406] Federally Enforceable Through Title V Permit
2. Particulate matter emissions shall not exceed 0.1 gr/dscf in concentration at the point of discharge. [District Rule 4201] Federally Enforceable Through Title V Permit
3. Only CARB certified diesel fuel containing not more than 0.0015% sulfur by weight is to be used. [District NSR Rule, 4801, and 17 CCR 93115] Federally Enforceable Through Title V Permit
4. This engine shall be equipped with an operational non-resettable elapsed time meter or other APCO approved alternative. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit
5. This engine shall be operated and maintained in proper operating condition as recommended by the engine manufacturer or emissions control system supplier. [District Rule 4702] Federally Enforceable Through Title V Permit
6. The engine shall be operated with the timing retarded four degrees from the manufacturer's standard recommended timing. [District NSR Rule] Federally Enforceable Through Title V Permit
7. The engine shall be equipped with a turbocharger and with an aftercooler or intercooler. [District NSR Rule] Federally Enforceable Through Title V Permit
8. The engine shall be equipped with a positive crankcase ventilation (PCV) system or a crankcase emissions control device of at least 90% control efficiency. [District NSR Rule] Federally Enforceable Through Title V Permit
9. This engine shall be operated only for maintenance, testing, and required regulatory purposes, and during emergency situations. Operation of the engine for maintenance, testing, and required regulatory purposes shall not exceed 20 hours per calendar year. [District NSR Rule, 4701, 4702, and 17 CCR 93115] Federally Enforceable Through Title V Permit
10. During periods of operation for maintenance, testing, and required regulatory purposes, the permittee shall monitor the operational characteristics of the engine as recommended by the manufacturer or emission control system supplier (for example: check engine fluid levels, battery, cables and connections; change engine oil and filters; replace engine coolant; and/or other operational characteristics as recommended by the manufacturer or supplier). [District Rule 4702] Federally Enforceable Through Title V Permit
11. An emergency situation is an unscheduled electrical power outage caused by sudden and reasonably unforeseen natural disasters or sudden and reasonably unforeseen events beyond the control of the permittee. [District Rule 4702] Federally Enforceable Through Title V Permit
12. This engine shall not be used to produce power for the electrical distribution system, as part of a voluntary utility demand reduction program, or for an interruptible power contract. [District Rule 4702] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

13. The permittee shall maintain monthly records of emergency and non-emergency operation. Records shall include the number of hours of emergency operation, the date and number of hours of all testing and maintenance operations, the purpose of the operation (for example: load testing, weekly testing, rolling blackout, general area power outage, etc.) and records of operational characteristics monitoring. For units with automated testing systems, the operator may, as an alternative to keeping records of actual operation for testing purposes, maintain a readily accessible written record of the automated testing schedule. [District Rule 4702] Federally Enforceable Through Title V Permit
14. The permittee shall maintain monthly records of the type of fuel purchased. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit
15. Compliance with permit conditions in the Title V permit shall be deemed compliance with the following applicable requirements of SJVUAPCD Rule 4201 and Fresno County Rule 406. A permit shield is granted from these requirements. [District Rule 2520, 13.2] Federally Enforceable Through Title V Permit
16. Compliance with permit conditions in the Title V permit shall be deemed compliance with the following subsumed requirements: Rules 402 (Madera) and 404 (Fresno, Merced, Kern, Kings, San Joaquin, Stanislaus, Tulare). A permit shield is granted from these requirements. [District Rule 2520, 13.2] Federally Enforceable Through Title V Permit
17. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-12-3 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
140 HP CATERPILLAR MODEL #3116-DIT DIESEL-FIRED TURBOCHARGED EMERGENCY IC ENGINE #2 SERVING A WATER TRANSFER PUMP

PERMIT UNIT REQUIREMENTS

1. Sulfur compound emissions shall not exceed 0.2% by volume, 2000 ppmv, on a dry basis averaged over 15 consecutive minutes. [District Rule 4801 and Fresno County Rule 406] Federally Enforceable Through Title V Permit
2. Particulate matter emissions shall not exceed 0.1 gr/dscf in concentration at the point of discharge. [District Rule 4201] Federally Enforceable Through Title V Permit
3. Only CARB certified diesel fuel containing not more than 0.0015% sulfur by weight is to be used. [District Rule 2520, 9.3.2, 4801, and 17 CCR 93115] Federally Enforceable Through Title V Permit
4. This engine shall be equipped with an operational non-resettable elapsed time meter or other APCO approved alternative. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit
5. This engine shall be operated only for maintenance, testing, and required regulatory purposes, and during emergency situations. Operation of the engine for maintenance, testing, and required regulatory purposes shall not exceed 20 hours per calendar year. [District NSR Rule, 4701, 4702, and 17 CCR 93115] Federally Enforceable Through Title V Permit
6. This engine shall be operated and maintained in proper operating condition as recommended by the engine manufacturer or emissions control system supplier. [District Rule 4702] Federally Enforceable Through Title V Permit
7. The engine shall be equipped with a positive crankcase ventilation (PCV) system or a crankcase emissions control device of at least 90% control efficiency. [District NSR Rule] Federally Enforceable Through Title V Permit
8. NOx emission rate shall not exceed 6.0 g/hp-hr. [District NSR Rule] Federally Enforceable Through Title V Permit
9. During periods of operation for maintenance, testing, and required regulatory purposes, the permittee shall monitor the operational characteristics of the engine as recommended by the manufacturer or emission control system supplier (for example: check engine fluid levels, battery, cables and connections; change engine oil and filters; replace engine coolant; and/or other operational characteristics as recommended by the manufacturer or supplier). [District Rule 4702] Federally Enforceable Through Title V Permit
10. An emergency situation is an unscheduled electrical power outage caused by sudden and reasonably unforeseen natural disasters or sudden and reasonably unforeseen events beyond the control of the permittee. [District Rule 4702] Federally Enforceable Through Title V Permit
11. The permittee shall maintain monthly records of the type of fuel purchased. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

12. The permittee shall maintain monthly records of emergency and non-emergency operation. Records shall include the number of hours of emergency operation, the date and number of hours of all testing and maintenance operations, the purpose of the operation (for example: load testing, weekly testing, rolling blackout, general area power outage, etc.) and records of operational characteristics monitoring. For units with automated testing systems, the operator may, as an alternative to keeping records of actual operation for testing purposes, maintain a readily accessible written record of the automated testing schedule. [District Rule 4702] Federally Enforceable Through Title V Permit
13. Compliance with permit conditions in the Title V permit shall be deemed compliance with the following applicable requirements of SJVUAPCD Rule 4201 and Fresno County Rule 406. A permit shield is granted from these requirements. [District Rule 2520, 13.2] Federally Enforceable Through Title V Permit
14. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-13-6 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
150 HP ODOR CONTROL SCRUBBING SYSTEM INCLUDING THREE(3) 50 HP RJ ENVIRONMENTAL PACKED TOWER CAUSTIC SCRUBBERS EACH EQUIPPED WITH A KIMRE MIST ELIMINATOR MODEL B-GON

PERMIT UNIT REQUIREMENTS

1. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District NSR Rule] Federally Enforceable Through Title V Permit
2. Maximum design influent flow rate through headworks shall not exceed 106 MGD. [District NSR Rule] Federally Enforceable Through Title V Permit
3. The total emissions from this operation shall not exceed 0.075 pounds VOC per MGD of influent flow. [District NSR Rule] Federally Enforceable Through Title V Permit
4. Scrubbers shall be maintained and operated according to manufacturer's specifications. [District NSR Rule] Federally Enforceable Through Title V Permit
5. Scrubber liquid to gas ratio shall be observed and recorded weekly during operation of this unit. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit
6. Records of scrubber liquid to gas ratio shall be maintained. The records shall include identification of the equipment, date of inspection, corrective action taken, and identification of the individual performing the inspection. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit
7. Records of daily influent flow rate through headworks shall be maintained and shall be made available for District inspection upon request. [District Rule 2520, 9.3.2] Federally Enforceable Through Title V Permit
8. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rule 1070 and 2520, 9.4.2] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-17-3 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
455 BHP CUMMINS MODEL NTA855 DIESEL-FIRED EMERGENCY STANDBY IC ENGINE POWERING AN ONAN MODEL 350DFCC, 350 KW ELECTRICAL GENERATOR

PERMIT UNIT REQUIREMENTS

1. Sulfur compound emissions shall not exceed 0.2% by volume, 2000 ppmv, on a dry basis averaged over 15 consecutive minutes. [District Rule 4801 and Fresno County Rule 406] Federally Enforceable Through Title V Permit
2. Particulate matter emissions shall not exceed 0.1 gr/dscf in concentration at the point of discharge. [District Rule 4201] Federally Enforceable Through Title V Permit
3. Only CARB certified diesel fuel containing not more than 0.0015% sulfur by weight is to be used. [District Rule 4801, Fresno County Rule 406, and 17 CCR 93115] Federally Enforceable Through Title V Permit
4. This engine shall be equipped with an operational non-resettable elapsed time meter or other APCO approved alternative. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit
5. This engine shall be operated only for maintenance, testing, and required regulatory purposes, and during emergency situations. Operation of the engine for maintenance, testing, and required regulatory purposes shall not exceed 20 hours per calendar year. [District NSR Rule, 4701 and 4702, and 17 CCR 93115] Federally Enforceable Through Title V Permit
6. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District NSR Rule] Federally Enforceable Through Title V Permit
7. Emissions shall not exceed 5.61 g NOx/bhp-hr. [District NSR Rule] Federally Enforceable Through Title V Permit
8. The engine shall be equipped with a positive crankcase ventilation (PCV) system or a crankcase emissions control device of at least 90% control efficiency. [District NSR Rule] Federally Enforceable Through Title V Permit
9. This engine shall be operated and maintained in proper operating condition as recommended by the engine manufacturer or emissions control system supplier. [District Rule 4702] Federally Enforceable Through Title V Permit
10. During periods of operation for maintenance, testing, and required regulatory purposes, the permittee shall monitor the operational characteristics of the engine as recommended by the manufacturer or emission control system supplier (for example: check engine fluid levels, battery, cables and connections; change engine oil and filters; replace engine coolant; and/or other operational characteristics as recommended by the manufacturer or supplier). [District Rule 4702] Federally Enforceable Through Title V Permit
11. An emergency situation is an unscheduled electrical power outage caused by sudden and reasonably unforeseen natural disasters or sudden and reasonably unforeseen events beyond the control of the permittee. [District Rule 4702] Federally Enforceable Through Title V Permit
12. This engine shall not be used to produce power for the electrical distribution system, as part of a voluntary utility demand reduction program, or for an interruptible power contract. [District Rule 4702] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

13. The permittee shall maintain monthly records of the type of fuel purchased. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit

14. The permittee shall maintain monthly records of emergency and non-emergency operation. Records shall include the number of hours of emergency operation, the date and number of hours of all testing and maintenance operations, the purpose of the operation (for example: load testing, weekly testing, rolling blackout, general area power outage, etc.) and records of operational characteristics monitoring. For units with automated testing systems, the operator may, as an alternative to keeping records of actual operation for testing purposes, maintain a readily accessible written record of the automated testing schedule. [District Rule 4702] Federally Enforceable Through Title V Permit

15. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rule 4702 and 17 CCR 93115] Federally Enforceable Through Title V Permit

16. Compliance with permit conditions in the Title V permit shall be deemed compliance with the following applicable requirements of SJVUAPCD Rule 4201 and Fresno County Rule 406. A permit shield is granted from these requirements. [District Rule 2520, 13.2] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-18-15 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
3.377 MW ALLISON MODEL 501 KB-5 DIGESTER/NATURAL GAS-FIRED TURBINE GENERATOR #1 WITH WATER INJECTION AND SELECTIVE CATALYTIC REDUCTION WITH AMMONIA INJECTION, HEAT RECOVERY STEAM GENERATOR, A 2.25 MW STEAM TURBINE SHARED WITH C-535-19, AND A PREDICTIVE EMISSION MONITORING SYSTEM (PEMS)

PERMIT UNIT REQUIREMENTS

1. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District Rule 2201] Federally Enforceable Through Title V Permit
2. Particulate matter emissions shall not exceed 0.1 grains/dscf in concentration. [District Rule 4201] Federally Enforceable Through Title V Permit
3. The gas-fired turbines shall be fired on natural gas or digester gas or any combination (blend) of natural gas and digester gas. [District Rule 2201] Federally Enforceable Through Title V Permit
4. The total sulfur content of the natural gas combusted by this unit shall not exceed 1.0 gr/100 scf. [District Rule 2201] Federally Enforceable Through Title V Permit
5. The H2S content of the digester gas combusted by this unit shall not exceed 200 ppmv. [District Rule 2201] Federally Enforceable Through Title V Permit
6. The owner or operator shall install, operate and maintain in calibration a system which continuously measures and records: the fuel consumption and the ratio of water to fuel being fired in the turbine. [40 CFR 60.334(a)] Federally Enforceable Through Title V Permit
7. During periods of start-up or shutdown, turbine exhaust emission rates shall not exceed any of the following limits: NOx (as NO2) - 5.74 lb/hr, SOx - 2.07 lb/hr, PM10 1.34 lb/hr, CO - 27.95 lb/hr, or VOC - 0.02 lb/hr. [District Rule 2201] Federally Enforceable Through Title V Permit
8. Emission rates from this unit, except during start-up and shutdown, shall not exceed any of the following limits: NOx (as NO2) - 0.95 lb/hr and 5 ppmvd @ 15% O2; SOx (as SO2) - 2.07 lb/hr; PM10 - 1.34 lb/hr; CO - 27.95 lb/hr and 188.0 ppmvd @ 15% O2; or VOC (as methane) - 0.02 lb/hr. [District Rules 2201 and 4703, 40 CFR 60.332(a)(2) and 40 CFR 60.333(a) & (b)] Federally Enforceable Through Title V Permit
9. Emissions from this unit (including emissions during start-up and shutdown), shall not exceed any of the following limits: NOx (as NO2) - 51.5 lb/day; SOx (as SO2) - 49.7 lb/day; PM10 - 32.2 lb/day; CO - 670.8 lb/day; or VOC - 0.5 lb/day. [District Rule 2201] Federally Enforceable Through Title V Permit
10. Emissions from this unit (including emissions during start-up and shutdown), shall not exceed any of the following limits: NOx (as NO2) - 9,299 lb/year; SOx (as SO2) - 18,141 lb/year; PM10 - 11,753 lb/year; CO - 244,842 lb/year; or VOC - 183 lb/year. [District Rule 2201] Federally Enforceable Through Title V Permit
11. Ammonia (NH3) emissions shall not exceed either of the following limits: 1.37 lb/hr or 10 ppmvd @ 15% O2 (based on a 24 hour rolling average). [District Rule 2201] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

12. Compliance with the ammonia emission limits shall be demonstrated utilizing one of the following procedures: 1.) calculate the daily ammonia emissions using the following equation: (ppmvd @ 15% O2) = ((a - (b x c/1,000,000)) x (1,000,000 / b)) x d, where a = average ammonia injection rate (lb/hr) / (17 lb/lb mol), b = dry exhaust flow rate (lb/hr) / (29 lb/lb mol), c = change in measured NOx concentration ppmvd @ 15% O2 across the catalyst, and d = correction factor. The correction factor shall be derived annually during compliance testing by comparing the measured and calculated ammonia slip; 2.) Utilize another District-approved calculation method using measured surrogate parameters to determine the daily ammonia emissions in ppmvd @ 15% O2. If this option is chosen, the permittee shall submit a detailed calculation protocol for District approval at least 60 days prior to commencement of operation; 3.) Alternatively, the permittee may utilize a continuous in-stack ammonia monitor to verify compliance with the ammonia emissions limit. If this option is chosen, the permittee shall submit a monitoring plan for District approval at least 60 days prior to commencement of operation; 4.) The permittee may utilize draeger tubes to measure the ammonia in the exhaust stack. If this option is chosen, the permittee shall monitor and record the stack concentration weekly using a portable emissions monitor that meets District specifications. If compliance with the ammonia emissions is demonstrated for eight consecutive weeks, then the monitoring frequency will be reduced to monthly. If deviations are observed in two consecutive months, monitoring shall revert to weekly until eight consecutive weeks show no deviations. Monitoring shall not be required if the unit is not in operation, i.e. the unit need not be started solely to perform monitoring. Monitoring shall be performed within one day of restarting the unit unless monitoring has been performed within the last month if on a monthly monitoring schedule, or within the week if on a weekly monitoring schedule. [District Rule 2201] Federally Enforceable Through Title V Permit
13. The duration of each startup or shutdown event shall not exceed two hours. Start-up and shutdown emissions shall be counted toward all applicable emission limits. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit
14. The emission control systems shall be in operation and emissions shall be minimized insofar as technologically feasible during startup and shutdown. [District Rule 4703] Federally Enforceable Through Title V Permit
15. Start-up is defined as the period of time during which a unit is brought from a shutdown status to its operating temperature and pressure, including the time required by the unit's emission control system to reach full operation. Shutdown is defined as the period of time during which a unit is taken from an operational to a non-operational status by allowing it to cool down from its operating temperature to ambient temperature as the fuel supply to the unit is completely turned off. [District Rule 4703] Federally Enforceable Through Title V Permit
16. The exhaust stack shall be equipped with permanent provisions to allow collection of stack gas samples consistent with EPA test methods and shall be equipped with safe permanent provisions to sample stack gases with a portable NOx, CO, and O2 analyzer during District inspections. The sampling ports shall be located in accordance with the CARB policy document titled California Air Resources Board Air Monitoring Quality Assurance Volume VI, Standard Operating Procedures for Stationary Source Emission Monitoring and Testing. [District Rule 1081] Federally Enforceable Through Title V Permit
17. Source testing to measure the NOx, CO, and NH3 emission rates (lb/hr and ppmvd @ 15% O2) shall be conducted at least once every twelve months. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit
18. Source testing shall be conducted using the methods and procedures approved by the District. The District must be notified at least 30 days prior to any compliance source test, and a source test plan must be submitted for approval at least 15 days prior to testing. [District Rule 1081] Federally Enforceable Through Title V Permit
19. The following test methods shall be used: NOx - EPA Method 7E or 20 or ARB Method 100, CO - EPA Method 10 or 10B or ARB Method 100, O2 - EPA Method 3, 3A, or 20 or ARB Method 100, and ammonia - BAAQMD Method ST-1B. NOx test results shall be corrected to ISO standard conditions as defined in 40 CFR Part 60 Subpart GG Section 60.335. EPA approved alternative test methods as approved by the District may also be used to address the source testing requirements of this permit. The request to utilize EPA approved alternative source testing methods must be submitted in writing and written approval received from the District prior to the submission of the source test plan. [District Rules 1081 and 4703 and 40 CFR 60.335] Federally Enforceable Through Title V Permit
20. HHV and LHV of the fuel shall be determined using ASTM D3588, ASTM 1826, or ASTM 1945. [District Rule 4703] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

21. The results of each source test shall be submitted to the District within 60 days thereafter. [District Rule 1081] Federally Enforceable Through Title V Permit

22. When the unit is fired solely on PUC-regulated natural gas, maintain on file copies of the natural gas bills. [District Rule 2520 and 40 CFR 60.334(h)(3)] Federally Enforceable Through Title V Permit

23. When the unit is not fired solely on PUC-regulated natural gas, the sulfur content of the fuel shall be tested weekly except that if compliance with the fuel sulfur content limit in this permit has been demonstrated for 8 consecutive weeks, then the testing frequency shall be quarterly. If a test shows noncompliance with the sulfur content limit in this permit, the source must return to weekly testing until eight consecutive weeks show compliance. [District Rule 2520 and 40 CFR 60.334(i)(3)] Federally Enforceable Through Title V Permit

24. When the unit is not fired solely on PUC-regulated natural gas, the sulfur content of the fuel being fired in the turbine shall be determined using ASTM method D-1072, D-4084, D-3246 or D-4810. [District Rule 1081 and 40 CFR 60.335(b)(10)] Federally Enforceable Through Title V Permit

25. When the unit is not fired solely on PUC-regulated natural gas, the operator shall submit a semiannual report listing any daily period during which the sulfur content of the fuel being fired in the turbine exceeds 0.8% by weight. [40 CFR 60.334(j)] Federally Enforceable Through Title V Permit

26. The owner or operator shall install, certify, maintain, operate and quality-assure a Predictive Emission Monitoring System (PEMS) which continuously monitors and records the exhaust gas NOx, CO and O2 concentrations. Predictive emissions monitor(s) shall be capable of monitoring emissions during normal operating conditions, and during startups and shutdowns provided the PEMS passes the relative accuracy requirement for startups and shutdowns specified herein. If relative accuracy of PEMS cannot be demonstrated during startup conditions, PEMS results during startup and shutdown events shall be replaced with startup emission rates obtained from source testing to determine compliance with emission limits contained in this permit. [District Rules 1080, 2201, and 4703 and 40 CFR 60.334(b)] Federally Enforceable Through Title V Permit

27. Operation and calibration of the PEMS equipment shall be performed in accordance with the requirements of 40 CFR, Part 60, Appendix B, Performance Specification 16. [District Rule 1080] Federally Enforceable Through Title V Permit

28. The PEMS sensor evaluation system shall check the integrity of each input at least once per day. [District Rule 1080] Federally Enforceable Through Title V Permit

29. The owner/operator shall perform a relative accuracy test audit (RATA) for the NOx, CO and O2 PEMS at least once every four calendar quarters. The permittee shall comply with the applicable requirements for quality assurance testing and maintenance of the predictive emission monitoring equipment in accordance with the procedures and guidance specified in 40 CFR Part 60, Appendix B, Performance Specification 16. [District Rule 1080] Federally Enforceable Through Title V Permit

30. The owner/operator shall perform a relative accuracy audit (RAA) of the PEMS at least once each calendar quarter, except during quarters in which a RATA is performed, in accordance with EPA guidelines. Audit reports shall be submitted along with quarterly compliance reports to the District. [District Rule 1080] Federally Enforceable Through Title V Permit

31. If a PEMS passes all quarterly RAAs in the first year and also passes the subsequent yearly RATA in the second year, the permittee may elect to perform a single mid-year RAA in the second year in place of the quarterly RAAs as specified in Section 9.3 of EPA Performance Specification 16. This option may be repeated, but only until the PEMS fails either a mid-year RAA or a yearly RATA. When such a failure occurs, the operator must resume quarterly RAAs in the quarter following the failure and continue conducting quarterly RAAs until the PEMS successfully passes both a year of quarterly RAAs and a subsequent RATA. [District Rule 1080] Federally Enforceable Through Title V Permit

32. Results of continuous emissions monitoring equipment shall be reduced according to the procedure established in 40 CFR, Part 51, Appendix P, paragraphs 5.0 through 5.3.3, or by other methods deemed equivalent by mutual agreement with the District, the ARB, and the EPA. [District Rule 1080] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

33. The facility shall maintain equipment, facilities, and systems compatible with the District's continuous emission monitor data polling software system and shall make PEMS data available to the District's automated polling system on a daily basis. [District Rule 1080] Federally Enforceable Through Title V Permit

34. Upon notice by the District that the facility's PEM system is not providing polling data, the facility may continue to operate without providing automated data for a maximum of 30 days per calendar year provided the PEMS data is sent to the District by a District-approved alternative method. [District Rule 1080] Federally Enforceable Through Title V Permit

35. The owner or operator shall, upon written notice from the APCO, provide a summary of the data obtained from the CEM systems. This summary of data shall be in the form and the manner prescribed by the APCO. [District Rule 1080] Federally Enforceable Through Title V Permit

36. The owner or operator shall submit a written report of PEMS operations for each calendar quarter to the APCO. The report is due on the 30th day following the end of the calendar quarter and shall include the following: Time intervals, data and magnitude of excess emissions, nature and the cause of excess (if known), corrective actions taken and preventative measures adopted; Averaging period used for data reporting corresponding to the averaging period specified in the emission test period and used to determine compliance with an emissions standard; Applicable time and date of each period during which the PEMS was inoperative (monitor downtime), except for zero and span checks, and the nature of system repairs and adjustments; A negative declaration when no excess emissions occurred. [District Rule 1080] Federally Enforceable Through Title V Permit

37. When the turbine is operating and it is determined that the predictive emission monitoring system (PEMS) for NOx and CO is not operating properly, the permittee shall notify the District of the breakdown condition in accordance with Rule 1100 (Equipment Breakdown). During the breakdown period, the facility shall demonstrate emissions compliance by monitoring and recording hourly NOx and CO concentrations utilizing a portable analyzer that meets District specifications. The facility shall operate the portable analyzer providing data to the District for a maximum of 96 hours per breakdown occurrence. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit

38. Portable analyzer readings shall be taken with the unit operating either at conditions representative of normal operations or conditions specified in the Permit to Operate. The analyzer shall be calibrated, maintained, and operated in accordance with the manufacturer's specifications and recommendations or a protocol approved by the APCO. Emission readings taken shall be averaged over a 15 consecutive-minute period by either taking a cumulative 15 consecutive-minute sample reading or by taking at least five (5) readings, evenly spaced out over the 15 consecutive-minute period. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit

39. If the NOx and/or CO concentrations, as measured by the permittee with a portable analyzer, exceed the permitted emission limits, the permittee shall notify the District and return the NOx and CO concentrations to the permitted emission limits as soon as possible but no longer than eight (8) hours after detection. If the permittee's portable analyzer readings continue to exceed the permitted emissions limits after eight (8) hours, the permittee shall notify the District within the following one (1) hour, and conduct a certified source test within 60 days to demonstrate compliance with the permitted emissions limits. In lieu of conducting a source test, the permittee may stipulate that a violation has occurred, subject to enforcement action. The permittee must correct the violation, show compliance has been re-established, and resume monitoring procedures. If the deviations are the result of a qualifying breakdown condition pursuant to Rule 1100, the permittee may fully comply with Rule 1100 in lieu of performing the notification and testing required by this condition. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit

40. Operator shall maintain a stationary gas turbine operating log that includes, on a daily basis, the actual local start-up and stop time, length and reason for reduced load periods, total hours of operation, type and quantity of fuel used. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit

41. The owner or operator shall maintain records that contain the following: the occurrence and duration of any start-up, shutdown or malfunction, performance testing, evaluations, calibrations, checks, adjustments, any periods during which a continuous monitoring system or monitoring device is inoperative, maintenance of any PEM system that has been installed pursuant to District Rule 1080, and emission measurements. [District Rules 1080 and 4703 and 40 CFR 60.8(d)] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

42. Records shall be maintained on the quality and accuracy of all instruments to verify compliance. [District Rules 1070 and 2520] Federally Enforceable Through Title V Permit

43. All records required to be maintained by this permit shall be maintained for a period of at least five years and shall be made readily available for District inspection upon request. [District Rules 2201 and 4703] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-24-4 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
TRANSPORTABLE 125 BHP JOHN DEERE MODEL 4045HF275 TIER 3 CERTIFIED DIESEL-FIRED IC ENGINE POWERING AN AIR COMPRESSOR

PERMIT UNIT REQUIREMENTS

1. Particulate matter emissions shall not exceed 0.1 grains/dscf in concentration. [District Rule 4201] Federally Enforceable Through Title V Permit
2. The exhaust stack shall vent vertically upward. The vertical exhaust flow shall not be impeded by a rain cap, roof overhang, or any other obstruction. [District Rule 4102]
3. Only CARB certified diesel fuel containing not more than 0.0015% sulfur by weight is to be used. [District Rules 2201 and 4801 and 17 CCR 93116] Federally Enforceable Through Title V Permit
4. This engine shall be equipped with an operational non-resettable elapsed time meter or other APCO approved alternative. [District Rule 4702 and 17 CCR 93116] Federally Enforceable Through Title V Permit
5. The only approved storage and operational location for this IC engine shall be Facility C-535 at 5607 W Jensen Avenue, Fresno. [District Rule 2201] Federally Enforceable Through Title V Permit
6. This transportable IC engine shall not be attached to a foundation or operated at any location at this facility for more than 12 consecutive months. The period during which the engine is maintained at a storage location shall be excluded from the residency time determination. [District Rule 4701, 40 CFR Part 89, 13 CCR 2421, and 17 CCR 93116] Federally Enforceable Through Title V Permit
7. Total combined annual NOx emissions from the waste gas flare (C-535-9), the transportable diesel-fired IC engine powering an air compressor (C-535-24), and the transportable diesel-fired IC engine powering a pump (C-535-44) shall not exceed 19,272 pounds in any calendar year. [District Rule 2201] Federally Enforceable Through Title V Permit
8. Total combined annual NOx emissions from the waste gas flare (C-535-9), the transportable diesel-fired IC engine powering an air compressor (C-535-24), and the transportable diesel-fired IC engine powering a pump (C-535-44) shall be calculated as follows: Annual NOx Emissions (lbs/year) = [(33.0 lb/MMscf x Waste Gas Flare's Annual Fuel Combusted (MMscf/year)) + (1.13 lbs/hr x IC Engine Powering an Air Compressor Annual Hours of Operation (hrs/year)) + (0.51 lbs/hr x IC Engine Powering a Pump Annual Hours of Operation (hrs/year))]. [District Rule 2201] Federally Enforceable Through Title V Permit
9. Emissions from this IC engine shall not exceed any of the following limits: 4.10 g-NOx/bhp-hr, 0.75 g-CO/bhp-hr, or 0.30 g-VOC/bhp-hr. [District Rule 2201 and 17 CCR 93116] Federally Enforceable Through Title V Permit
10. Emissions from this IC engine shall not exceed 0.19 g-PM10/bhp-hr based on USEPA certification using ISO 8178 test procedure. [District Rules 2201 and 4102, and 17 CCR 93116] Federally Enforceable Through Title V Permit
11. This engine shall be operated and maintained in proper operating condition as recommended by the engine manufacturer or emissions control system supplier. [District Rule 4702] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

12. During periods of operation, the permittee shall monitor the operational characteristics of the engine as recommended by the manufacturer or emission control system supplier (for example: check engine fluid levels, battery, cables and connections; change engine oil and filters; replace engine coolant; and/or other operational characteristics as recommended by the manufacturer or supplier). [District Rule 4702] Federally Enforceable Through Title V Permit
13. The permittee shall maintain an engine-operating log that shall include the following: daily records of the date, location at the facility, operational time; a record of the cumulative annual hours of operation of the engine; and records of operational characteristics monitoring. [District Rules 2201 and 4702] Federally Enforceable Through Title V Permit
14. Records of the total annual NOx emissions from units C-535-9, -24 and -44 shall be maintained and updated monthly. [District Rule 1070] Federally Enforceable Through Title V Permit
15. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rule 4702 and 17 CCR 93116] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-26-6 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
DIGESTER GAS TREATMENT SYSTEM CONSISTING OF A CHILLER; COMPRESSOR; HYDROGEN SULFIDE REMOVAL UNIT; MEMBRANE PROCESSING UNIT; A 7.46 MMBTU/HR JOHN ZINK MODEL ZBRID WASTE GAS COMBUSTION DEVICE USING RAW DIGESTER GAS OR PUC-QUALITY NATURAL GAS AS SUPPLEMENTAL FUEL; AND ACTIVATED CARBON ADSORPTION BEDS

PERMIT UNIT REQUIREMENTS

1. Particulate matter emissions from the exhaust of the combustion device shall not exceed 0.1 grains/dscf in concentration. [District Rule 4201] Federally Enforceable Through Title V Permit
2. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District Rule 2201] Federally Enforceable Through Title V Permit
3. The exhaust stack shall vent vertically upward. The vertical exhaust flow shall not be impeded by a rain cap (flapper ok), roof overhang, or any other obstruction. [District Rule 4102]
4. The combustion device shall only be fired on raw digester gas or PUC-quality natural gas. [District Rule 2201] Federally Enforceable Through Title V Permit
5. Emission rates from the combustion device shall not exceed any of the following limits: NOx - 0.06 lb/MMBtu; CO - 0.20 lb/MMBtu; 20 ppmv VOC @ 3% O2 (as hexane) or 0.084 lb-VOC/MMBtu; or PM10 - 0.016 lb/MMBtu. [District Rule 2201] Federally Enforceable Through Title V Permit
6. The H2S content of the raw digester gas processed through this gas treatment system shall not exceed 200 ppmv. [District Ruled 2201 and 4801] Federally Enforceable Through Title V Permit
7. Source testing of the NOx and CO emissions from the exhaust of the combustion device shall be performed at least once every five years. Source testing is only required for the fuel type being used at the time. [District Rules 2201 and 2520] Federally Enforceable Through Title V Permit
8. Within 60 days of commencing operation after switching the fuel type between digester gas and PUC-quality natural gas, source testing of the NOx and CO emissions from the exhaust of the combustion device shall be performed on the new fuel type, unless source testing on the new fuel has been completed within the last 5 years. [District Rule 2201] Federally Enforceable Through Title V Permit
9. Testing to demonstrate compliance with the raw digester gas H2S content limit shall be conducted quarterly. Once eight (8) consecutive quarterly test show compliance, the H2S content testing frequency may be reduce to once every calendar year. If an annual test shows violation of the H2S content limit, then quarterly testing shall resume and continue until eight (8) consecutive tests show compliance. Once compliance is shown on eight (8) consecutive quarterly tests, then testing may return to once every calendar year. [District Rule 2201] Federally Enforceable Through Title V Permit
10. Source testing shall be conducted using the methods and procedures approved by the District. The District must be notified at least 30 days prior to any compliance source test, and a source test plan must be submitted for approval at least 15 days prior to testing. [District Rule 1081] Federally Enforceable Through Title V Permit
11. NOx emissions for source test purposes shall be determined using EPA Method 19. [District Rules 2201 and 2520] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

12. CO emissions for source test purposes shall be determined using EPA Method 10 or ARB Method 100. [District Rules 2201 and 2520] Federally Enforceable Through Title V Permit
13. Testing to measure the H2S content of the fuel shall be conducted using either EPA Method 15, ASTM Method D1072, D3031, D3246, D4084, D4810, D5504, D6228 or with the use of the Testo 350 XL portable analyzer. [District Rule 2201] Federally Enforceable Through Title V Permit
14. The results of each source test shall be submitted to the District within 60 days thereafter. [District Rule 1081] Federally Enforceable Through Title V Permit
15. The combustion zone of the combustion device shall be maintained at a minimum of 1,400 degrees Fahrenheit. [District Rule 2520] Federally Enforceable Through Title V Permit
16. The combustion device shall be equipped with a continuous temperature monitoring and recording device, in operation at all times. [District Rule 2520] Federally Enforceable Through Title V Permit
17. The permittee shall maintain daily records of the thermal oxidizer combustion temperature. [District Rule 2520] Federally Enforceable Through Title V Permit
18. The permittee shall maintain records of: (1) daily amount of waste gas, raw digester gas, and/or PUC-quality natural gas consumed by the combustion device, in standard cubic feet; (2) copy of source test reports; and (3) copies of all annual reports submitted to the District. [District Rules 2201 and 2520] Federally Enforceable Through Title V Permit
19. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rules 2201 and 2520] Federally Enforceable Through Title V Permit

San Joaquin Valley
Air Pollution Control District

PERMIT UNIT: C-535-28-1 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
UNCONFINED ABRASIVE BLASTING OPERATION WITH A 600 LB SARACCO NATIONAL BOARD #34188 BLASTING POT (POWERED BY ENGINE PERMITTED UNDER C-535-24)

PERMIT UNIT REQUIREMENTS

1. All equipment shall be maintained in good operating condition and shall be operated in a manner to minimize emissions of air contaminants into the atmosphere. [District Rule 4102]
2. The blasting operations shall be carried out in a manner to prevent any nuisances. [District Rule 4102]
3. All abrasive blasting shall be conducted in accordance with California Code of Regulations Title 17, Subchapter 6, Sections 92000 through 92540. [92000 through 92540 CCR]
4. A used certified abrasive shall not be considered certified for reuse unless the abrasive conforms to its original cut-point fineness. [92530 CCR]
5. Unconfined abrasive blasting operations shall not discharge air contaminants into the atmosphere for a period or periods aggregating more than three minutes in any one hour which is as dark or darker than Ringelmann 2 or equivalent to 40% opacity. [92200 CCR]
6. Except as otherwise provided in this permit, abrasive blasting shall be conducted within a permanent building unless steel or iron shot/grit is used. [92500 CCR]
7. Abrasive blasting of items exceeding 8 feet in any dimension, or of a surface situated at its permanent location, or no further away from its permanent location than is necessary to allow the surface to be blasted, may be performed outside a permanent building only if one of the following is used: steel or iron shot/grit; abrasives certified by CARB for permissible dry outdoor blasting; wet abrasive blasting, hydroblasting; or vacuum blasting. [92500 CCR]
8. Unconfined abrasive blasting shall be limited to 5 hours in any one day and 250 hours per rolling 12-month period. [District Rule 4102]
9. Operator shall record the date and hours when unconfined blasting occurs. [District Rules 1070 and 4102]
10. All records required by this permit shall be retained on-site for a period of at least five years and shall be made available for District inspection upon request. [District Rules 1070 and 4102]

PERMIT UNIT: C-535-44-0 **EXPIRATION DATE:** 01/31/2021

EQUIPMENT DESCRIPTION:
TRANSPORTABLE 74 BHP JOHN DEERE MODEL 4045TFC03 TIER 4 FINAL CERTIFIED DIESEL-FIRED IC ENGINE POWERING A PUMP

PERMIT UNIT REQUIREMENTS

1. Particulate matter emissions shall not exceed 0.1 grains/dscf in concentration. [District Rule 4201] Federally Enforceable Through Title V Permit
2. The exhaust stack shall vent vertically upward. The vertical exhaust flow shall not be impeded by a rain cap, roof overhang, or any other obstruction. [District Rule 4102]
3. Only CARB certified diesel fuel containing not more than 0.0015% sulfur by weight is to be used. [District Rules 2201 and 4801 and 17 CCR 93116] Federally Enforceable Through Title V Permit
4. This engine shall be equipped with an operational non-resettable elapsed time meter or other APCO approved alternative. [District Rule 4702 and 17 CCR 93116] Federally Enforceable Through Title V Permit
5. Operation of this engine shall not exceed 2,160 hours per year. [District Rule 2201] Federally Enforceable Through Title V Permit
6. The only approved storage and operational location for this IC engine shall be Facility C-535 at 5607 W Jensen Avenue, Fresno. [District Rule 2201] Federally Enforceable Through Title V Permit
7. This transportable IC engine shall not be attached to a foundation or operated at any location at this facility for more than 12 consecutive months. The period during which the engine is maintained at a storage location shall be excluded from the residency time determination. [District Rule 4701, 40 CFR Part 89, 13 CCR 2421, and 17 CCR 93116] Federally Enforceable Through Title V Permit
8. Total combined annual NOx emissions from the waste gas flare (C-535-9), the transportable diesel-fired IC engine powering an air compressor (C-535-24), and the transportable diesel-fired IC engine powering a pump (C-535-44) shall not exceed 19,272 pounds in any calendar year. [District Rule 2201] Federally Enforceable Through Title V Permit
9. Total combined annual NOx emissions from the waste gas flare (C-535-9), the transportable diesel-fired IC engine powering an air compressor (C-535-24), and the transportable diesel-fired IC engine powering a pump (C-535-44) shall be calculated as follows: Annual NOx Emissions (lbs/year) = [(33.0 lb/MMscf x Waste Gas Flare's Annual Fuel Combusted (MMscf/year)) + (1.13 lbs/hr x IC Engine Powering an Air Compressor Annual Hours of Operation (hrs/year)) + (0.51 lbs/hr x IC Engine Powering a Pump Annual Hours of Operation (hrs/year))]. [District Rule 2201] Federally Enforceable Through Title V Permit
10. Emissions from this IC engine shall not exceed any of the following limits: 3.12 g-NOx/bhp-hr, 0.0746 g-CO/bhp-hr, or 0.16 g-VOC/bhp-hr. [District Rule 2201 and 17 CCR 93116] Federally Enforceable Through Title V Permit
11. Emissions from this IC engine shall not exceed 0.0007 g-PM10/bhp-hr based on USEPA certification using ISO 8178 test procedure. [District Rules 2201 and 4102, and 17 CCR 93116] Federally Enforceable Through Title V Permit
12. This engine shall be operated and maintained in proper operating condition as recommended by the engine manufacturer or emissions control system supplier. [District Rule 4702] Federally Enforceable Through Title V Permit

PERMIT UNIT REQUIREMENTS CONTINUE ON NEXT PAGE

13. During periods of operation, the permittee shall monitor the operational characteristics of the engine as recommended by the manufacturer or emission control system supplier (for example: check engine fluid levels, battery, cables and connections; change engine oil and filters; replace engine coolant; and/or other operational characteristics as recommended by the manufacturer or supplier). [District Rule 4702] Federally Enforceable Through Title V Permit
14. The permittee shall maintain an engine-operating log that shall include the following: daily records of the date, location at the facility, operational time; a record of the cumulative annual hours of operation of the engine; and records of operational characteristics monitoring. [District Rules 2201 and 4702] Federally Enforceable Through Title V Permit
15. Records of the total annual NOx emissions from units C-535-9, -24 and -44 shall be maintained and updated monthly. [District Rules 1070 and 2201] Federally Enforceable Through Title V Permit
16. All records shall be maintained and retained on-site for a minimum of five (5) years, and shall be made available for District inspection upon request. [District Rule 4702 and 17 CCR 93116] Federally Enforceable Through Title V Permit

Appendix 3-A

USER INFORMATION FACT SHEETS

Exceptional Quality BIOSOLIDS

A Natural Crop Enhancer

Turf, Garden, Landscaping & Ag Utilization

Information Sheet

What are Exceptional Quality (EQ) Biosolids?

Exceptional Quality (EQ) biosolids are a slow-release fertilizer, rich in **organic matter**, and made from stabilized residuals resulting from the treatment of wastewater.

How are EQ Biosolids Produced?

EQ BIOSOLIDS are produced at permitted wastewater reclamation facilities (WRFs). The WRFs offer advanced treatment, utilizing high temperature anaerobic digestion for stabilization and pathogen reduction. This product has been treated to such a high degree that the most rigorous standards imposed by state and federal regulations are satisfied. EQ biosolids meet stringent quality criteria relative to specific trace elements and pollutants (including heavy metals), pathogen destruction, and vector attraction reduction (stability).

Plant Growth and Soil Quality

EQ BIOSOLIDS are an excellent moderate-grade fertilizer and a valuable source of organic matter (Table 1). Benefits Include:

- Improved soil tilth
- Increased soil water holding capacity
- Increased soil aeration and infiltration
- Provides slow-release nutrients
- Reduced soil surface crusting and compaction

TABLE 1

Typical Primary Nutrient Content[(1)] (As-Is Basis)

1.5 – 2.1 – 0.1

Primary Nutrients	***Projected Value***	***lbs. N / Wet Ton***	***lbs. PAN[(2)] / Wet Ton***
% Organic N	1.4%	27.5	5.5
% Ammonium N	0.2%	4.9	2.4
% *Total* Phosphate (P_2O_5)	2.1%		
% Total Potash (K_2O)	0.1%		

Tons needed to apply 100 lbs. of PAN[(2)] = 12.6 Tons

250 lbs. EQ biosolids = 1 lb. of PAN[(2)]

[(1)] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

[(2)] PAN = Plant Available Nitrogen

Recommendations for Use

The biosolids plant available nitrogen (PAN) content determines the amount of fertilizer that may be applied for a particular use (for gardening, landscaping, or sod production) or to a farm field and crop. The sum total of all PAN sources must not exceed projected plant or crop N uptake. The application rates for row crops (Table 2), garden and potted plants (Table 3) and turf (Table 4) will take the N source listed in Table 1 into account. Because ***EQ BIOSOLIDS*** meet the EPA's most stringent trace element limits, Class A pathogen and vector reduction standards, they can be applied anywhere.

Bulk Agriculture

EQ Biosolids is an excellent fertilizer for use in the production of agronomic crops, such as corn, hay, or small grains, for feed crops, such as tomatoes or grapes, or establishment and/or maintenance of mechanically harvested forage grass (Table 2).

TABLE 2

Typical Agronomic Rates[(1,2)]

Planned Crop (Yield / Acre)	**Total Crop N Requirement (lb./Ac)**	**EQ Biosolids Application Rate (Ton/Ac)**
Almonds (1.5 T/ac)	250	31
Corn, Silage (25 T/ac)	175	22
Alfalfa (8 T/ac)	400	50
Wheat/Rye (15 T/ac)	140	17

[(1)] Crop yields and crop nitrogen needs based on University of California N recommendations

[(2)] The rates provided do not reflect historic nutrient applications. Specific guidance will be provided to farmers upon request.

It is recommended that farm fields proposed for agricultural utilization of ***EQ BIOSOLIDS*** be managed to reduce the potential for soil erosion (e.g. have an implemented soil conservation plan). Nutrient (nitrogen) management accounting should be performed to assure that biosolids additions, in combination with other N sources, do not exceed crop N uptake. Additionally, biosolids field application records should be maintained.

Specialty Markets

EQ BIOSOLIDS may be used as a fertilizer for flower and vegetable gardens, shrubbery, ornamentals, and as a potting mix component (Table 3).

TABLE 3
Container/Garden Typical Application Rates

Garden Plants	***Application Rate***
Cell Pack Bedding Plants or Quart/Gal Transplants	2 cup per ft^2
Established Plants	$2\ ^1/_2$ cup per ft^2 around root zone
Flower Beds	16 quarts per 25 ft^2

EQ BIOSOLIDS should be incorporated into the top 1-2" of soil in established perennial and annual gardens in spring. For new plantings, mix with the backfill soil and fill around the plant.

Potted Plants*	***Indoor***	***Outdoor***
4" Diameter	5 Tbsp	6 Tbsp
8" Diameter	1 cup	$1\ ^1/_2$ cup
12" Diameter	$2\ ^1/_2$ cup	$4\ ^1/_4$ cup
14" Diameter	$3\ ^1/_4$ cup	$5\ ^1/_2$ cup

*For container gardens, mix evenly into the potting soil in spring.

EQ BIOSOLIDS are also an excellent fertilizer for sod production and to support turf health.

TABLE 4
SOD/TURF TYPICAL APPLICATION RATES

Planned Vegetation	**Recommended Application Timeframe**	**EQ Biosolids Application Rate (per appl. event)**
Sod Establishment (1 lb. PAN/1,000 ft^2)	Apply at seeding; and as needed 4-8 weeks after seeding	**400 lb./1,000ft^2** or 8.8 ton/acre
Turf/Lawn Seasonal Topdress, Landscaping (0.75 lb. PAN/1,000 ft^2)	Spring and fall	**300 lb./1,000ft^2** or 6.6 ton/acre
Build Organic Matter in Soil (1.0 lb. PAN/1,000 ft^2)	Early spring	**400 lb./1,000ft^2** or 8.8 ton/acre

(1)Application rates based on University of California Guidelines

Characteristics

The chemical and physical properties of ***EQ BIOSOLIDS*** are shown in Table 5. Note that they contain very low levels of trace elements.

TABLE 5
Typical Characteristics & Accepted Levels for Trace Elements

Parameter(1)	Accepted Concentration(2) (mg/kg)	EQ Biosolids Concentration(3) (mg/kg)
Metals/PCBs:		
Arsenic	41	2
Cadmium	39	2
Copper	1,500	915
Lead	300	16
Mercury	17	2
Molybdenum	n/a	19
Nickel	420	29
Selenium	100	11
Zinc	2,800	1,015
Other Parameters:		
pH	7.5	
Total Solids Content	30% (approx.)	

(1) All values expressed on dry weight basis
(2) USEPA limits for EQ biosolids
(3) Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

Environmental Sustainability

Beneficial use of biosolids has an excellent track record, over a period of more than 50 years. Hundreds of academic and actual field studies, along with the experience of thousands of growers/ farmers/ producers show that biosolids use provides greater crop yields.

Please note: *The information provided in this document has been developed for use as a tool for* ***market research purposes only****.*

For Additional Information Contact:

Material Matters, Inc.
820 North Hanover Street
Elizabethtown, PA 17022
(717) 367-9697 (phone)

MATERIAL MATTERS, Inc.

Email: lchallenger@materialmatters.com
Web: http://www.materialmatters.com

Exceptional Quality COMPOST

A Natural Crop Enhancer

Turf, Garden, Landscaping & Ag Utilization

Information Sheet

What is Compost?

Compost is the product that results from the biological decomposition of raw organic materials ("feedstocks") under controlled aerobic conditions in a process called composting. ***EXCEPTIONAL QUALITY (EQ)*** biosolids compost is produced by composting ground woody material with biosolids, the nutrient-rich organic materials produced from the extensive multi-stage physical, chemical, and biological treatment of wastewater. Prior to use in composting, biosolids are processed and refined through a stabilization process called anaerobic digestion.

How is *EQ Compost* Produced?

EQ COMPOST is produced via composting. To begin, the feedstocks are combined in a specific ratio ("recipe") to create ideal growth conditions for aerobic microbes to further decompose organic wastes such as biosolids and woody wastes.

As the microbes decompose the material, they release heat that causes the temperature in the pile to raise dramatically, killing disease causing organisms that may be present. The screened finish compost product is a stable, earthy, organic-rich material that is highly regarded as an excellent soil amendment, often referred to as "black gold."

Benefits of EQ compost Includes:

- Improved soil tilth
- Increased soil water holding capacity
- Increased water infiltration and soil aeration
- Increased mineral fertilizer plant uptake efficiency
- Provides slow-release nutrients for plant growth
- Reduced potential for erosion and soil compaction

Exceptional Plant Growth and Soil Quality

EQ COMPOST is an excellent soil amendment high in valuable organic matter. Use of EQ compost supports California's 2017 *Healthy Soils Initiative (Assembly Bill 1613)*, as a practice that can improve soil health and reduce greenhouse gas emissions.

Compost also serves as a fertilizing material. In addition to primary nutrients, ***EQ COMPOST*** contains secondary and micronutrients that are essential to plant health and vigor (Table 1).

TABLE 1 - Typical Nutrient Content

EQ COMPOST

Primary Nutrients	***Avg***
% Organic N	1.0%
% Ammonium N	0.2%
% Phosphate (P_2O_5)	1.5%

Carbon/Nitrogen Ratio 15:1

1 cu yd. EQ Compost = 2 lb Plant Avail. N

[1] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

Recommendations for Use

EQ COMPOST may be used to build the soil in lawns and sports turf, flower and vegetable gardens, shrubbery, ornamentals, and it can serve as a potting mix component (Table 2). It is a valuable source of organic matter and serves as erosion control for the establishment and/or maintenance of sod, turf grass, home lawns, and athletic fields.

EQ COMPOST may also be used as an agent for soil blending with other approved residuals or as a soil enhancement/low-N fertilizer on farmland.

EQ COMPOST application rates should not exceed the PAN need of the established or planned crop and other uses should adhere to the USCC's recommended application rates.

TABLE 2
Typical Application Rates [1]

Compost Usage	*Application Type*	*Application Rate*
Turf Establishment	*Incorporation*	*1" to 2" layer (~3 to 6 yd^3/1,000 ft^2)*
Planting Bed Establishment	*Incorporation*	*1"-2" layer (~3 to 6 yd^3/1,000 ft^2)*
Landscape Mulch	*Surface Application*	*1"-3" layer (~3 to 9 yd^3/1,000 ft^2)*
Blended Topsoil	*Incorporation*	*10 – 50% of volume*
Potted Plants	*Incorporation*	*20 – 33% of volume*
Vegetable Garden	*Incorporation*	*1" to 2" layer (~3-6 yd^3/1,000 ft^2)*

[1] The US Composting Council: Field Guide to Compost Use (2001)

General Use Guidelines

Because ***EQ Compost*** meets EPA's most stringent trace element limits, Class A pathogen, and vector reduction standards, it can generally be applied anywhere that fertilizer is applied. Like all commercial fertilizer products, ***EQ Biosolids*** should be used in a way to avoid potential environmental impacts. Therefore, the standard application practices used with any commercial fertilizer, including keeping the product away from surface waters and streams, are recommended for the application of ***EQ Compost.***

Standard practices include limiting use during the following conditions:

- During or immediately prior to a rain event
- When ground is saturated, snow covered, or frozen (deeper than 2 inches)

Characteristics

The chemical and physical properties of ***EQ Compost*** are shown in Table 3. Note that it contains very low levels of trace elements.

TABLE 3
Typical Characteristics & Accepted Levels for Trace Elements

Parameter[1]	Accepted [2] Concentration (mg/kg)	EQ Compost[3] Concentration (mg/kg)
Metals/PCBs:		
Arsenic	41	3
Cadmium	39	1
Copper	1,500	79
Lead	300	5
Mercury	17	0.5
Molybdenum	n/a	5
Nickel	420	8
Selenium	100	1
Zinc	2,800	250
Other Parameters:		
pH	7.0	
Total Solids Content	65% (approx)	
Bulk density	800 lb/cu yd	

[1] All values expressed on dry weight basis, excluding bulk density
[2] USEPA limits for EQ biosolids
[3] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

Transport and Use

EQ Compost can be applied anywhere other composts are used. Similar to any N or P fertilizer, it is suggested that ***EQ Compost*** be covered and stored appropriately until conditions are suitable for use.

Please note: *The information provided in this document has been developed for use as a tool for* ***market research purposes only****.*

For Additional Information Contact:

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Email: lchallenger@materialmatters.com
Web: http://www.materialmatters.com

Exceptional Quality Liquid BIOSOLIDS

A Natural Crop Enhancer

Turf & Ag Utilization

Information Sheet

What are Exceptional Quality (EQ) Biosolids?

Exceptional Quality (EQ) biosolids are a slow-release fertilizer, rich in **organic matter**, and made from stabilized residuals resulting from the treatment of wastewater.

How are EQ Biosolids Produced?

EQ BIOSOLIDS are produced at permitted wastewater reclamation facilities (WRFs). The WRFs offer advanced treatment, utilizing high temperature and chemical pretreatment in conjunction with anaerobic digestion for stabilization and pathogen reduction. This product has been treated so the most rigorous standards imposed by state and federal regulations are satisfied. EQ biosolids meet stringent quality criteria relative to specific trace elements and pollutants, pathogen destruction, and vector attraction reduction (stability).

Plant Growth and Soil Quality

EQ BIOSOLIDS are an excellent moderate-grade fertilizing material and a valuable source of organic matter (Table 1).

TABLE 1

Typical Primary Nutrient Content[1] ("As-is" Basis)

Primary Nutrients	***0.8-1.0-0 Projected Value***	***lbs. N / 1,000 gal***	***lbs. PAN[2] / 1,000 gal***
% Organic N	0.7%	57.3	11.5
% Ammonium N	0.1%	10.1	1.2
% *Total* Phosphate (P_2O_5)	1.0%		
% Total Potash (K_2O)	0.0%		
% Organic Matter	60%		

Gallons needed to apply 100 lbs. of PAN[2] = 6,000 gallons

60 gallons EQ biosolids = 1 lb. of PAN[2]

[1] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

[2] PAN = Plant Available Nitrogen

Benefits Include:

- Improved soil tilth
- Increased soil water holding capacity
- Increased soil aeration and infiltration
- Provides slow-release nutrients
- Reduced soil surface crusting and compaction
- Reduced potential for erosion

Recommendations for Use

The biosolids plant available nitrogen (PAN) content determines the amount of fertilizer material that may be applied for a farm field and crop. The sum total of all PAN sources must not exceed projected plant or crop N uptake. The application rates for row crops (Table 2), and turf (Table 3) will take the N source listed in Table 1 into account. Because ***EQ BIOSOLIDS*** meet the EPA's most stringent trace element limits, Class A pathogen and vector reduction standards, they can be applied anywhere.

Bulk Agriculture

EQ Biosolids is an excellent fertilizer for use in the production of agronomic crops, such as corn, hay, or small grains, for food crops such as tomatoes and grapes, or establishment and/or maintenance of mechanically harvested forage grass (Table 2).

TABLE 2

Example Agronomic Rates [1,2]

Planned Crop (Yield / Acre)	**Total Crop N Requirement (lb./Ac)**	**EQ Biosolids Application Rate (Gallons/Ac)**
Almonds (1.5 T/ac)	250	15,000
Corn, Silage (25 T/ac)	175	10,500
Alfalfa (8 T/ac)	400	24,200
Wheat/Rye (15 T/ac)	140	8,400

[1] Crop yields and crop nitrogen needs based on University of California N recommendations

[2] The rates provided do not reflect historic nutrient applications. Specific guidance will be provided to farmers upon request.

It is recommended that farm fields proposed for agricultural utilization of ***EQ Biosolids*** be managed to reduce the potential for soil erosion (e.g. have an implemented soil conservation plan). Nutrient (nitrogen) management accounting should be performed to assure that biosolids additions, in combination with other N sources, do not exceed crop N uptake. Additionally, biosolids field application records should be maintained.

Specialty Markets

EQ biosolids are also an excellent fertilizer for sod production and to support turf health (Table 3).

Table 3

Sod/Turf Typical Application Rates[1]

Planned Vegetation	Recommended Application Timeframe	EQ Biosolids Application Rate (per appl. event)
Sod Establishment (1 lb. PAN/1,000 ft^2)	Apply at seeding; and as needed 4-8 weeks after seeding	**60 gal./1,000 ft^2** or 2,600 gal./acre
Turf/Lawn Seasonal Topdress, Landscaping (0.75 lb. PAN/1,000 ft^2)	Spring and fall	**45 gal./1,000 ft^2** or 1,900 ton/acre
Build Organic Matter in Soil (1.0 lb. PAN/1,000 ft^2)	Early spring	**60 gal./1,000 ft^2** or 2,600 gal./acre

[1] Application rates based on University of California Guidelines

Characteristics

The chemical and physical properties of ***EQ Biosolids*** are shown in Table 4. Note that they contain very low levels of trace elements.

Table 4

Typical Characteristics & Accepted Levels for Trace Elements

Parameter[1]	Accepted Concentration[2] (mg/kg)	EQ Biosolids Concentration[3] (mg/kg)
Metals/PCBs:		
Arsenic	41	8
Cadmium	39	3
Copper	1,500	240
Lead	300	14
Mercury	17	1.3
Molybdenum	75	14
Nickel	420	23
Selenium	100	4
Zinc	2,800	750
Other Parameters:		
pH	7.5	
Total Solids Content	15% (approx.)	

[1] All values expressed on dry weight basis
[2] USEPA limits for EQ biosolids
[3] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

Environmental Sustainability

Beneficial use of biosolids has an excellent track record, over a period of more than 50 years. Hundreds of academic and actual field studies, along with the experience of thousands of growers/ farmers/ producers show that biosolids use provides greater crop yields.

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Exceptional Quality DRIED BIOSOLIDS

A Natural Crop Enhancer

Turf, Garden, Landscaping & Ag Utilization

Information Sheet

What are Exceptional Quality (EQ) Biosolids?
Exceptional Quality (EQ) biosolids are a slow-release fertilizer, rich in organic matter, and made from stabilized residuals produced during the treatment of wastewater.

How are EQ Biosolids Produced?
EQ BIOSOLIDS are produced at permitted wastewater reclamation facilities (WRFs). The WRFs provide advanced treatment, anaerobic digestion, and thermal drying for stabilization and pathogen reduction. This product has been treated to such a high degree that the most rigorous standards imposed by state and federal regulations are satisfied. Such residuals meet stringent quality criteria relative to trace elements (heavy metals), pathogen destruction, and vector attraction reduction (stability).

Plant Growth and Soil Quality
EQ BIOSOLIDS are an excellent moderate-grade fertilizing material and a valuable source of organic matter (Table 1). Benefits Include:

- Improved soil tilth
- Increased soil water holding capacity
- Increased soil aeration and infiltration
- Provides slow-release nutrients
- Reduced soil surface crusting and compaction

TABLE 1
Typical Primary Nutrient Content[(1)]
5 - 6.5 - 0.2

Primary Nutrients	***Projected Value***	***lbs. N / Ton***	***lbs. PAN***[(2)] ***/ Ton***
% Organic N	4.3%	87.0	17.0
% Ammonium N	0.7%	15.4	7.7
% *Total* Phosphate (P_2O_5)	6.5%		
% *Total* Potash (K_2O)	0.2%		
Organic Matter:	72%		

Tons needed to apply 100 lbs. of PAN[(2)] **= 4 Tons**
80 lbs. EQ biosolids = 1 lb. of PAN[(2)]

[(1)] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data
[(2)] PAN = Plant Available Nitrogen

Recommendations for Use
The plant available nitrogen (PAN) content determines the amount of fertilizer that may be applied for a particular use (for gardening, landscaping, or sod production) or to a farm crop. The sum total of all PAN sources must not exceed projected plant N uptake. The application rates for row crops (Table 2), potted or garden plants (Table 3) and turf (Table 4) will take the N source listed in Table 1 into account.

Bulk Agriculture
EQ Biosolids is an excellent fertilizer for use in the production of agronomic crops, such as corn, hay, or small grains, food crops, such as tomatoes and grapes, or establishment and/or maintenance of mechanically harvested forage grass (Table 2).

TABLE 2
Typical Agronomic Rates [(1)]

Planned Crop (Yield / Acre)	**Total Crop N Requirement (lb./Ac)**	**EQ Biosolids Application Rate (Ton/Ac)**
Almonds (1.5 T/ac)	250	10.0
Corn, Silage (25 T/ac)	175	7.0
Alfalfa (8 T/ac)	400	15.9
Wheat/Rye (15 T/ac)	140	5.6

[(1)] Crop yields and crop nitrogen needs based on University of California N recommendations
[(2)] The rates provided do not reflect historic nutrient applications. Specific guidance will be provided to farmers upon request.

It is recommended that farm fields proposed for agricultural utilization of ***EQ BIOSOLIDS*** be managed to reduce the potential for soil erosion (e.g. have an implemented soil conservation plan). Nutrient management accounting should be performed to assure that biosolids additions, in combination with other N sources, do not exceed crop N uptake. Additionally, biosolids field application records should be maintained.

Specialty Markets

EQ BIOSOLIDS may be used as a fertilizer for flower and vegetable gardens, shrubbery, ornamentals, and as a potting mix component (Table 3).

TABLE 3
Container/Garden Typical Application Rates

Garden Plants	***Application Rate***	
Cell Pack Bedding Plants or Quart/Gal Transplants	3/8 cup per ft^2	
Established Plants	1/2 cup per ft^2 near root zone	
Flower Beds	3 quarts per 25 ft^2	

EQ BIOSOLIDS should be incorporated into the top 1-2" of soil in established perennial and annual gardens in spring. For new plantings, mix with the backfill soil and fill around the plant.

Potted Plants*	***Indoor***	***Outdoor***
4" Diameter	3 tsp	4 tsp
8" Diameter	$^1/_8$ cup	$^3/_8$ cup
12" Diameter	$^1/_2$ cup	$^3/_4$ cup
14" Diameter	$^5/_8$ cup	1 $^1/_{16}$ cup

*For container gardens, mix evenly into the potting soil in spring.

EQ BIOSOLIDS are also an excellent fertilizer for sod production and to support turf health.

TABLE 4
SOD/TURF TYPICAL APPLICATION RATES

Planned Vegetation	**Recommended Application Timeframe**	**EQ Biosolids Application Rate (per appl. event)**
Sod Establishment (1 lb. PAN/1,000 ft^2)	Apply at seeding; and as needed 4-8 weeks after seeding	**80 lb./1,000ft^2** or 1.7 ton/acre
Turf/Lawn Seasonal Topdress, Landscaping (0.75 lb. PAN/1,000 ft^2)	Spring and fall	**60 lb./1,000ft^2** or 1.3 ton/acre
Build Organic Matter in Soil (1.0 lb. PAN/1,000 ft^2)	Early spring	**80 lb./1,000ft^2** or 1.7 ton/acre

(1) Application rates based on University of California Guidelines

Characteristics

The chemical and physical properties of ***EQ BIOSOLIDS*** are shown in Table 5. Note that they contain very low levels of trace elements.

TABLE 5
Typical Characteristics & Accepted Levels for Trace Elements

Parameter(1)	Accepted (2) Concentration (mg/kg)	EQ Biosolids Concentration(3) (mg/kg)
Metals/PCBs:		
Arsenic	41	8
Cadmium	39	2
Copper	1,500	235
Lead	300	13
Mercury	17	1.3
Molybdenum	75	14.5
Nickel	420	23
Selenium	100	4
Zinc	2,800	750
Other Parameters:		
pH	7.5	
Total Solids Content	95% (approx.)	

(1) All values expressed on dry weight basis
(2) USEPA limits for EQ biosolids
(3) Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

Environmental Sustainability

Beneficial use of biosolids has an excellent track record over a period of more than 40 years. Hundreds of academic and actual field studies, along with the experience of thousands of growers/ farmers/ producers show that biosolids use provides greater crop yields.

Please note: *The information provided in this document has been developed for use as a tool for **market research purposes only**.*

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Exceptional Quality Biochar

A Natural Crop Enhancer

Turf, Garden, Landscaping & Ag Utilization

Information Sheet

What is Biochar?

BIOCHAR is a fine-grained, highly porous charcoal material made from a high temperature, oxygen-limited treatment process. The feedstock for biosolids biochar is stabilized residuals (biosolids) resulting from the treatment of wastewater.

How are EQ Biosolids Produced?

BIOSOLIDS BIOCHAR (***BIOCHAR***) is produced by subjecting biosolids to a process called pyrolysis. First, biosolids are processed through a thermal dryer to create a very dry (<10% moisture) granule. The granule is transferred to the pyrolysis vessel, where it is heated (>400°C) under pressure, and in a controlled oxygen supply to produce a very stable, carbon-rich product called ***BIOCHAR***.

Plant Growth and Soil Quality

BIOCHAR is an excellent moderate-grade soil amendment material and a valuable source of carbon (Table 1).

Benefits Include:

- Increased water infiltration
- Increased carbon exchange capacity
- Increased nutrient retention
- Improved soil pH buffering and stability
- Soil carbon sequestration

TABLE 1
Typical Primary Nutrient Content[1]
1.7 - 13.5 - 0.4

Primary Nutrients	***Projected Value***	***lbs. N / Wet Ton***	***lbs. PAN / Wet Ton***
% Organic N	1.5%	30.4	6.1
% Ammonium N	0.2%	5.4	2.7
% *Total* Phosphate (P_2O_5)	13.6%		
% *Total* Potash (K_2O)	0.4%		
% Carbon[3]	30 to 35%		

Tons needed to apply 100 lbs. of PAN[2] = 11.4 tons
230 lbs. EQ biosolids = 1 lb. of PAN[2]

[1] Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data
[2] PAN = Plant Available Nitrogen
[3] Estimate provided by BioForceTech

Recommendations for Use

Biochar is a great soil amendment, and can be used to supply carbon and nitrogen to the soil. If used as a nitrogen source, plant available nitrogen (PAN) content determines the amount of fertilizer material that may be applied for a particular use (for gardening, landscaping, or sod production) or to a farm field and crop. The sum total of all PAN sources must not exceed projected plant N uptake. The application rates for row crops (Table 2), potted or garden plants (Table 3) and turf (Table 4) will take the N source listed in Table 1 into account.

Bulk Agriculture

Biochar may be used as a soil amendment for use in the production of crops, such as corn, hay, or small grains, for food crops such as tomatoes or grapes, or establishment and/or maintenance of mechanically harvested forage grass (Table 2).

TABLE 2
Typical Agronomic Rates [1,2]

Planned Crop (Yield / Acre)	**Total Crop N Requirement (lb./Ac)**	**Biochar Application Rate (Ton/Ac)**
Almonds (1.5 T/ac)	250	31
Corn, Silage (25 T/ac)	175	19
Alfalfa (8 T/ac)	400	45
Wheat/Rye (15 T/ac)	140	71

[1] Crop yields and crop nitrogen needs based on University of California N recommendations
[2] The rates provided do not reflect historic nutrient applications. Specific guidance will be provided to farmers upon request.

It is recommended that farm fields proposed for agricultural utilization of ***BIOCHAR*** be managed to reduce the potential for soil erosion (e.g. have an implemented soil conservation plan).

Specialty Markets

Biochar may be used as a fertilizer or soil amendment for flower and vegetable gardens, shrubbery, ornamentals, and as a potting mix component (Table 3).

Table 3
Container/Garden Typical Application Rates

Garden Plants	***Application Rate***
Cell Pack Bedding Plants or Quart/Gal Transplants	1 cup per ft^2
Established Plants	1 ¼ up per ft^2 around root zone
Flower Beds	8 quarts per 25 ft^2

Biochar should be incorporated into the top 1-2" of soil in established perennial and annual gardens in spring. For new plantings, mix with the backfill soil and fill around the plant.

Potted Plants*	***Indoor***	***Outdoor***
4" Diameter	8 tsp	11 tsp
8" Diameter	$^1/_2$ cup	1 cup
12" Diameter	1 $^1/_4$ cup	2 $^1/_4$ cup
14" Diameter	1 $^3/_4$ cup	3 cup

*For container gardens, mix evenly into the potting soil in spring.

Biochar is also an excellent soil amendment for sod production and to support turf health.

Table 4
Sod/Turf Typical Application Rates

Planned Vegetation	**Recommended Application Timeframe**	**Biochar Application Rate (per appl. event)**
Sod Establishment (1 lb. PAN/1,000 ft^2)	Apply at seeding; and as needed 4-8 weeks after seeding	**230 lb./1,000ft^2** or 5 ton/acre
Turf/Lawn Seasonal Topdress, Landscaping (0.75 lb. PAN/1,000 ft^2)	Spring and fall	**170lb./1,000ft^2** or 3.7 ton/acre
Build Organic Matter in Soil (1.0 lb. PAN/1,000 ft^2)	Early spring	**230 lb./1,000ft^2** or 5 ton/acre

(1) Application rates based on University of California Guidelines

Characteristics

The chemical and physical properties of ***Biochar*** are shown in Table 5. Note that they contain very low levels of trace elements.

Table 5
Typical Characteristics & Accepted Levels for Trace Elements

Parameter(1)	Accepted Concentration(2) (mg/kg)	EQ Biosolids Concentration(3) (mg/kg)
Metals/PCBs:		
Arsenic	41	21
Cadmium	39	6
Copper	1,500	600
Lead	300	35
Mercury	17	1
Molybdenum	75	36
Nickel	420	60
Selenium	100	10
Zinc	2,800	1,900
Other Parameters:		
pH	7.5	
Total Solids Content	99% (approx.)	

(1) All values expressed on dry weight basis
(2) USEPA limits for EQ biosolids
(3) Values estimated based on current Fresno Clovis Regional Wastewater Reclamation Facility biosolids data

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Appendix 3-B

MARKET ASSESSMENT CONTACT LIST

Fresno-Clovis Regional Wastewater Reclamation Facility

Market Assessment Contacts

Business Name	Subcategory	Address	City	State	Zip	Phone Number	Email Addres	Website	Contact Name	Title	Called? (Y/N)	Phone Interview (Y/N)?	Visited? (Y/N)	On-site Interview? (Y/N)
Abundant Harvest Organics	Agriculture	38694 Rd 16	Kingsburg	CA	93631	NP	vernon@abundantharvestorganics.com	https://www.abundantharvestorganics.com/	Vernon Peterson	Owner	Y	Y	N	N
Avellar Moore Farms	Agriculture	466 W Fallbrook Ave	Fresno	CA	93711	559-313-5588	NP	NA	Steve Moore	NP	Y	N	N	N
Barcellos Farms	Agriculture	14851 Rd. 168	Porterville	CA	93272	559-752-4360	tomb@barcellosfarms.com	NP	Tom Barcellos	Farming/Trucking/Excavating/Harvest	Y	Y	N	N
Booth Ranches	Agriculture	12201 Avenue 480	Orange Cove	CA	93646	559-626-4732 o	jplumlee@boothranchesllc.com	https://boothranches.com/	Jared Plumlee	Vice President of Farming Operations	Y	Y	N	N
Bowles Farm	Agriculture	11609 Hereford Rd	Los Banos	CA	93635	209-827-3000	derek@bfarm.com	https://bfarm.com/contact-bowles/	Derek Azevedo	Executive Vice President	Y	Y	N	N
Britz Farming Corporation	Agriculture	3265 W Figarden Dr	Fresno	CA	93711	559-448-8000	NP	NP	Jeremy Seibert	Farm Supervisor	Y	Y	N	N
California Dairies	Agriculture	755 F Street	Fresno	CA	93775-1865	(559) 233-5154	NA	https://www.californiadairies.com/	NP	NP	Y	N	N	N
Castle Farms	Agriculture	5935 N State Hwy 59	Merced	CA	95348	559-227-6400	NP	NP	Vince Kavanovich	NP	Y	Y	N	N
Cotton Growers and Ginners Association	Agriculture	1785 N Fine Ave	Fresno	CA	93727	559-252-0684	NP	https://ccgga.org/	Roger	NP	Y	N	N	N
Daybreak Organics	Agriculture	40200 Road 28	Kingsburg	CA	93631-8839	559-790-5151	Robert@YosemiteClean.com	NA	Robert Jackson	President	Y	Y	N	N
Englemann Cellars	Agriculture	3275 North Rolinda	Fresno	CA	93723	559-274-9463	NA	http://www.engelmanncellars.com/	NA	NA	Y	N	N	N
Errotabere Ranches	Agriculture	22895 S Dickenson Ave	Riverdale	CA	93656	559-867-4461	NP	NP	Dan Errotabere	Vice President	Y	N	N	N
Fresno County Farm Bureau	Agriculture	1274 W. Hedges Ave.	Fresno	CA	93728	559 237-0263	ryan@fcfb.org	http://www.fcfb.org/	Ryan Jacobson	CEO/ Executive Director	Y	Y	Y	Y
Fresno County Farm Service Agency	Agriculture	4625 W Jennifer Ave. Ste. 109	Fresno	CA	93722-6424	559-276-7494	NP	https://offices.sc.egov.usda.gov/	Russ Friend	County Executive Director	Y	N	N	N
GAR Tootelian	Agriculture	8246 S. Crawford Ave	Reedley	CA	93654	559-638-6311	gmusson@gtipros.com	https://gtipros.com/	Greg Musson	President and CEO	Y	Y	N	N
Harlan Ranch Company	Agriculture	9010 Tollhouse Road	Clovis	CA	93619	559-299-2354	NP	NP	Shawn Stevenson	Vice President	Y	N	N	N
Harris Farms	Agriculture	16277 S McCall Ave	Selma	CA	93662	559-884-2477	steveozuna@harrisfarms.com	NP	Steve Ozuna / David Bolderoff	Farm Manager	Y	N	N	N
Hester Orchards, Inc	Agriculture	26800 Road 164	Farmersville	CA	93223	559 594-5025	NA	http://hesterorchards.com/	Gary Hester	Owner	Y	Y	Y	N
HMC Farms	Agriculture	13138 S. Bethel Ave.	Kingsburg	CA	93631	559-897-1025	drewk@hmcfarms.com	http://www.hmcfarms.com/	Drew Ketelsen	Farm Manager	Y	N	N	N
Hudson Farms	Agriculture	4300 South Academy	Sanger	CA	93657	559-875-5962	hudsonfarms@aol.com	http://www.hudsonfarmssanger.com/	Linda Hudson	Owner	Y	Y	N	N
Kettleman Pistachio Growers	Agriculture	39005 25th Ave	Kettleman City	CA	93239	831-768-9972	NP	NP	Larry Easterling	Administrator	Y	N	N	N
Lindsey Farms	Agriculture	5378 East Avenue	Fresno	CA	93725	559-905-1724	mattfarmin@gmail.com	NA	Matt Lindsey	NP	Y	N	N	N
Maddox Farms	Agriculture	12863 W Kamm Ave # 1	Riverdale	CA	93656	559-866-5308 ext. 1	NP	NP	Steve Jr.	NP	Y	N	N	N
McKean Farms	Agriculture	9830 W Mt Whitney Ave	Riverdale	CA	93656	559-866-8600	NP	NP	Mark	NP	Y	N	N	N
Meyers Farms	Agriculture	901 N St #103	Firebaugh	CA	93622	559-659-3033	trevor-mfi@sbcglobal.net	NP	Trevor	NP	Y	N	N	N
Needham Ag Services	Agriculture	3921 East Mary Avenue	Visalia	CA	93292	559 977-7282	needhamagservices@gmail.com	https://needhamagservices.com/	Edward Needham	Previously worked at Synagro	Y	Y	N	N
NRCS-Fresno County	Agriculture	4625 W Jennifer Ave. Ste. 109	Fresno	CA	93722-6424	559-490-8024	NP	https://offices.sc.egov.usda.gov/	Jae Lee	District Conservationist	Y	N	N	N
Pacheco Dairy	Agriculture	23200-24614 Rd 180	Exeter	CA	93221	559-846-8058	NP	NP	Brian Pacheco	Owner	Y	Y	N	N
PR Farms	Agriculture	2917 E Shepherd Ave	Clovis	CA	93619	559-299-0201	pat@prfarms.com	http://www.prfarms.com/	Pat Ricchiuti	Owner	Y	N	N	N
Sun Valley Raisins	Agriculture	9503 S Hughes Ave	Fresno	CA	93706	559-647-6661	sunvalleyraisin@aol.com	NP	Ed Barios	NP	Y	Y	N	N
Terra Nova Ranch	Agriculture	16729 West Floral Avenue	Helm	CA	93627	559-269-1118	dcameron@terranovaranchinc.com	http://www.terranovaranch.com/	Don Cameron	Owner	Y	Y	N	N
Tulare County Farm Bureau	Agriculture	737 N. Ben Maddox Way	Visalia	CA	93292	559 732-8301	pstever@tulcofb.org	http://www.tulcofb.org/	Tricia Stever Blattler	CEO/ Executive Director	Y	Y	Y	Y
University of California - Fresno	Agriculture	550 E. Shaw Avenue	Fresno	CA	93710	559-241-7521	dsmunk@ucanr.edu	http://cefresno.ucanr.edu/	Daniel Munk	Farm Advisor	Y	Y	N	N
University of California - Fresno	Agriculture	550 E. Shaw Avenue	Fresno	CA	93710	559-241-7515	gzhuang@ucanr.edu	http://cefresno.ucanr.edu/	George Zhuang	Viticulture Farm Advisor	Y	Y	N	N
University of California - Fresno	Agriculture	550 E. Shaw Avenue	Fresno	CA	93710	559-241-7515	cmculumber@ucanr.edu	http://cefresno.ucanr.edu/	Mae Culumber	Nut Crops Farm Advisor	N	N	N	N
University of California - Fresno	Agriculture	550 E. Shaw Avenue	Fresno	CA	93710	559 241-7515	mkreiter@ucanr.edu	http://cefresno.ucanr.edu/	Maggie Reiter	Environmental Horticulture Advisor	Y	Y	N	N
University of California - Fresno	Agriculture	680 Campus Drive, Suite A	Hanford	CA	93230	559-852-2788	neclark@ucanr.edu	http://cefresno.ucanr.edu/	Nicholas Clark	Agronomic Cropping Systems and Nut	Y	Y	N	N
University of California - Fresno	Agriculture	550 E. Shaw Avenue	Fresno	CA	93710	559-375-3147	taturini@ucanr.edu	http://cefresno.ucanr.edu/	Thomas Turini	Vegetable Crops	Y	N	N	N
University of California - Kings/Tulare	Agriculture	680 Campus Drive	Hanford	CA	93230	559 684-3315	sdwright@ucanr.edu	https://ucanr.edu/	Steve Wright	Cotton, Small Grains, Weed Control (r	Y	N	N	N
University of California - Madera	Agriculture	550 E. Shaw Avenue, Ste. 210-B	Fresno	CA	93710	559 241-6564	rkozeran@ucanr.edu	http://cemadera.ucanr.edu/	Rebecca Ozeran	Livestock and Natural Resources Advi	N	N	Y	Y
University of California - Merced/Madera	Agriculture	2145 Wardrobe Avenue	Merced	CA	95341-6445	209 385-7403	csstoddard@ucanr.edu	http://cemadera.ucanr.edu/	Scott Stoddard	Farm Advisor Vegetable Crops and Sc	Y	N	N	N
Woolf Farming	Agriculture	18036 W Gale Ave	Huron	CA	93234	559-978-7588	dhartwig@woolffarming.com	http://woolffarming.com/	Daniel Hartwig	Resources Manager	Y	Y	N	N
Akeida Capital Merced Power	Biomass to Energy	30 W. Sandy Mush Road	El Nido	CA	95340	NA	NA	NA	NA	NA	N	N	N	N
Ampersand Chowchilla Biomass	Biomass to Energy	16457 Avenue 24	Chowchilla	CA	93610	559-665-0807	cfane@chownido.com	NA	Charlie Fane	Manager	Y	Y	N	N
Rio Bravo Fresno	Biomass to Energy	3350 South Willow Ave	Fresno	CA	93725	559-264-4575 ext. 1	rspurlock@rbfresno.com	http://www.calbiomass.org/	Rick Spurlock	Plant Manager	Y	Y	N	N
Hanson Permanente Cement	Cement Kiln	24001 Stevens Creek Blvd	Cupertino	CA	95014	858-715-5647	Kolsen@lehighcement.com	NA	Kelly Olson	Director of Purchasing - Region West	Y	N	N	N
New Era Farm Service	Fertilizer Distributor	2904 E. Oakdale Avenue	Tulare	CA	93274	559-686-3833	NA	https://newerafarmservice.com/	N/A	N/A	Y	N	Y	N
Soil Basics Corporation	Fertilizer Distributor	17014 Avenue 296	Visalia	CA	92292	559-651-2772	jim@soilbasics.com	http://soilbasics.com/	Jim	Soil Basics	Y	N	Y	N
Valley Gardening Supplies	Fertilizer Distributor	1501 West Main Street	Merced	CA	95340	209-580-4425	NA	https://www.valleygardeningsupplies.com/	NA	NA	N	N	N	N
Wilbur Ellis	Fertilizer Distributor	2737 S. Golden State Blvd.	Fresno	CA	93725	559-269-7342	NA	https://www.wilburellis.com/	Mike Cline	Sales Representative	Y	N	N	N
Airways Golf Club	Golf Course	5440 E Airways Blvd	Fresno	CA	93727	559-305-9582	Genaro@sierragolfmanagementinc.com	https://www.airways.golf/contactus/	Genaro Cuan	Superintendent	Y	Y	Y	N
Belmont Country Club	Golf Course	8253 East Belmont Avenue	Fresno	CA	93737	559-251-5078	NA	http://www.belmontcountryclub.net/	Derek Stone	Superintendent	Y	N	N	N
Copper River Country Club	Golf Course	2140 E. Clubhouse Drive	Fresno	CA	93730	559-434-5200	NA	https://www.copperrivercountryclub.com/	Not Provided	General Manager	Y	N	N	N
Dragonfly Golf Club	Golf Course	43369 Ave 12	Madera	CA	93636	559-432-3020	NA	https://dragonflygolfclub.com/	Not Provided	Personnel at Maintenance Shop	Y	N	N	N
Eagle Springs Golf & Country	Golf Course	21722 Fairway Oaks Ln	Friant	CA	93626	559-325-8900	mbest@eaglespringsgcc.com	http://www.eaglespringsgcc.com/	Mike Best	Superintendent	Y	N	Y	Y
Fig Garden Golf Club	Golf Course	7700 N Van Ness Blvd	Fresno	CA	93711	559-439-2928	NA	http://www.figgardengolf.com/	N/A	N/A	Y	N	Y	N
Madera Municipal Golf Course	Golf Course	23200 Avenue 17	Madera	CA	93637	559-675-3504	NA	https://www.maderamuni.com/	Not Provided	Personnel at Pro Shop	Y	N	N	N
Ridge Creek Dinuba Golf Club	Golf Course	3018 Ridge Creek Drive	Dinuba	CA	93618	559-288-1846 cell	NA	http://www.golfridgecreek.com/	Rob Lomeli	Superintendent	Y	N	N	N
River Park Golf Center	Golf Course	41445 Ave 9	Fresno	CA	93720	559-448-9467	NA	http://www.riverparkgolf.com/golf/	Not Provided	Not Provided	Y	N	N	N
Riverside Golf Course	Golf Course	7492 N Riverside Dr.	Fresno	CA	93722	559-275-5900	kwiles@playriverside.com	https://www.playriverside.com/	Kevin Wiles	Superintendent	Y	N	Y	Y
Sherwood Forest Golf Club	Golf Course	79 North Frankwood Avenue	Sanger	CA	93657	559-787-2611	NA	https://sherwood-forest-golf-club.business.site/	Not Provided	Not Provided	Y	N	N	N
Sierra Golf Management	Golf Course	P.O. Box 788	Chowchilla	CA	93610	209-559-5633	NA	https://www.sierragolfmanagement.com/	Jon Christiansen	Director of Agronomy	Y	N	N	N
Sunnyside's Country Club	Golf Course	5704 E Butler Ave	Fresno	CA	93727	559-665-4462	NA	http://sunnyside-cc.com/	Not Provided	Not Provided	Y	N	N	N
Bluff Pointe Golf Course and Learning Center	Golf Course	8225 N Milburn Ave	Fresno	CA	93722	559-275-0060	NA	http://www.bluffpointegolf.com/	Not Provided	Not Provided	Y	Y	N	N
California Soils	Landscape Supply	3401 Gaffery Road	Vernalis	CA	95385	201-835-9530	NA	https://californiasoils.com/	Connor Davis	Owner	Y	N	N	N
Ewing Irrigation & Landscape Supply	Landscape supply	7530 N Ingram Ave	Fresno	CA	93711	559-438-9530	NA	https://www.ewingirrigation.com/	N/A	N/A	N	N	Y	N
Ewing Irrigation & Landscape Supply	Landscape supply	1160 W 15th St	Merced	CA	95340	209-388-9530	NA		N/A	N/A	N	N	N	N
EZ Haul Ready Mix and Landscape Supply	Landscape Supply	1538 N Blackstone Ave	Fresno	CA	93703	559-233-6603	NP	http://www.e-zhaul.com/	Julio	Operations Manager	N	N	Y	Y
Green Valley Recycling	Landscape Supply	2365 E. North Avenue	Fresno	CA	93725	559-266-2650	NA	NA	Anjelica	Manager	Y	N	N	N
Harvest Power	Landscape Supply	24487 Road 140	Tulare	CA	93274	559-753-0063	jsears@harvestpower.com	http://www.harvestpower.com/	Jason Sears	Sales Manager	Y	Y	Y	Y
Horizon Distributors	Landscape Supply	3065 CA-59	Merced	CA	95348	209-383-3330	NA	http://www.horizononline.com	N/A	N/A	N	N	N	N

Fresno-Clovis Regional Wastewater Reclamation Facility

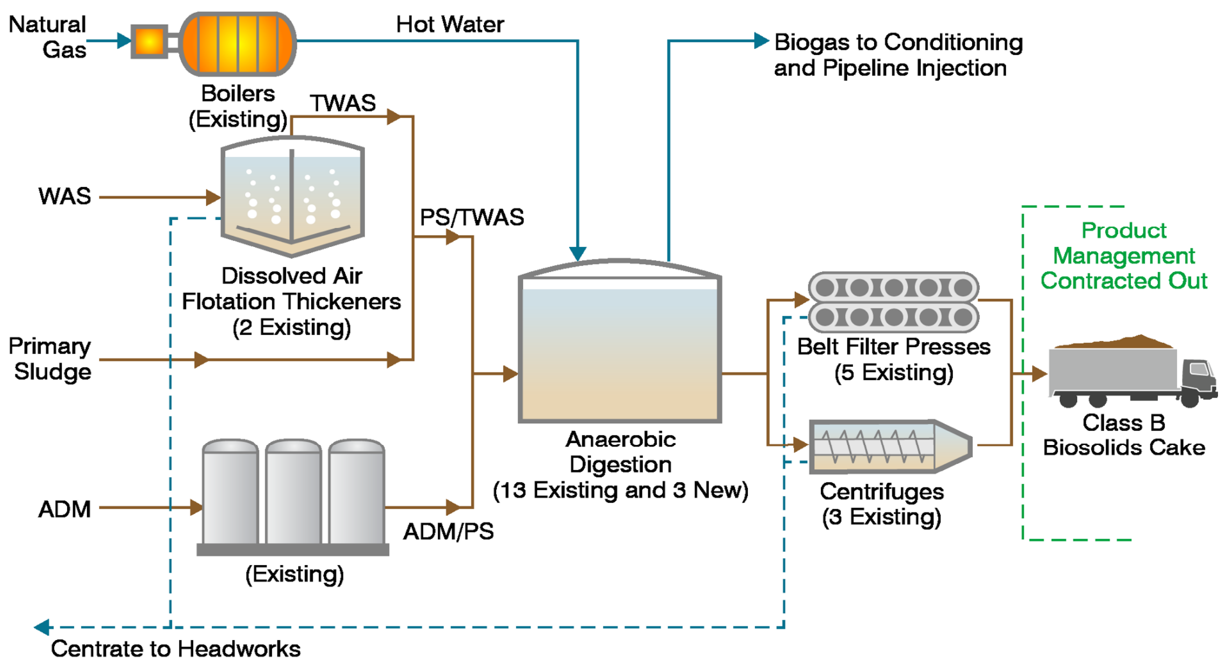
Market Assessment Contacts

Horizon Distributors	Landscape Supply	349 W Bedford Ave	Fresno	CA	93711	559-431-2714	NA	http://www.horizononline.com/	Not Provided	Not Provided	N	N	Y	Y
Lotus Gardens	Landscape supply	2271 N Grantland Ave	Fresno	CA	93723	559-255-3311	matt.lotusgardensfresno@gmail.com	http://www.lotusgardensfresno.com/	Matthew	Manager	N	N	Y	Y
Mid Valley Composting	Landscape Supply	15300 W Jensen Ave	Kerman	CA	93630	559-237-9425	NA	https://www.midvalleydisposal.com/	Martin	Composting Supervisor	Y	Y	N	N
Rosenbalm Rockery Inc	Landscape Supply	1745 N Hughes Ave	Fresno	CA	93705	559-256-3900	rick@therockery.com	http://therockery.com/	Rick Perez	Dispatcher	N	N	Y	Y
Sierra Materials	Landscape Supply	2857 Business Parkway	Merced	CA	95348	209-722-9713	NP	https://www.sierramaterials.com/	Danny Pelayo	Owner	N	N	Y	Y
SiteOne Landscape Supply	Landscape supply	293 Noble Ave	Farmersville	CA	93223-2501	559-635-7833	NA	https://www.siteone.com/	Not Provided	Not Provided	Y	Y	N	N
SiteOne Landscape Supply	Landscape supply	2380 N Larkin Ave	Fresno	CA	93727-8645	559-292-5302	NA	https://www.siteone.com/	Not Provided	Not Provided	Y	Y	N	N
SiteOne Landscape Supply	Landscape Supply	5530 W Spruce Ave	Fresno	CA	93722	559-227-1630	NA	https://www.siteone.com/	Tony	Employee	N	N	Y	N
Stoney's Sand and Gravel	Landscape Supply	9181 CA-41	Lemoore	CA	93245	559-924-9229	david@stoneysllc.com	https://stoneysllc.com/	David	NA	Y	N	N	N
Superior Soils	Landscape Supply	10367 Houston Ave	Hanford	CA	93230	559-904-3372	asike@superiorsoil.com	NA	Andrea Sike	Salesman	Y	N	N	N
Valley Soil and Forest Products	Landscape Supply	21415 E Manning Ave.	Reedley	CA	93654	559-638-4589	NA	http://www.valleysoilandforestproducts.com/	NA	NA	Y	N	N	N
West Coast Sand and Gravel	Landscape Supply	7715 Avenue 296	Visalia	CA	93921	800-734-3053	NA	http://www.wcsg.com/	Kevin Hofsey	Operations Manager	Y	Y	N	N
West Coast Waste	Landscape Supply	3077 S. Golden State Frontage Rd	Fresno	CA	93725	559-497-5320	NP	https://westcoastwaste.info/	Dennis Balakian	Owner	N	N	Y	Y
All Commercial Landscape Services	Landscaping	5213 E Pine Ave	Fresno	CA	93727	559-453-1670	NA	https://www.acls.bz/	N/A	N/A	Y	N	N	N
Anderson Landscaping	Landscaping	2855 N Sunnyside Ave	Fresno	CA	93727	559-500-3308 ext.	NA	https://www.andersonlandscapebydesign.com/	N/A	N/A	Y	N	N	N
Calscape Landscaping Inc.	Landscaping	285 W Shaw Ave	Fresno	CA	93704	559-264-7301	NA	https://porch.com/fresno-ca/landscapers/	NA	N/A	Y	N	N	N
Fornaro's Landscape and Custom Design Inc	Landscaping	3563 W Holland	Fresno	CA	93722	559-431-3225	NA	http://www.fornaroslandscape.com/	N/A	N/A	Y	N	N	N
Lidyoff Landscape Development Co.	Landscaping	4460 W Shaw Avenue, #112	Fresno	CA	93722	559-276-1090	NA	http://www.lidyofflandscape.com/	N/A	N/A	Y	N	N	N
Picture Perfect Lawn	Landscaping	547 W Gettysburg Ave	Fresno	CA	93705	559-974-1703	NA	https://fresnolandscapes.net/	N/A	N/A	Y	N	N	N
The Landscaping Masters Inc.	Landscaping	4985 E Dakota Ave	Fresno	CA	93727	559-899-9053	NA	http://www.thelandscapingmasters.com/	N/A	N/A	Y	N	N	N
Yard Masters Inc.	Landscaping	1968 Business Pkwy	Merced	CA	95348	209-722-3056	NP	https://www.yardmastersworld.com/	Not Provided	Not Provided	Y	Y	N	N
Belmont Nursery	Nursery	7730 E Belmont Ave	Fresno	CA	93737	559-255-6645	NA	http://belmontnursery.com/	Danielle	Personnel at Front Desk	Y	N	N	N
Burchell Nursery	Nursery	6705 S. Clovis Avenue	Fowler	CA	93625	831-293-4698	NP	http://www.burchellnursery.com/	Mauricio De Amid	Greenhouse Manager	Y	N	Y	Y
Champagne Landscape Nursery	Nursery	3233 N Cornelia Ave	Fresno	CA	93722	559-277-8188	NP	https://champagnelandscapenursery.com/	Stephany	Accounts Recievable	Y	Y	N	N
Evergreen Garden Center	Nursery	210 W Alluvial Ave	Fresno	CA	93611	559-299-3107	NP	NP	Leonard Ichimoto	Retail/Wholesale Staff	Y	Y	N	N
Fonseca's Nursery	Nursery	8924 E Lacey Blvd	Hanford	CA	93230	559-804-7681	NP	NA	Fred Fonseca	Owner	Y	Y	N	N
Gazebo Gardens Inc.	Nursery	3204 N Van Ness Blvd	Fresno	CA	93704	559-222-7673	NA	http://www.gazebogardens1922.com/	Not Provided	N/A	Y	N	N	N
Green Hills Nursery	Nursery	2408 N Armstrong Ave	Fresno	CA	93727	559-291-8733	NA	http://greenhillsnursery.com/	Rigo Hernandex	Owner	Y	N	Y	Y
Intermountain Nursery	Nursery	30443 N. Auberry Rd.	Prather	CA	93651	559-855-3113	Bonnie@IntermountainNursery.com	http://www.intermountainnursery.com/	Raymond Laclergue	Owner	Y	Y	Y	Y
Leo's Nursery	Nursery	31804 Rd 124	Visalia	CA	93291	559-741-0178	NP	NP	Leo Jr.	NP	Y	Y	N	N
Luis' Nursery	Nursery	139 S Mariposa Ave	Visalia	CA	93292	559-747-5015	NA	http://luisnursery.com/	Not Provided	Not Provided	Y	N	N	N
Mazzei Nursery & Seed	Nursery	308 E. Jensen	Fresno	CA	93706	559-233-8952	NA	https://www.tslseed.com/	Gary Colburn	Not Provided	Y	Y	N	N
McCall's Nursery	Nursery	8151 East Olive Ave	Fresno	CA	93737	559-255-7679	NA	http://mccallsnurseries.com/	Brian	Not Provided	Y	N	N	N
Merced Gardens and Nursery	Nursery	1007 Tahoe St	Merced	CA	95348	209-384-0513	NA	http://mercedgardens.com/	N/A	N/A	N	N	N	N
Mezquite Nursery	Nursery	8606 Avenue 280	Visalia	CA	93277	559-651-1838	NA	http://mezquitenurseryinc.com/	Not Provided	Not Provided	Y	N	Y	N
Mid Valley Trees	Nursery	32595 Road 132	Visalia	CA	93292	559-734-4641	NA	http://midvalleytrees.com/	Not Provided	Not Provided	Y	N	N	N
Monrovia Nursery Company	Nursery	32643 Rd 196	Woodlake	CA	93286	559 564-1207 ext.	NA	https://www.monrovia.com/	N/A	Not Provided	Y	N	N	N
Sago Rey Palm Plantation	Nursery	6706 East Central Avenue	Fresno	CA	93725	559-268-6650	NA	http://sagorey.com/contact-sago-rey	Not Provided	Not Provided	Y	Y	N	N
Sierra View Nursery	Nursery	6222 N Academy Ae	Clovis	CA	93619	559-325-2929	NA	https://www.sierraviewnurseryinc.org/	Not Provided	Not Provided	Y	N	N	N
Takao Nursery	Nursery	2665 N Polk Ave	Fresno	CA	93722	559-275-7627	NA	https://takaonursery.com/		Not Provided	Y	Y	N	N
Westside Transplant	Nursery	45019 West Nees Avenue	Firebaugh	CA	93622	559-924-1506	NA	https://westsidetransplant.com/	Not Provided	Not Provided	Y	N	N	N
Willow Gardens Nursery	Nursery	10428 N. Willow Ave	Clovis	CA	93619	559-299-5402	NA	https://www.willowgardensclovis.com/	Abel Salias	General Manager	Y	N	Y	N
A-G Sod Farms Inc	Sod Farm	15390 S Fowler Ave	Selma	CA	93662	559-289-6381	alemay@agsod.com	https://www.agsod.com/	Alex Lemay	Sales Representative	Y	N	Y	N
Fox Farms	Soil Blender	2200 Bendixsen Street	Samoa	CA	95564	707-443-4369	foxfarm@foxfarmfertilizer.com	https://foxfarmfertilizer.com/	Genevieve	Not Provided	Y	N	N	N
Humboldt Nutrients	Soil Blender	6 Fifth Street	Eureka	CA	95501	888-420-7770	NA	http://www.humboldtnutrients.com/	N/A	N/A	Y	N	N	N
Sunland Soils / Berger	Soil Blender	90 Pioneer Rd	Watsonville	CA	95076	831-724-6500	martinr@berger.ca	https://www.berger.ca/	Martin Reyes	Soil Manager	Y	Y	N	N

Appendix 4-A

MASS AND ENERGY BALANCE

Baseline: Mesophilic Anaerobic Digestion (MAD)



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Class B Cake
Flow	**gal/d**	565,000	338,000	49,000	951,000	951,000	95,000
Flow	**wet ton/yr**						145,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	173,000	167,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	2.2%	21.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	107,000	104,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	62.0%	62.0%
Natural gas use	**therm/hr**				125		

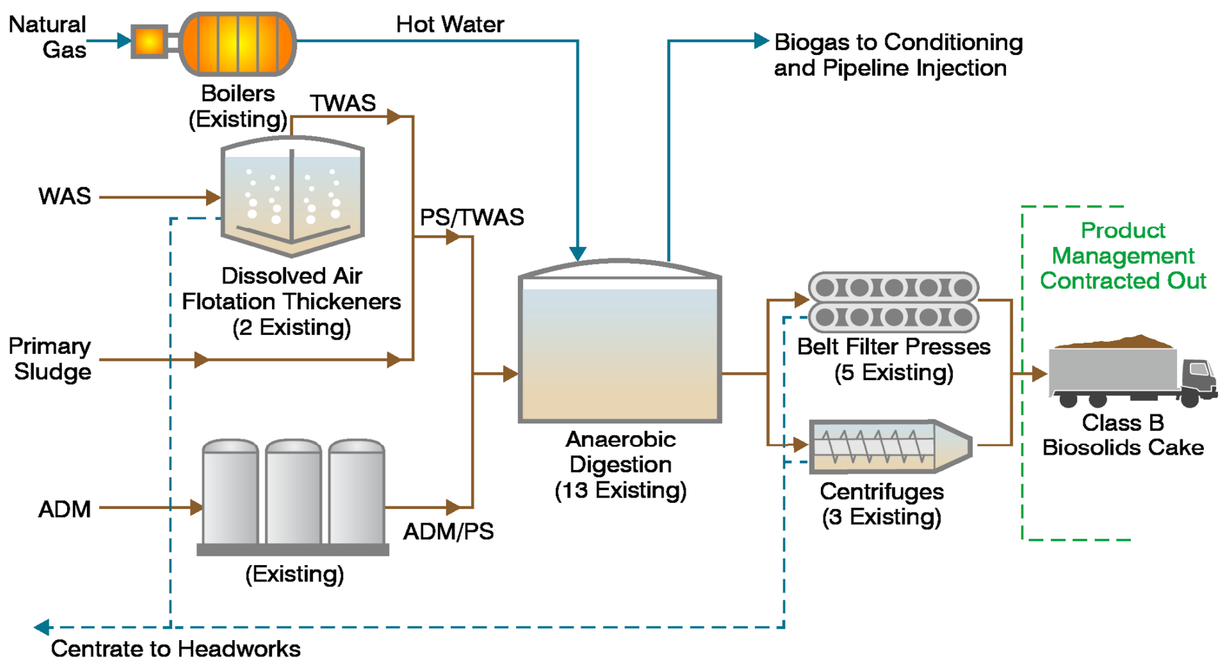
Key Assumptions and Performance Parameters

1. Three additional large digesters needed to meet 15 day SRT at 95% peak flow, with digester 1 or 2 as storage, and 1 large digester out of service.

2. Assume VSR of 62.8% based on historical average.

3. Assume biogas upgrading. Digester heating boilers fueled with natural gas.

Baseline: MAD with Process Optimization (Higher %TS)



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Class B Cake
Flow	**gal/d**	516,000	248,000	49,000	812,000	812,000	95,000
Flow	**wet ton/yr**						145,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	173,000	167,000
TS Content	**%TS**	4.6%	6.0%	7.7%	5.2%	2.5%	21.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	107,000	104,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	62.0%	62.0%
Natural gas use	**therm/hr**				107		

Key Assumptions and Performance Parameters

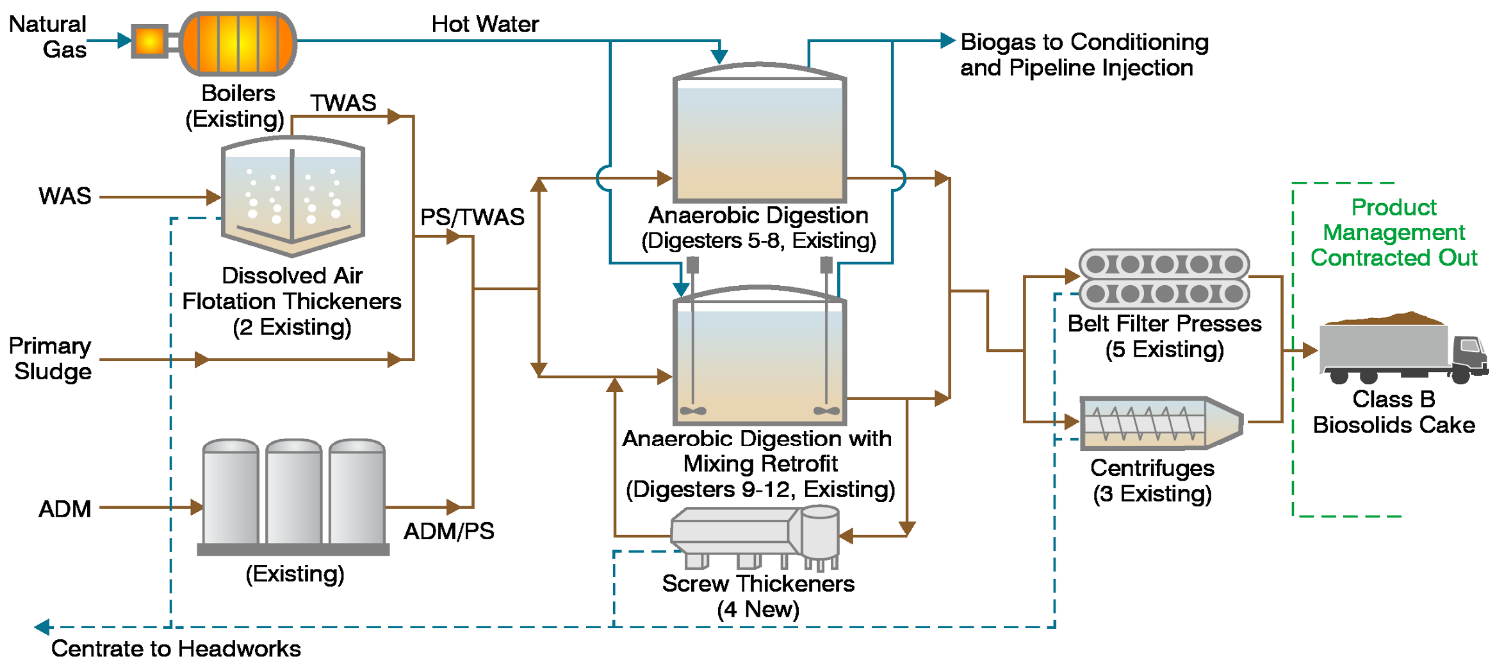
1. Assume TWAS thickness increased to 6% TS and primary sludge thickness increased to 4.6% TS through process optimization.

2. Thicker sludge may require new sludge pumps. Costs for pump replacement included in life-cycle cost analysis.

3. Assume VSR of 62.8% based on historical average.

4. Assume biogas upgrading. Digester heating boilers fueled with natural gas.

Baseline: MAD with Recuperative Thickening



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	MADs 5-8 In	MADs 9-12 In	MADs 5-8 Out	MADs 9-12 Out	Dewatering Feed	Class B Cake
Flow	**gal/d**	565,000	338,000	49,000	951,000	200,000	752,000	200,000	327,000	526,000	95,000
Flow	**wet ton/yr**										145,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	74,000	279,000	36,000	136,000	173,000	167,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	4.5%	4.5%	2.2%	5.0%	3.9%	21.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	60,000	227,000	22,000	85,000	107,000	104,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	81.5%	81.5%	62.0%	62.0%	62.0%	62.0%
Natural gas use	**therm/hr**				125	26	99				

Key Assumptions and Performance Parameters

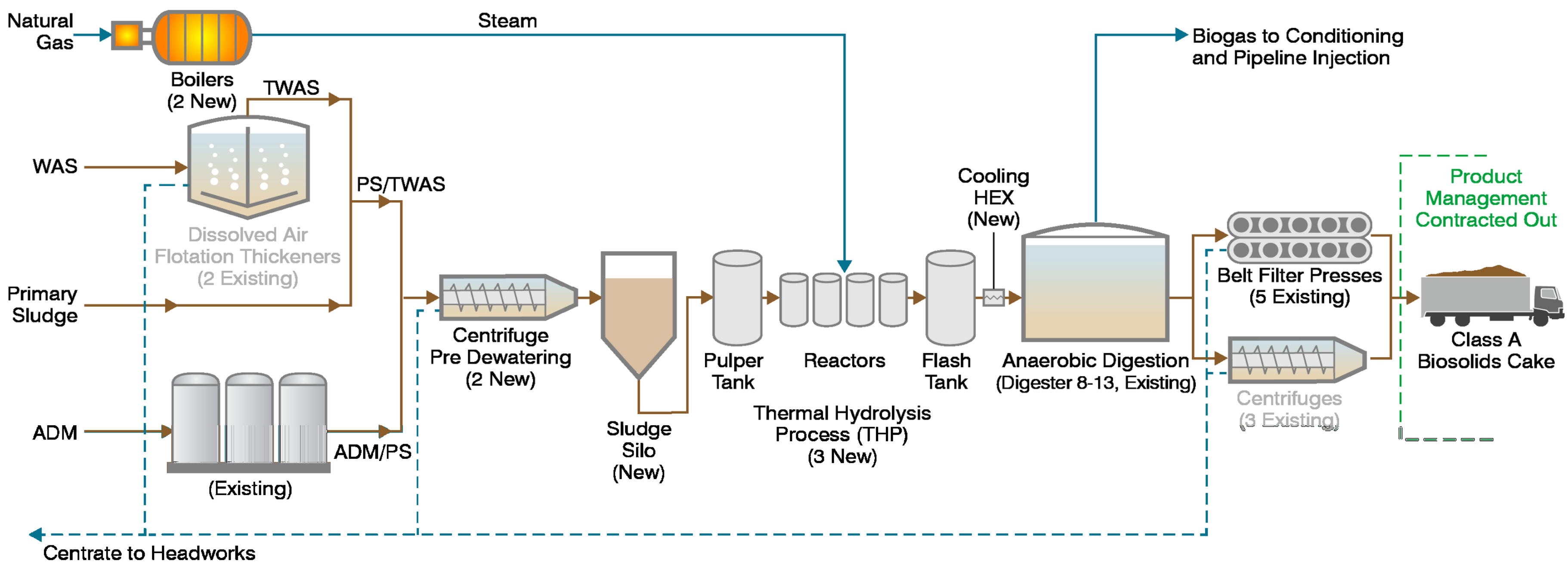
1. Assume set of digesters 9-12 are retrofitted with recuperative thickening. This retrofit approximately doubles their capacity.

2. Four of the existing digesters can be taken out of service to reduce O&M costs. Only need either digesters 5-8, or digesters 6-8 + 13.

3. Assume VSR of 62.8% based on historical average.

4. Assume biogas upgrading. Digester heating boilers fueled with natural gas.

Pre-Digestion Thermal Hydrolysis



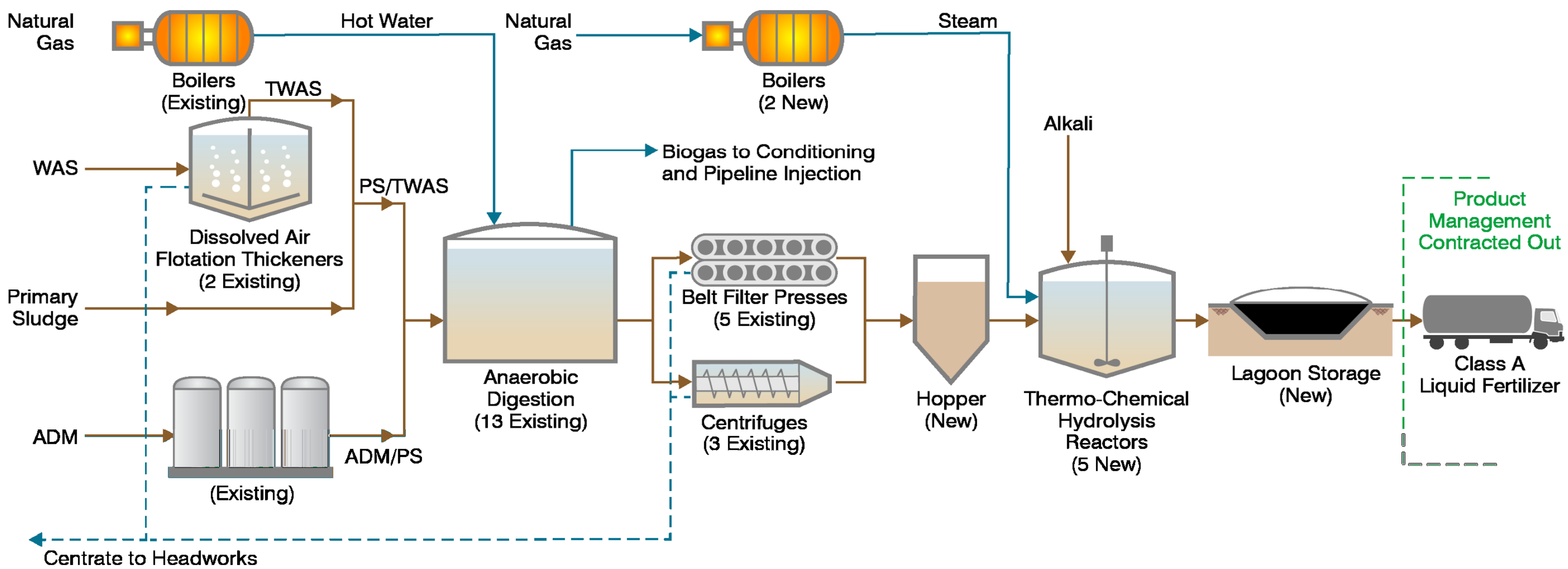
Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	Pre-dewatering Feed	Cambi THP Feed	MAD Feed	Dewatering Feed	Class B Cake
Flow	**gal/d**	565,000	338,000	49,000	951,000	257,000	423,000	423,000	60,000
Flow	**wet ton/yr**								92,000
Total Solids	**lb/d**	198,000	124,000	31,000	353,000	353,000	353,000	166,000	161,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	16.5%	10.0%	4.7%	32.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	288,000	288,000	101,000	98,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	81.5%	81.5%	60.6%	60.6%
Natural gas use	**therm/hr**					235			

Key Assumptions and Performance Parameters

1. *Assume all primary sludge, TWAS, and ADM go through thermal hydrolysis.*
2. *Six of the existing digesters can be taken out of service to reduce O&M costs. Only need digesters 8-13.*
3. *DAFT can be decomissioned to reduce O&M costs.*
4. *Assume higher VSR of 65% with thermal hydrolysis (Baseline = 62.8%).*
5. *Assume biogas upgrading. Steam from new natural gas boilers.*

Post-Digestion Thermo-Chemical Hydrolysis - Onsite



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Reactor Feed	Class A Liquid Fertilizer
Flow	**gal/d**	565,000	338,000	49,000	951,000	951,000	100,000	140,000
Flow	**wet ton/yr**							213,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	181,000	175,000	175,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	2.3%	21.0%	15.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	115,000	111,000	111,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	63.7%	63.7%	63.7%
Natural gas use	**therm/hr**				125		64	

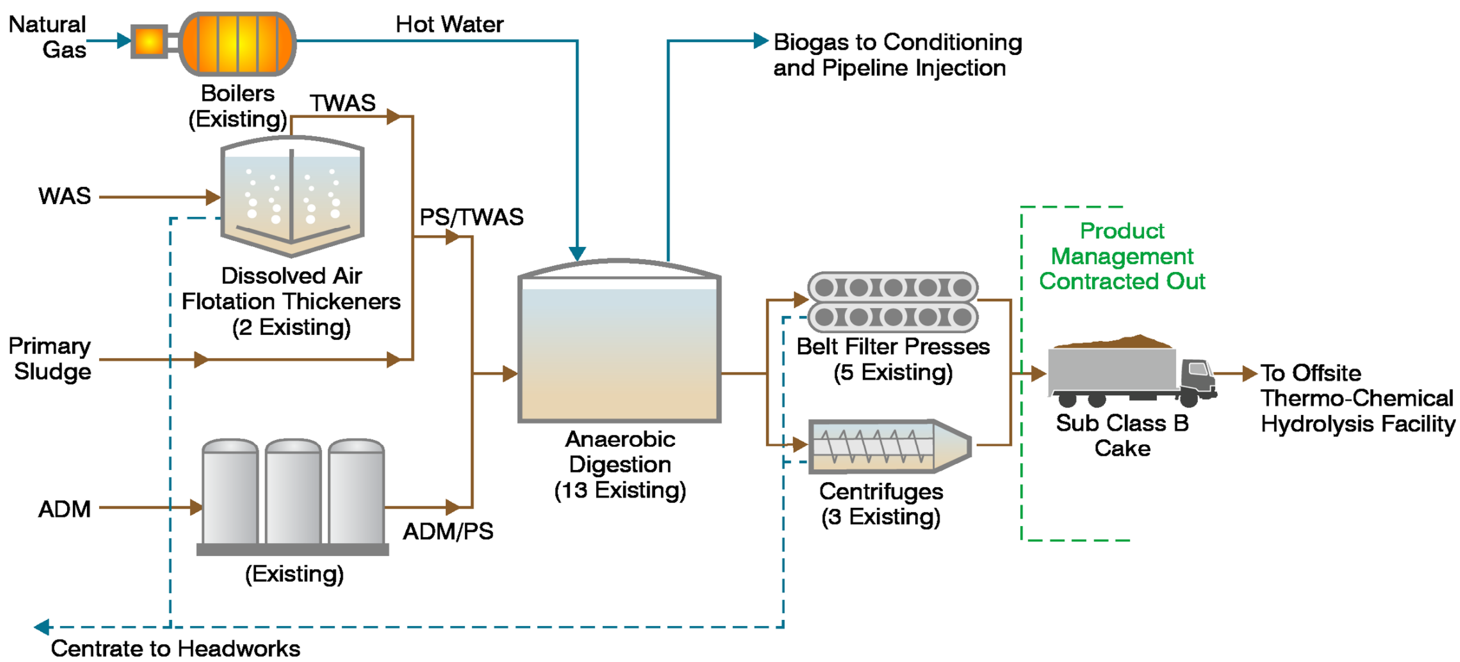
Key Assumptions and Performance Parameters

1. MAD does not need to meet SRT of 15 days because downstream process (Lystek) meets 40 CFR Part 503 pathogen reduction requirement.

2. Assume lower VSR of 60% with shorter SRT (Baseline = 62.8%).

3. Assume biogas upgrading. Steam from new natural gas boilers.

Post-Digestion Thermo-Chemical Hydrolysis - Offsite



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Dewatered Cake
Flow	**gal/d**	565,000	338,000	49,000	951,000	951,000	100,000
Flow	**wet ton/yr**						152,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	181,000	175,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	2.3%	21.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	115,000	111,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	63.7%	63.7%
Natural gas use	**therm/hr**				125		

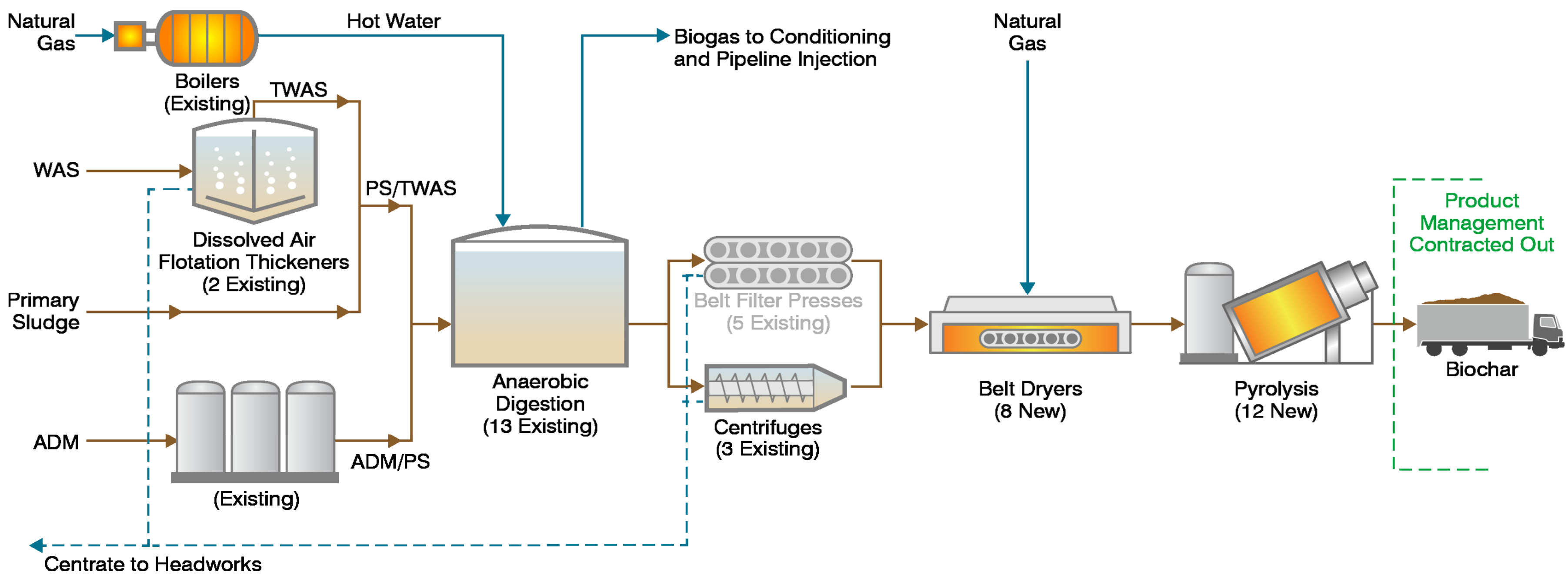
Key Assumptions and Performance Parameters

1. MAD does not need to meet SRT of 15 days because downstream process (Lystek) meets 40 CFR Part 503 pathogen reduction requirement.

2. Assume lower VSR of 60% with shorter SRT (Baseline = 62.8%).

3. Assume biogas upgrading. Digester heating boilers fueled with natural gas.

Thermal Drying and Pyrolysis



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Dryer Feed	Pyrolyzer Feed	Biochar
Flow	**gal/d**	565,000	338,000	49,000	951,000	951,000	87,000	26,000	
Flow	**wet ton/yr**						132,000	39,900	16,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	181,000	175,000	175,000	88,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	2.3%	24.1%	80.0%	99.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	115,000	111,000	111,000	
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	63.7%	63.7%	63.7%	
Natural gas use	**therm/hr**				125		151		

Key Assumptions and Performance Parameters

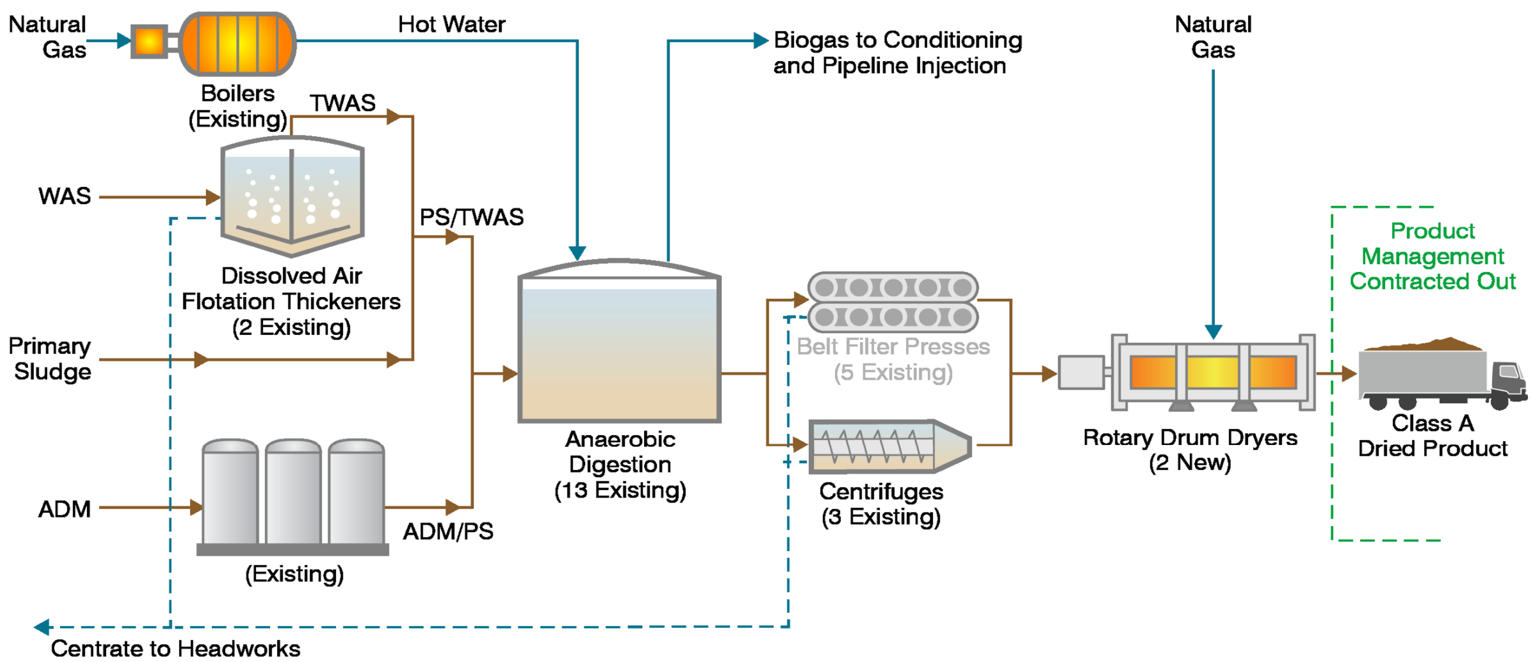
1. MAD does not need to meet SRT of 15 days because downstream process (drying) meets 40 CFR Part 503 pathogen reduction requirement.

2. Assume lower VSR of 60% with shorter SRT (Baseline = 62.8%).

3. Assume all digested sludge processed through centrifuges to achieve higher %TS dryer feed.

4. Assume biogas upgrading. Digester heating boilers and dryers fueled with natural gas.

Thermal Drying



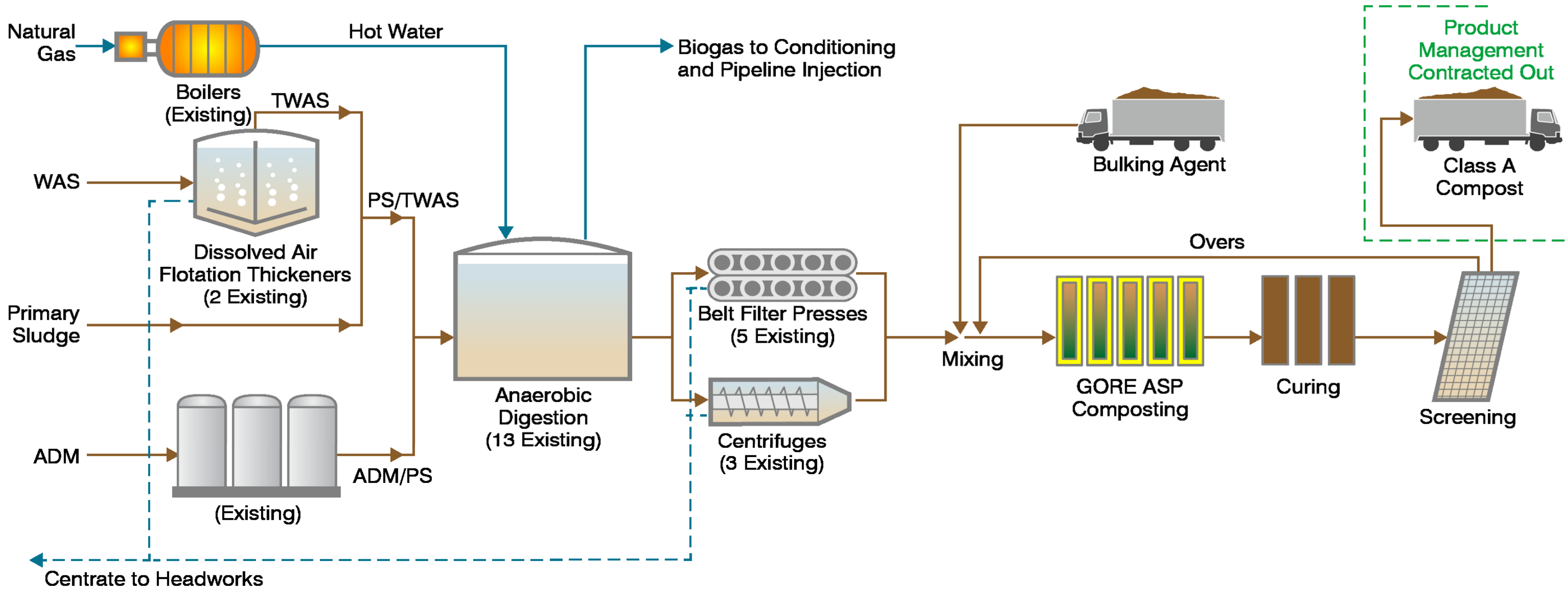
Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Dryer Feed	Dried product
Flow	**gal/d**	565,000	338,000	49,000	951,000	951,000	87,000	22,000
Flow	**wet ton/yr**						132,000	33,600
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	181,000	175,000	175,000
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	2.3%	24.1%	95.0%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	115,000	111,000	111,000
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	63.7%	63.7%	63.7%
Natural gas use	**therm/hr**				125		301	

Key Assumptions and Performance Parameters

1. *MAD does not need to meet SRT of 15 days because downstream process (drying) meets 40 CFR Part 503 pathogen reduction requirement.*
2. *Assume lower VSR of 60% with shorter SRT (Baseline = 62.8%).*
3. *Assume all digested sludge processed through centrifuges to achieve higher %TS dryer feed.*
4. *Assume biogas upgrading. Digester heating boilers and dryers fueled with natural gas.*

Covered Aerated Static Pile (ASP) Composting



Mass and Energy Balance

Parameter	Units	Primary Sludge	TWAS	ADM	MAD Feed	Dewatering Feed	Class B Cake	Bulking Agent	Compost
Flow	**gal/d**	565,000	338,000	49,000	951,000	951,000	100,000		
Flow	**wet ton/yr**						152,000	106,000	84,000
Volume	**cy/yr**						183,000	426,000	304,000
Total Solids	**dry lb/d**	198,000	124,000	31,000	353,000	181,000	175,000		
TS Content	**%TS**	4.2%	4.4%	7.7%	4.5%	2.3%	21.0%		>60%
Volatile Solids	**lb/d**	160,000	99,000	29,000	288,000	115,000	111,000		
VS Content	**%VS**	81.0%	79.5%	92.2%	81.5%	63.7%	63.7%		
Natural gas use	**therm/hr**				125				

Key Assumptions and Performance Parameters

1. MAD does not need to meet SRT of 15 days because downstream process (compost) meets 40 CFR Part 503 pathogen reduction requirement.

2. Assume lower VSR of 60% with shorter SRT (Baseline = 62.8%).

3. Assume pre-ground woody material used as bulking agent; 1 wet ton needed for 1 wet ton of cake; 30% recycling of screened overs.

4. Assume biogas upgrading. Digester heating boilers fueled with natural gas.

Appendix 4-B

PAIRWISE RANKING PROCESS

Pairwise Analysis - Process

Relative Values ("A" is on the Row, and "B" is in the Column)*:	**A Score**	**B Score**
If "A" is **MUCH MORE (STRONG) IMPORTANT** than "B"	5	1/5
If "A" is **MORE (MODERATE) IMPORTANT** than "B"	3	1/3
If "A" is of **EQUAL IMPORTANCE** as "B"	1	1
If "A" is **LESS (MODERATE) IMPORTANT** than "B"	1/3	3
If "A" is **MUCH LESS (WEAK) IMPORTANT** than "B"	1/5	5
Intermediates of the above values:	2, 4 1/2, 1/4	1/2, 1/4 2, 4

*If "A" is assigned a score of 1 through 5 when compared to "B", then "B" has the reciprocal value when compared to "A" and vice-versa.

Pairwise Analysis - Example

RANKING OF CRITERIA AGAINST EACH OTHER

	CRITERIA RANKING	*RELIABILITY*	*PROJECT DURATION*	*COST*	*STAKEHOLDER ACCEPTANCE*	SCORE	Relative Weights
1	*RELIABILITY*	1	5.00	3.00	1.00	10.00	0.40
2	*PROJECT DURATION*	0.20	1	5.00	2.00	8.20	0.33
3	*COST*	0.33	0.20	1	2.00	3.53	0.14
4	*STAKEHOLDER ACCEPTANCE*	1.00	0.50	0.50	1	3.00	0.12

In the above example, Reliability is valued as **MUCH MORE IMPORTANT** than Project Duration, so Reliability gets a "5". That implies Project Duration is **MUCH LESS IMPORTANT** than Reliability, so it gets a "1/5" when compared to Reliability. Likewise, Reliability is ranked **MORE IMPORTANT** than Cost, so Reliability gets a "3", and therefore Cost is **LESS IMPORTANT** than Reliability, so it gets a "1/3". Finally, Reliability is valued **ABOUT THE SAME IMPORTANCE** as Stakeholder Acceptance, so they both get a "1".

The cells below the diagonal are **AUTOMATICALLY** determined.

Appendix 4-C

NON-FINANCIAL EVALUATION DETAILED SCORING

Evaluation Criteria	Description		Baseline: Mesophilic Anaerobic Digestion (MAD)	Baseline: MAD with Process Optimization (Higher %TS)	Baseline: MAD with Recuperative Thickening	Pre-Digestion Thermal Hydrolysis	Post-Digestion Thermo-Chemical Hydrolysis - Onsite	Post-Digestion Thermo-Chemical Hydrolysis - Offsite	Thermal Drying & Pyrolysis	Thermal Drying	Covered Aerated Static Pile (ASP) Compost
Technical											
Established Technology/ Reliability	How many installations does the technology have in the US and Canada, and worldwide? How many years of proven reliable operation?	Score	5	5	2	4	3	3	2	5	5
		Justification	Hundreds of installations with thousands of successful operating hours. Mesophilic anaerobic digestion is one of the most common processes used for sludge stabilization at large WWTPs.	Hundreds of installations with thousands of successful operating hours. Mesophilic anaerobic digestion is one of the most common processes used for sludge stabilization at large WWTPs.	3 full Omnivore installations worldwide + 2 in construction, of which 3 are in the US (1 in Singapore, and 1 in Italy). First worldwide installation in in Victor Valley, CA in 2014; 5 years of proven reliable operation. Each component has been installed separately in many other sites (mixers: 1600 sites; recuperative thickeners: 100s of sites)	30+ Cambi installations worldwide, of which ~3 are in the US + ~3 in construction. First installation started operating in 1995; 24 years of proven reliable operations. Additional Biothelys and Excelys installations.	10 installations worldwide (US and Canada); of which 2 are in the US (St. Cloud, MN 2018 and Fairfield, CA 2016). First installation started operating in 2008; 11 years of proven reliable operations. Succesful operations with minimal issues.	10 installations worldwide (US and Canada); of which 2 are in the US (St. Cloud, MN 2018 and Fairfield, CA 2016). First installation started operating in 2008; 11 years of proven reliable operations. Succesful operations with minimal issues.	Level of success of sludge pyrolysis facilities has been mixed, with several pyrolysis companies going out of business and/or discontinuing supply of pyrolysis technology. Bioforcetech has had successful operations at their 1 installation in the US (Silicon Valley 2017), and over 20 installations in Europe. First installation started operation in 2011; 8 years of proven reliable operations.	Thermal drying is a well-established process for sludge stabilization in the US and worldwide. The rotary drum dryer technology has more than 40 installations in the US. First installation started operating in 1926; 93 years of proven reliable operations.	Composting is a well-established process for sludge stabilization in the US and worldwide. GORE, in particular, has 300 installations worldwide, of which 30 are in North America, and 4 in California. First installation in Germany 1998, first US installation in US 2002; 21 years of proven reliable operations.
Simplicity/ Ease of O&M	Is staff already familiar with the process or will it require substantial staff training? Will the alternative require hiring specialized staff? Will the labor hours required to operate and maintain the system increase significantly? Is additional monitoring required for regulatory compliance? Can maintenance be performed by staff or will it require maintenance to be contracted out? Will the alternative require a third party operator? Is the technology serviceable within the US or does it require parts from outside the US? Is additional monitoring required for regulatory compliance? Will a third party manage/market the product?	Score	5	5	4	2	3	5	2	3	3
		Justification	Training: staff already familiar with the process; no training required. Specialized staff: not required. Labor hours: increase slightly to operate and maintain 3 additional digesters (additional 1.5 hrs/d estimated) Process monitoring: same as current. Maintenance: same as current; majority performed by plant staff, some maintenance contracted out. Operations: performed by plant staff; third party operator not required. Service: technology and equipment are all serviceable within the US. Compliance monitoring: same as current; digester time and temperature and VSR. Produce management: as currently done, a third party (Synagro and Holloway) are assumed to continue managing the product.	Training: staff already familiar with the process; no training required. Specialized staff: not required. Labor hours: no increase. Process monitoring: same as current. Maintenance: same as current; majority performed by plant staff, some maintenance contracted out. Operations: performed by plant staff; third party operator not required. Service: technology and equipment are all serviceable within the US. Compliance monitoring: same as current; digester time and temperature and VSR. Product management: as currently done, a third party (Synagro and Holloway) are assumed to continue managing the product.	Training: new screw thickener, mixers, and recuperative thickening digester operations. Specialized staff: not required Labor hours: increase slightly to operate and maintain thickeners (additional 3 hrs/d estimated) Process monitoring: thickener performance, digester HRT and SRT, closer monitoring of digester stability parameters like pH, VA/Alk ratio on Omnivore digesters. Maintenance: majority performed by plant staff; some mixer and screw thickener maintenance may be contracted out. Operations: performed by plant staff; third party operator not required. Technology and equipment are all serviceable within the US. Compliance monitoring: slightly more complex tracking of digester SRT Product management: As currently done, a third party (Synagro and Holloway) are assumed to continue managing the product.	Training: new pre-dewatering centrifuges, THP system, steam boilers, modified digester and dewatering operations. Specialized staff: operations of steam above 15 psi may require special certification. Labor hours: increase slightly to operate and maintain pre-dewatering, THP system, steam boilers (additional 6 hrs/d estimated). In addition to that, 2 facility engineers, 24/7, which equates to 8.4 FTE may be required for >15 psi steam operations. Process monitoring: pre-dewatering performance, THP system, steam boilers, closer monitoring of digester stability parameters. Maintenance: majority performed by plant staff, some centrifuge, THP and steam boiler maintenance may be contracted out. Operations: performed by plant staff; third party operator not needed. Service: technology and equipment are all serviceable within the US. Compliance monitoring: as currently done, monitor time and temperature to meet Class A. Product management: as currently done, a third party (Synagro and Holloway) are assumed to continue managing the product. Option to identify new haulers for local use of product with robust marketing campaign.	Training: new thermo-chemical hyrolysis reactor and chem feed system. Specialized staff: not required. Labor hours: increase slightly to operate and maintain thermo-chemical hydrolysis reactor (additional 3 hrs/d estimated). Process monitoring: closer monitoring of digester stability parameters, thermo-chemical hydrolysis performance. Maintenance: majority performed by plant staff, some centrifuge, THP and steam boiler maintenance may be contracted out. Operations: performed by plant staff; third party operator not needed. May require additional safety protocols for chemical (caustic) handling. Service: technology and equipment are all serviceable within the US. Compliance monitoring: monitor time, temperature and pH in thermo-chemical reactor to meet Class A. Product management: Lystek typically manages the product hauling and land application.	Training: staff already familiar with the process; no training required. Specialized staff: not required. Labor hours: no increase. Process monitoring: same as current. Maintenance: same as current; majority performed by plant staff, some maintenance contracted out. Operations: performed by plant staff; third party operator not required. Service: technology and equipment are all serviceable within the US. Compliance monitoring: same as current; digester time and temperature and VSR. Product management: as currently done--third party hauls away cake; likely different hauler arranged by Lystek.	Training: new thermal drying, pyrolyzers, and associated emissions control system. Specialized staff: not required. Labor hours: increase slightly to operate and maintain thermal dryers and pyrolyzers (additional 24 hrs/d estimated). Process monitoring: closer monitoring of digester stability parameters, thermal dryers, pyrolyzers and emissions control equipment performance. Maintenance: majority performed by plant staff, some dryer and pyrolyzer maintenance contracted out. Operations: performed by plant staff; third party operator not needed. Service: some equipment and replacement parts may need to be shipped from Europe by Bioforcetech. Compliance monitoring: monitor dried product %TS, metal content. Product management: options to continue contract with current haulers, identify new haulers for local use of product, or partner with Bioforcetech to manage product and share percentage of product sales.	Training: new thermal drying and associated emissions control system. Specialized staff: not required. Labor hours: increase substantially to operate and maintain thermal dryers (additional 64 hrs/d estimated). Process monitoring: closer monitoring of digester stability parameters, thermal dryer and emissions control equipment performance. Maintenance: majority performed by plant staff, some dryer maintenance contracted out. Operations: performed by plant staff; third party operator not needed, but option is available (through NEFCO, etc.) Service: technology and equipment are all serviceable within the US. Compliance monitoring: monitor dried product %TS to meet Class A. Product management: options to continue contract with current haulers or identify new haulers for local use of product with robust marketing campaign.	Training: new composting system. Specialized staff: special certification may be required for driving front end haulers. Labor hours: increase substantially to operate and maintain composting facility (additional 53 hrs/d estimated). Process monitoring: closer monitoring of digester stability parameters, composting process performance. Maintenance: majority performed by plant staff, some mixing, screening, and blower equipment maintenance may be contracted out. Operations: performed by plant staff; third party operator not needed, but option is available. Service: technology and equipment are all serviceable within the US. Compliance monitoring: monitor time and temperature in compost piles to meet Class A. Product management: options to continue contract with current haulers or identify new haulers for local use of product.
Impacts on facility infrastructure/ Footprint	Will the technology require additional plant infrastructure such as a further expansion of the electrical substation? Does the alternative avoid stranding assets (before the end of their useful life)? What is the footprint of the alternative?	Score	4	5	4	1	3	5	2	3	1
		Justification	Additional ancillary plant infrastructure: none required. Stranded assets: none. Footprint: 3 additional digesters require 26,000 sf footprint. This space had been already planned for digester expansion.	Additional ancillary plant infrastructure: none required. Stranded assets: none. Footprint: no additional footprint.	Additional ancillary plant infrastructure: none required. Stranded assets: several digesters will not be needed and operations can be discontinued. Footprint: New screw thickeners will be placed between each pair of digesters. Footprint of ~4500 sf. May make area around digesters crowded and make access to equipment difficult.	Additional ancillary plant infrastructure: none required. Stranded assets: several digesters will not be needed and operations can be discontinued. DAFT will not be needed with pre-dewatering centrifuges. Footprint: new pre-dewatering centrifuges (indoors), THP system (outdoors), and steam system (indoors) will require 16,000 sf.	Additional ancillary plant infrastructure: none required. Stranded assets: none Footprint: 4,800 sf building + 7.5 acres lined lagoon storage. It is assumed that new thermo-chemical hydrolysis process will be in a new building adjacent the dewatering building. In addition, will require storage for end product (lined lagoon/bladder), and truck filling station.	Additional ancillary plant infrastructure: none required. Stranded assets: none. Footprint: no additional footprint.	Additional ancillary plant infrastructure: may require more natural gas, and associated utility meter. Stranded assets: none Footprint: new drying system including dust and emissions control, and new pyrolysis system on outdoor concrete pad with cover/canopy will require 80,000 sf.	Additional ancillary plant infrastructure: may require more natural gas, and associated utility meter. Stranded assets: none Footprint: new drying system including dust and emissions control will require 30,000 sf inside a building. It is assumed that new dryer process will be in a new building adjacent the dewatering building.	Additional ancillary plant infrastructure: none required. Stranded assets: none Footprint: Largest footprint requirement of all the alternatives. New composting system (outdoors) will require 20 acres (870,000 sf). It is assumed that the composting facility is located in the land adjacent the RWRF.

Evaluation Criteria	Description		Baseline: Mesophilic Anaerobic Digestion (MAD)	Baseline: MAD with Process Optimization (Higher %TS)	Baseline: MAD with Recuperative Thickening	Pre-Digestion Thermal Hydrolysis	Post-Digestion Thermo-Chemical Hydrolysis - Onsite	Post-Digestion Thermo-Chemical Hydrolysis - Offsite	Thermal Drying & Pyrolysis	Thermal Drying	Covered Aerated Static Pile (ASP) Compost
Ability to construct/ Implement / Permit	How difficult will it be to fit/integrate the technology with existing equipment? How difficult will it be to continue operations of existing processes during construction? How long will it take to implement (including permitting)?	Score	5	5	4	2	4	5	3	4	4
		Justification	Ease of integration: easy; digester control building already designed to accomodate 3 new additional digesters. Continuity of operations during construction: minimal impact; construction will be close to existing digester 13 and may impact operation of that digester. Implementation time (including permitting): expected to be 1 year quicker than new process because permits are already in place, 1-2 years for design and permitting, 2-3 years for construction, 6 months for commissioning.	Ease of integration: easy; operational testing to determine achievable thickness of primary sludge and TWAS; depending on results from operational testings, may need to make some relatively minor modifications like replacing pumps, make modificiations to clarifier collectors, etc. Continuity of operations during construction: minimal impact. Implementation time (including permitting): expected to be less than time required for a new process, 1 year for design and permitting, 1 year for construction, 6 months for commissioning.	Ease of integration: medium; only one set of 4 digesters is assumed to be retroffited with recuperative thickening to facilitate integration. Continuity of operations during construction: medium impact; operation of set of 4 digesters may be impacted; could likely retrofit one digester at a time. . Implementation time (including permitting): expected to be similar to any new process, 2-3 years for design and permitting, 2-3 years for construction, 6 months for commissioning.	Ease of integration: difficult; new pre-dewatering centrifuges and THP process occur following thickening and prior to anaerobic digestion. Operations of anaerobic digestion and dewatering processes downstream will be affected. Continuity of operations during construction: difficult; installation of new pre-dewatering building, THP process, and steam systemwill occur close to existing thickening and anaerobic digestion. Implementation time (including permitting): expected to be similar to any new process, 2-3 years for design and permitting, 2-3 years for construction, 6 months for commissioning.	Ease of integration: easy; new thermo-chemical hydrolysis process occurs after dewatering, so will not affect any of the existing processes. Continuity of operations during construction: minimal impact; construction inside the dewatering building may impact dewatering operations. Implementation time (including permitting): expected to be similar to any new process, 2-3 years for design and permitting, 2-3 years for construction, 6 months for commissioning.	Ease of integration: easy; simple pump replacement at most. Continuity of operations during construction: low impact; needs a tie in for cake to be conveyed to thermo-chemical hydrolysis rather than the silos. Implementation time (including permitting): expected to be less than time required for a new process, 1 year for design and permitting, 1 year for construction, 6 months for commissioning.	Ease of integration: medium; thermal drying and pyrolysis occurs after dewatering so will not affect any of the existing processes. Continuity of operations during construction: low impact; needs a tie in for cake to be conveyed to drying rather than the silos. Thermal drying will be placed in a new building close to the dewatering building. Implementation time (including permitting): expected to take same as new process (pyrolysis recently permitted in Bay Area AQMD), 2-3 years for design and permitting, 2-3 years for construction, 1 year for commissioning.	Ease of integration: easy; thermal drying occurs after dewatering so will not affect any of the existing processes. Integration required for heat recovery from dryers to heat anaerobic digesters. Continuity of operations during construction: low impact; needs a tie in for cake to be conveyed to drying rather than the silos. Thermal drying will be placed in a new building close to the dewatering building. Implementation time (including permitting): expected to take same as new process, 2-3 years for design and permitting, 2-3 years for construction, 6 months for commissioning.	Ease of integration: easy; composting occurs after dewatering so will not affect any of the existing processes. Continuity of operations during construction: no impact; the composting facility will be located adjacent to the RWRF. Implementation time (including permitting): expected to be similar to any new process, several similar composting facilities have been permitted in San Joaquin AQMD, 2-3 years for design and permitting, 2-3 years for construction, 6 months for commissioning.
Process impacts & risks	Will the alternative impact mainstream treatment (e.g., by increasing sidestream nutrient loads)? Will the alternative adversely impact water reuse? What are the impacts if the process fails?	Score	5	4	4	2	4	5	4	4	5
		Justification	Impact to mainstream treatment: none Impact to water reuse: none Impact if process fails: If anaerobic digestion does not meet Class B, material needs to taken to landfill.	Impact to mainstream treatment: none Impact to water reuse: none Impact if process fails: Operations at higher VS loading rate may increase risk of digester upset. If anaerobic digestion does not meet Class B, material needs to taken to landfill or offsite processing.	Impact to mainstream treatment: none Impact to water reuse: none Impact if process fails: Operations at very high VS loading rate in the Omnivore digesters may increase risk of digester upset. If anaerobic digestion does not meet Class B, material needs to taken to landfill. If Omnivore digesters fail, other digesters would be overloaded.	Impact to mainstream treatment: increased sidestream nitrogen and phosphorus loads. Increased recalcitrant nitrogen. This could be an issue if effluent nutrient limits become more stringent in the future. Impact to water reuse: increased sidestream color load may decrease transmissivity affecting UV disinfection. Impact if process fails: If THP fails, digesters would be overloaded and not able to meet Class B, material would need to be taken to landfill.	Impact to mainstream treatment: none Impact to water reuse: none Impact if process fails: Since additional digesters are not provided, if the thermo-chemical hydrolysis process fails, sludge from digestion would not necessarily meet Class B and would need to be taken to landfill or offsite processing.	Impact to mainstream treatment: none Impact to water reuse: none Impact if process fails: If off-site Lystek facility is down, material from Fresno would need to go to landfill or further processing. Contract term would likely require Lystek to take responsibility of managing product when the Lystek facility is down. Operations at higher VS loading rate may increase risk of digester upset.	Impact to mainstream treatment: minimal additional sidestream load. Drying + Pyrolysis alternative will require that only centrifuges be used for dewatering. Centrifuge dewatering is more operationally intensive, uses more power and polymer, and will require longer operating schedule. Impact to water reuse: none Impact if process fails: Since additional digesters are not provided, if thermal drying fails, un-classified sludge would need to be taken to landfill.	Impact to mainstream treatment: minimal additional sidestream load. Drying alternative will require that only centrifuges be used for dewatering. Centrifuge dewatering is more operationally intensive, uses more power and polymer, and will require longer operating schedule. Impact to water reuse: none Impact if process fails: Since additional digesters are not provided, if thermal drying fails, un-classified sludge would need to be taken to landfill.	Impact to mainstream treatment: minimal additional sidestream load. Impact to water reuse: none Impact if process fails: Composting is a relatively reliable process; likelihood of failure is small. However, if composting fails, un-classified sludge would need to be taken to landfill or offsite processing.
Social											
Ability to continue/ expand ADM program	Will the alternative enable the City to continue providing a service to local industries through their ADM program and potentially expand it?	Score	3	3	5	5	3	3	3	3	3
		Justification	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.	Process will allow the City to continue ADM program. The process will result in spare anaerobic digestion capacity which could be used to expand the ADM program further, if desired.	Process will allow the City to continue ADM program. The process will result in spare anaerobic digestion capacity which could be used to expand the ADM program further, if desired.	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.	Process will allow the City to continue ADM program, with expansion proportional to increase in sludge quantities.
Community acceptability	Does the alternative introduce a source of odors, noise, and/or other emissions? Will the alternative increase or decrease local truck traffic? Does the alternative produce a product that can be used by the local community?	Score	2	2	2	3	2	3	4	4	5
		Justification	Odors, noise, emissions: same as current. Local truck traffic: baseline (16 trucks/d) Product use by local community: No, land application of Class B cake is currently not allowed in Fresno county. Class B cake is limited to agricultural bulk land aplication in Merced, King, and Tulare county or further processing off-site.	Odors, noise, emissions: same as current. Local truck traffic: baseline (16 trucks/d) Product use by local community: No, land application of Class B cake is currently not allowed in Fresno county. Class B cake is limited to agricultural bulk land aplication in Merced, King, and Tulare county or further processing off-site.	Odors, noise, emissions: same as current. Local truck traffic: baseline (16 trucks/d) Product use by local community: No, land application of Class B cake is currently not allowed in Fresno county. Class B cake is limited to agricultural bulk land aplication in Merced, King, and Tulare county or further processing off-site.	Odors, noise, emissions: Steam boilers are new source of emissions. Local truck traffic: reduce truck traffic compared to baseline by 34% (11 trucks/d) Product use by local community: Possible. Class A cake is allowed for land application in Fresno county. With a robust marketing campaign, "Cured" Class A cake can be distributed to homeowners, landscapers, and gardeners. "Fresh" Cambi cake can have ammonia odor issues.	Odors, noise, emissions: Steam boilers are new source of emissions. Local truck traffic: increase truck traffic compared to baseline by 46% (23 trucks/d) Product use by local community: Possible. Class A is land application is allowed in Fresno. To date, Lystegro has only been used in the bulk agriculture market.	Odors, noise, emissions: same as current. Local truck traffic: baseline (16 trucks/d) Product use by local community: Possible. Class A is land application is allowed in Fresno. To date, Lystegro has only been used in the bulk agriculture market.	Odors, noise, emissions: Dryers and pyrolyzers are new sources of emissions; which can be mitigated with adequate emissions control. Local truck traffic: substantial reduction in truck traffic compared to baseline by 85% (2 trucks/d) Product use by local community: Likely. While the product is new, it has potential for being used in various agricultural markets and in other markets outside of agriculture.	Odors, noise, emissions: Dryers are a new source of emissions; which can be mitigated with adequate emissions control. Local truck traffic: substantial reduction in truck traffic compared to baseline by 69% (5 trucks/d) Product use by local community: Likely. Class A product can be used in Fresno county. Can be marketed to soil blending, soil production, and landscaping.	Odors, noise, emissions: Composting facility new source of emissions and odors; GORE process mitigates VOC emissions by 99% compared to typical composting facility. This alternative provides a service to the local community for processing of woody wastes, and may reduce open burns. Local truck traffic: substantial increase in truck traffic for amendment hauling (39 trucks/d) and compost hauling (28 trucks/d); overall increase of 317%. Product use by local community: Very likely. Compost is widely accepted and could be used by local farms and homeowners. Various facilities give product away for free to homeowners as part of their educational/marketing strategy.

Evaluation Criteria	Description		Baseline: Mesophilic Anaerobic Digestion (MAD)	Baseline: MAD with Process Optimization (Higher %TS)	Baseline: MAD with Recuperative Thickening	Pre-Digestion Thermal Hydrolysis	Post-Digestion Thermo-Chemical Hydrolysis - Onsite	Post-Digestion Thermo-Chemical Hydrolysis - Offsite	Thermal Drying & Pyrolysis	Thermal Drying	Covered Aerated Static Pile (ASP) Compost
Environmental											
Maximize biosolids beneficial use	Does the alternative produce a biosolids product that is more marketable than the existing product (i.e., Class B biosolids)?	Score	2	2	2	3	3	2	3	4	5
		Justification	Same product; Class B cake. Class B cake is banned in Fresno county. Class B cake is lmited to agricultural bulk land application in Merced, King, and Tulare County.	Same product; Class B cake. Class B cake is banned in Fresno county. Class B cake is lmited to agricultural bulk land application in Merced, King, and Tulare County.	Same product; Class B cake. Class B cake is banned in Fresno county. Class B cake is lmited to agricultural bulk land application in Merced, King, and Tulare County.	Improved product: Class A cake. Class A cake is allowed for land application in Fresno county. Fresh THP cake has only been used in the bulk agriculture market. "Cured" THP cake has been distributed to homeowners, landscapers, and gardeners.	Improved product: Class A liquid fertilizer. Class A products are allowed for land application in Fresno county. To date, Lystegro has only been used in the bulk agriculture market.	Improved product: Class A liquid fertilizer. Class A products are allowed for land application in Fresno county. To date, Lystegro has only been used in the bulk agriculture market. Risk: if offsite Lystek facility is not accepting material, will need to revert back to Class B cake handling.	Improved product: biochar. Biochar has typically been used in the bulk agriculture market. Expansion into other markets (i.e., as an activated carbon replacement) is currently being explored. Risk: new product, uses other than bulk agriculture are yet to be proven.	Improved product: dried pellets or granules. Class A products are allowed for land application in Fresno county. Depending on the quality, can be marketed beyond bulk agriculture, to soil blending, sod production, landscaping and others.	Improved product: Class A compost. Compost has the highest potential for expansion to other markets. It can be used as a direct substitute for compost products, in a variety of markets including topsoil manufacturing, landscaping, sod production, and others.
Minimize volume of residuals	Does the alternative reduce the volume of residuals (or biosolids)?	Score	3	3	3	4	2	3	5	5	1
		Justification	No change in cake volume (175,000 cy/yr).	No change in cake volume (175,000 cy/yr).	No change in cake volume (175,000 cy/yr).	Medium reduction in cake volume due to increased VSR and improved dewaterability (115,000 cy/yr; 34% decrease)	Medium increase in product volume due to liquid product (251,000 cy/yr; 43% increase).	Minimal increase in cake volume (183,000 cy/yr; 5%).	Substantial reduction in product volume due to drying and pyrolysis (25,900 cy/yr; 85% decrease).	Substantial reduction in product volume due to drying (53,800 cy/yr; 69% decrease).	Substantial increase in product volume due to addition of amendment and lower bulk density (304,000 cy/yr; 74% increase)
Minimize GHG Emissions	Does the alternative increase or decrease GHG emissions relative to the existing operations? This criterion will holistically take into account energy and chemical use of the process, fuel use for transport, and product carbon sequestration and fertilizer offsets.	Score	5	5	5	3	3	5	2	1	5
		Justification	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives	Quantitative score based on relatice GHG emissions of alternatives

Appendix 4-D

NON-FINANCIAL EVALUATION BACKGROUND

Parameter	Units	Baseline (+3 Digesters)	Baseline - Higher %TS	Baseline + Recuperative Thickening (Omnivore)	Pre-digestion Thermal Hydrolysis (Cambi)	Post-digestion Thermo-Chemical Hydrolysis (Lystek)	Off-site Thermo-Chemical Hydrolysis (Lystek)	Drying + Pyrolysis (Bioforcetech)	Thermal Drying	Covered Aerated Static Pile Composting (GORE)
Product quantity	wt/yr	145,000	145,000	145,000	92,000	213,000	152,000	16,200	33,600	83,600
% increase	%	0%	0%	0%	-37%	47%	5%	-89%	-77%	-42%
Truck traffic (based on 25 ton capacity)	truck/d	16	16	16	10	23	17	2	4	9
Product bulk density	lb/cy	1660	1660	1660	1600	1700	1660	1250	1250	550
Product volume	cy/yr	175,000	175,000	175,000	115,000	251,000	183,000	25,900	53,800	304,000
% increase	%	0%	0%	0%	-34%	43%	5%	-85%	-69%	74%
Truck traffic (based on 30 cy capacity)	truck/d	16	16	16	11	23	17	2	5	28
Amendment	cy/yr									425,600
Truck traffic (based on 30 cy)	truck/d									39
Total truck traffic	truck/d	16	16	16	11	23	17	2	5	67
% increase	%	0%	0%	0%	-34%	46%	5%	-85%	-69%	317%
Footprint	acres	0.60	0	0.10	0.43	0.12	0	1.84	0.60	20
Footprint	sf	25,977	0	4536	18900	5400	0	80000	26250	871,200
Labor	hr/d	1.5	0	3	6	3	0	24	64	53

Omnivore

US Omnivore Installations:

- Victor Valley Wastewater Reclamation Authority (First Omnivore Installation- 2014)
- City of South San Francisco, CA
- City of Camden, NJ

International Omnivore Installations:

- PUB Singapore
- Terni, Italy

Mixer Installations (North America)
-Clean Water Services, Oregon (2018)
-Silicon Valley Clean Water (2018)
-Toronto (2018)

Mixer Installations (Global) over 1600 dating back to 2009.

Bioforcetech

Installation list in US/Canada for both the dryer and the pyrolyzer; operating history
SVCW: 6 BioDyers and 1 Pyrolysis Unit (P-FIVE). Operating since June 2017
Yakama, WA: 1 BioDryer. Operating since January 2019
Installation list worldwide, for both the dryer and the pyrolyzer BioDryers have been installed in US only.
By the end of 2019, Bioforcetech will have another 2 installations in Europe.
Pyrolysis: about 20 installations in Europe. Please find below some references:

GORE Composting

Date of First Installation

- Date of 1st Install: 1998 Marburg, Germany (Global) – still in Operation
- Date of 1st Install: 2002 Lynden, WA (North America) – still in Operation

Total # of Installations*

- 30 North America (300 + Global)

* Installations include and not limited to full-scale facilities, demonstration and R & D projects.

The first GORE® Cover installations are still running according to and with original components, utilizing the same process control and with similar design being offered today. Any improvements to the system over time are associated with software upgrades, component upgrades (i.e. analog to digital) and design improvements.

Similar projects in Feed stocks in California.

SG and W.L Gore & Associates have built multiple facilities across United States and Canada. These included the current facilities in California: LACSD (Tulare Lake Compost, Burrtec West Valley, Mid Valley Disposal, City of San Diego) facilities and we are currently in permitting with several new projects in CA (undisclosed confidential clients). Note; That Burrtec and Mid Valley both received CalRecycle GHG Grant money being associated with benefits that GORE® Cover technology delivers.

Appendix 4-E

GREENHOUSE GAS CALCULATIONS

Global Warming Potential

GHG	GWP
Carbon Dioxide (CO2)	1
Methane (CH4)	25
Nitrous Oxide (N2O)	298

GHG Emission Factors

Factor	Units	Value	Sources
Electricity, CAMX - WECC California	lbs CO_2e/MWh	529.889	US EPA, eGRID Summary Tables 2016; Table 1. Subregion Output Emission Rates
Electricity, CAMX - WECC California	kg CO2e/MWh	240.3538932	Calculated
Natural gas - US Average	kg CO2/mmBtu	53.06	US EPA 40 CFR Part 98 Subsection C. Table C-1 CO2 Emission Factors and HHV
Natural gas - US Average	kg CH_4/mmBtu	0.001	US EPA 40 CFR Part 98 Subsection C. Table C-2 CH4 and N2O Emission Factors
Natural gas - US Average	kg N_2O/mmBtu	0.0001	US EPA 40 CFR Part 98 Subsection C. Table C-2 CH4 and N2O Emission Factors
Natural gas - US Average	kg CO2e/mmBtu	53.1148	Calculated from CO2, CH4, and N2O
Polymers	Petroleum Btu/lb	17000	Owen, William F. 1982. pg. 43. Energy in Wastewater Treatment. Prentice-Hall, Inc., Englewood Cliffs, NJ.
Distillate Fuel Oil No. 1	kg CO2/mmBtu	73.25	US EPA 40 CFR Part 98 Subsection C. Table C-1 CO2 Emission Factors and HHV
Distillate Fuel Oil No. 1	kg CH_4/mmBtu	0.003	US EPA 40 CFR Part 98 Subsection C. Table C-2 CH4 and N2O Emission Factors
Distillate Fuel Oil No. 1	kg N_2O/mmBtu	0.0006	US EPA 40 CFR Part 98 Subsection C. Table C-2 CH4 and N2O Emission Factors
Distillate Fuel Oil No. 1	kg CO2e/mmBtu	73.5038	Calculated from CO2, CH4, and N2O
Polymer	kgCO2e/lb	1.2495646	Calculated assuming petroleum fuel used is distillate fuel oil no. 1.
Polymer production	Mg CO2e/100 Mg dry solids	5	Brown et al, 2010
Caustic potash (potassium hydroxide, KOH)			
Caustic soda Sodium hydroxide (NaOH)	kWh/lb	1.5	Range of 0.9 to 2.1 from Owen, William F. 1982. pg. 43. Energy in Wastewater Treatment. Prentice-Hall, Inc., Englewood Cliffs, NJ.
Sodium hypochlorite (NaOCl)	kWh/lb	2.5	"General Electrochemistry", by Dr. R. C. Rhees, Vice President Research, Pepcon Systems Inc. P.O. Box 629, Cedar City, Utah 8472012/14/07 (MLH) - Have not checked this reference; obtained thi
Diesel	kg CO_2/gal	10.21	Table 2, US EPA Center for Corporate Climate Leadership, Emission Factors Hub, updated 9-Mar-2018
Fuel efficiency	miles/gal	6	GHGEmissionsEstimate_022616.xls
Diesel Medium- and Heavy-Duty Vehicels	g CH4/mile	0.0051	Table 4, US EPA Center for Corporate Climate Leadership, Emission Factors Hub, updated 9-Mar-2018
Diesel Medium- and Heavy-Duty Vehicels	g N2O/mile	0.0048	Table 4, US EPA Center for Corporate Climate Leadership, Emission Factors Hub, updated 9-Mar-2018
Fertilizer offset	Mg CO2e/100 Mg dry solids	-23	Brown et al, 2010
Fertilizer offset	kg CO2/kg dry solids	-0.23	Calculated
Carbon Sequestration	Mg CO2e/100 Mg dry solids	-25	Brown et al, 2010
Carbon Sequestration	kg CO2/kg dry solids	-0.25	Calculated

Alternative Inputs

Parameter	Units	Baseline: Mesophilic Anaerobic Digestion (MAD)	Baseline: MAD with Process Optimization (Higher %TS)	Baseline: MAD with Recuperative Thickening	Pre-Digestion Thermal Hydrolysis	Post-Digestion Thermo-Chemical Hydrolysis - Onsite	Post-Digestion Thermo-Chemical Hydrolysis - Offsite	Thermal Drying & Pyrolysis	Thermal Drying	Covered Aerated Static Pile (ASP) Compost	Sources
Power Usage	kWh/yr	7,197,657	6,222,657	3,516,859	4,376,801	8,169,598	6,222,657	21,359,486	12,035,816	9,468,465	O&M Cost
Natural Gas Usage	million Btu/yr	109,500	109,500	109,500	205,860	165,564	109,500	241,776	373,176	109,500	O&M Cost
Polymer Usage	lb active/yr	787,360	787,360	1,042,070	1,835,647	824,124	824,124	1,120,809	1,120,809	824,124	O&M Cost
Caustic (sodium hydroxide) Usage	lb/yr					8,298,436		1,330	1,330		O&M Cost
Bleach (sodium hypochlorite) Usage	lb/yr							31,917	31,917		O&M Cost
Hauling Distance (one way)	miles	80	80	80	60	60	26	40	40	30	Discussion with Lisa Challenger
Biosolids Hauling	wet ton/yr	145,206	145,206	145,206	91,795	212,780	151,986	15,951	33,597	83,592	Mass & Energy Balance
Number of Trucks	trucks/d	16	16	16	11	23	17	5	2	33	Sheet "Reference Values"
Vehicle Miles Traveled (VMT)	VMT/yr	933,333	933,333	933,333	460,000	1,022,400	317,200	143,467	69,067	729,600	Calculated
Diesel Usage for Hauling	gal/yr	155,556	155,556	155,556	76,667	170,400	52,867	23,911	11,511	121,600	Calculated
Biosolids to Land Application	dry ton/yr	30,493	30,493	30,493	29,374	31,917	31,917	31,917	31,917	31,917	Mass & Energy Balance
Biosolids to Land Application	dry kg/yr	27,662,961	27,662,961	27,662,961	26,648,079	28,954,630	28,954,630	28,954,630	28,954,630	28,954,630	Calculated

GHG Emissions

Parameter	Units	Baseline: Mesophilic Anaerobic Digestion (MAD)	Baseline: MAD with Process Optimization (Higher %TS)	Baseline: MAD with Recuperative Thickening	Pre-Digestion Thermal Hydrolysis	Post-Digestion Thermo-Chemical Hydrolysis - Onsite	Post-Digestion Thermo-Chemical Hydrolysis - Offsite	Thermal Drying & Pyrolysis	Thermal Drying	Covered Aerated Static Pile (ASP) Compost
Power Usage	metric tons CO_2e/yr	1,730	1,496	845	1,052	1,964	1,496	5,134	2,893	2,276
Natural Gas Usage	metric tons CO_2e/yr	5,816	5,816	5,816	10,934	8,794	5,816	12,842	19,821	5,816
Polymer Usage	metric tons CO_2e/yr	984	984	1,302	2,294	1,030	1,030	1,401	1,401	1,030
Caustic Usage	metric tons CO_2e/yr					2,992			0.5	
Bleach Usage	metric tons CO_2e/yr								19	
Biosolids Hauling	metric tons CO_2e/yr	1,590	1,590	1,590	783	1,741	540	244	118	1,243
Fertilizer Offset	metric tons CO_2e/yr	-6,362	-6,362	-6,362	-6,129	-6,660	-6,660	-6,660	-6,660	-6,660
Carbon Sequestration	metric tons CO_2e/yr	-6,916	-6,916	-6,916	-6,662	-7,239	-7,239	-7,239	-7,239	-7,239
Total Emissions	**metric tons CO_2e/yr**	**10,120**	**9,885**	**9,553**	**15,063**	**16,521**	**8,882**	**19,621**	**24,252**	**10,364**
Total Offsets	**metric tons CO_2e/yr**	**-13,278**	**-13,278**	**-13,278**	**-12,791**	**-13,898**	**-13,898**	**-13,898**	**-13,898**	**-13,898**
Net Emissions	**metric tons CO_2e/yr**	**-3,159**	**-3,393**	**-3,725**	**2,272**	**2,622**	**-5,016**	**5,722**	**10,354**	**-3,534**
Normalized to Score 1-5		**5**	**5**	**5**	**3**	**3**	**5**	**2**	**1**	**5**
		5	5	5	3	3	5	2	1	5

$$value_{new} = \frac{max_{new} - min_{new}}{max_{old} - min_{old}} \times (value_{old} - max_{old}) + max_{new}.$$

max old	-5,016
min old	10,354
max new	5
min new	1
(maxnew-minnew)/(maxold-mi	-0.000260246

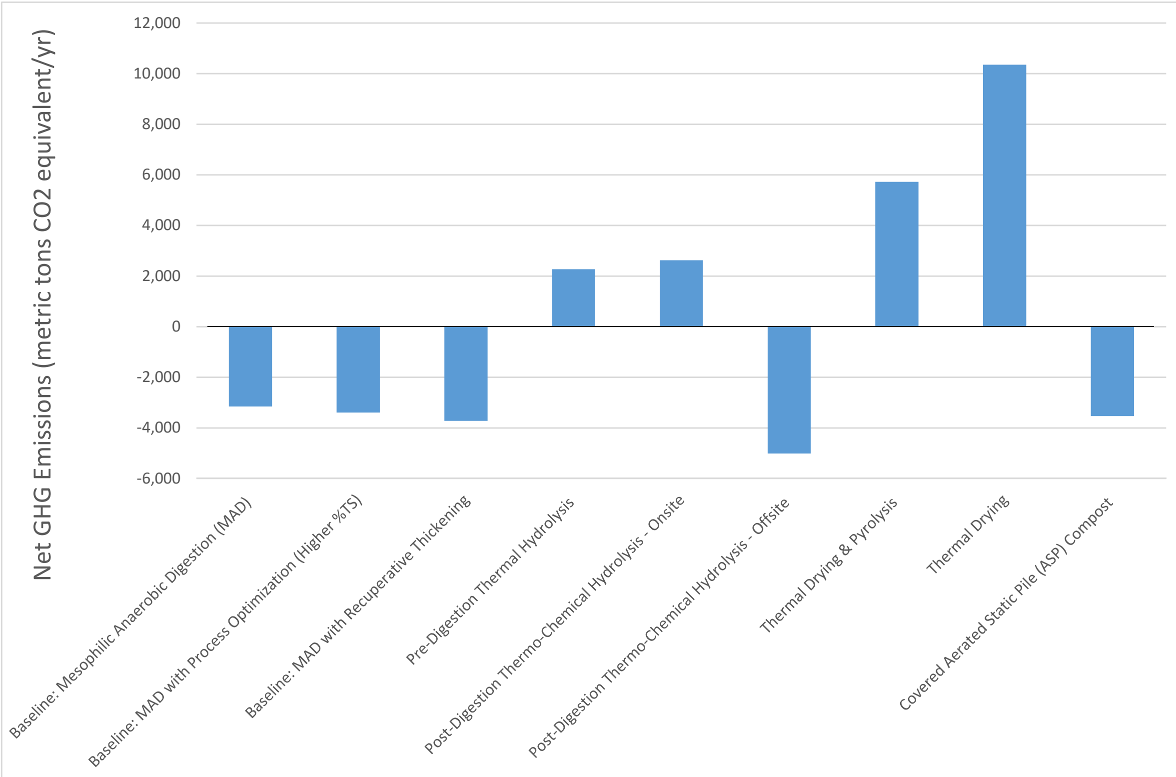
Notes from discussion with Lisa Challenger 16-April-2019:

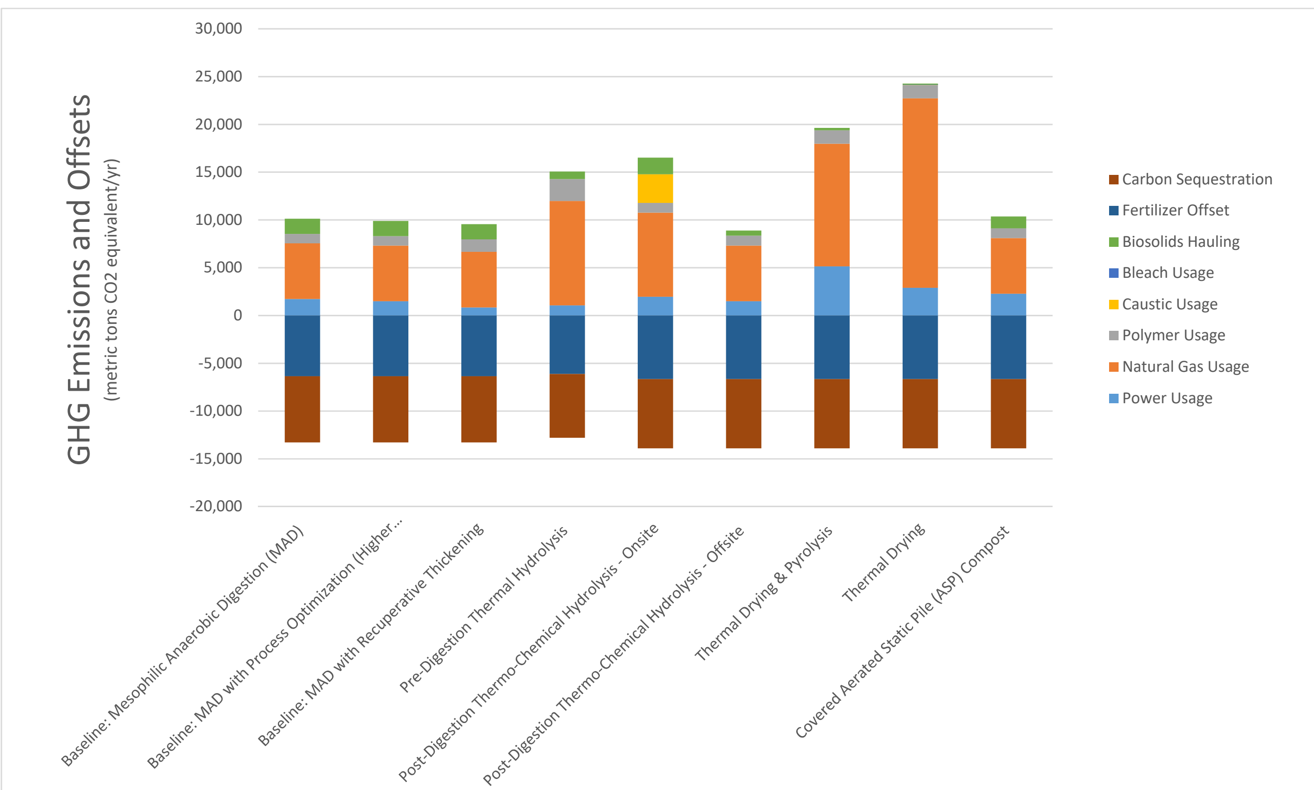
For Class B cake, Class A cake, and Lystek product, assume application on non-feed crops in Merced, King, and Tulare County

For compost, dried product and biochar, opportunity to use in food crops in Fresno county.

Fresno and Tulare County both have bans on Class B products.

Current distance to end use is 80 miles.


Net GHG Emissions (metric tons CO2 equivalent/yr)
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
Baseline: Mesophilic Anaerobic Digestion (MAD)
Baseline: MAD with Process Optimization (Higher %TS)
Baseline: MAD with Recuperative Thickening
Pre-Digestion Thermal Hydrolysis
Post-Digestion Thermo-Chemical Hydrolysis - Onsite
Post-Digestion Thermo-Chemical Hydrolysis - Offsite
Thermal Drying & Pyrolysis
Thermal Drying
Covered Aerated Static Pile (ASP) Compost


GHG Emissions and Offsets
(metric tons CO2 equivalent/yr)
30,000
25,000
20,000
15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Carbon Sequestration
Fertilizer Offset
Biosolids Hauling
Bleach Usage
Caustic Usage
Polymer Usage
Natural Gas Usage
Power Usage
Baseline: Mesophilic Anaerobic Digestion (MAD)
Baseline: MAD with Process Optimization (Higher...
Baseline: MAD with Recuperative Thickening
Pre-Digestion Thermal Hydrolysis
Post-Digestion Thermo-Chemical Hydrolysis - Onsite
Post-Digestion Thermo-Chemical Hydrolysis - Offsite
Thermal Drying & Pyrolysis
Thermal Drying
Covered Aerated Static Pile (ASP) Compost

Appendix 4-F

CAPITAL COST SUMMARIES

Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Baseline: Mesophilic Anaerobic Digestion (MAD)		$18,885,397
	Three (3) 1.88 MG, 105 ft diameter concrete, dome cover digester (typ)		
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	TOTAL DIRECT COST		**$18,885,397**
	Contingency	20%	$3,777,079
	Subtotal		**$22,662,477**
	General Conditions (mobilization, permits, bonds/insurance, etc.)	10%	$2,266,248
	Subtotal		**$24,928,724**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$753,055
	Subtotal		**$25,681,779**
	General Contractor Overhead and Profit	10%	$2,568,178
	Subtotal		**$28,249,957**
	Escalation to Mid-Point	3%	$3,423,578
	TOTAL ESTIMATED CONSTRUCTION COST		**$31,673,535**
	Design, Legal & Administration Fees	15%	$4,751,030
	Construction Management	10%	$3,167,354
	TOTAL ESTIMATED PROJECT COST		**$39,591,919**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Baseline: MAD with Process Optimization (Higher %TS)		$720,000
	12 new Primary Sludge and 6 new Thickened WAS pumps		
	Equipment Installation (Applied to Equipment Cost)	30%	$216,000
	Electrical, Instrumentation, & Controls (Applied to New Structures and Equipment)	15%	$108,000
	Misc. Process Piping (Applied to New Structures and Equipment)	15%	$108,000
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	TOTAL DIRECT COST		**$1,152,000**
	Contingency	30%	$345,600
	Subtotal		**$1,497,600**
	General Conditions (mobilization, permits, bonds/insurance, etc.)	10%	$149,760
	Subtotal		**$1,647,360**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$45,936
	Subtotal		**$1,693,296**
	General Contractor Overhead and Profit	10%	$169,330
	Subtotal		**$1,862,626**
	Escalation to Mid-Point	3%	$225,729
	TOTAL ESTIMATED CONSTRUCTION COST		**$2,088,355**
	Design, Legal & Administration Fees	15%	$313,253
	Construction Management	10%	$208,835
	TOTAL ESTIMATED PROJECT COST		**$2,610,444**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Baseline: MAD with Recuperative Thickening (for Digesters 9-12. Estimate includes 12 mixers and service boxes and 4 sludge screw thickeners)		$7,430,000
	Structural Reinforcement for Mixer Modification		$800,000
	Sludge Feed Pumps		$160,000
	Equipment Installation (Applied to Equipment Cost)	30%	$2,277,000
	Electrical, Instrumentation, & Controls	15%	$1,138,500
	Misc. Process Piping	15%	$1,138,500
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	TOTAL DIRECT COST		**$12,944,000**
	Contingency	30%	$3,883,200
	Subtotal		**$16,827,200**
	General Conditions (mobilization, permits, bonds/insurance, etc.)	10%	$1,682,720
	Subtotal		**$18,509,920**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$516,142
	Subtotal		**$19,026,062**
	General Contractor Overhead and Profit	10%	$1,902,606
	Subtotal		**$20,928,668**
	Escalation to Mid-Point	3%	$2,536,320
	TOTAL ESTIMATED CONSTRUCTION COST		**$23,464,988**
	Design, Legal & Administration Fees	15%	$3,519,748
	Construction Management	10%	$2,346,499
	TOTAL ESTIMATED PROJECT COST		**$29,331,235**

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Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Pre-Digestion Thermal Hydrolysis		$19,500,000
	Pre-Dewatering Centrifuges		$2,500,000
	Equipment Building		$822,500
	Equipment Installation (Applied to Equipment Cost)	30%	$6,567,000
	Electrical, Instrumentation, & Controls (Applied to New Structures and Equipment)	15%	$3,406,875
	Misc. Process Piping (Applied to New Structures and Equipment)	15%	$3,406,875
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	, etc.)		$0
	TOTAL DIRECT COST		**$36,203,250**
	Contingency	30%	$10,860,975
	Subtotal		**$47,064,225**
	General Conditions (mobilization, permits, bonds/insurance	10%	$4,706,423
	Subtotal		**$51,770,648**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$1,443,605
	Subtotal		**$53,214,252**
	General Contractor Overhead and Profit	10%	$5,321,425
	Subtotal		**$58,535,677**
	Escalation to Mid-Point	3%	$7,093,867
	TOTAL ESTIMATED CONSTRUCTION COST		**$65,629,545**
	Design, Legal & Administration Fees	15%	$9,844,432
	Construction Management	10%	$6,562,954
	TOTAL ESTIMATED PROJECT COST		**$82,036,931**

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PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Post-Digestion Thermo-Chemical Hydrolysis - Onsite		$11,546,000
	Product Storage Reservoir		$3,191,000
	Loadout Station		$250,000
	Equipment Building		$945,000
	Equipment Installation (Applied to Equipment Cost)	30%	$3,463,800
	Electrical, Instrumentation, & Controls	15%	$1,911,150
	Misc. Process Piping	15%	$1,911,150
			$0
			$0
			$0
			$0
			$0
			$0
		, etc.)	$0
	TOTAL DIRECT COST		**$23,218,100**
	Contingency	30%	$6,965,430
	Subtotal		**$30,183,530**
	General Conditions (mobilization, permits, bonds/insurance	10%	$3,018,353
	Subtotal		**$33,201,883**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$925,822
	Subtotal		**$34,127,705**
	General Contractor Overhead and Profit	10%	$3,412,770
	Subtotal		**$37,540,475**
	Escalation to Mid-Point	3%	$4,549,484
	TOTAL ESTIMATED CONSTRUCTION COST		**$42,089,960**
	Design, Legal & Administration Fees	15%	$6,313,494
	Construction Management	10%	$4,208,996
	TOTAL ESTIMATED PROJECT COST		**$52,612,449**

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PROJECT SUMMARY

		Estimate Class:	5
Project:	Biosolids Master Plan at the RWRF	PIC:	ETC
Client:	City of Fresno	PM:	SAD
Location:	Fresno	Date:	April 2019
Zip Code:	93706	By:	JRW
Carollo Job #	11099A00	Reviewed:	CP

NO.	DESCRIPTION		TOTAL
	Post-Digestion Thermo-Chemical Hydrolysis - Offsite		$11,546,000
	Product Storage Reservoir		$3,191,000
	Loadout Station		$250,000
	Equipment Building		$945,000
	Equipment Installation (Applied to Equipment Cost)	30%	$3,463,800
	Electrical, Instrumentation, & Controls	15%	$1,911,150
	Misc. Process Piping	15%	$1,911,150
			$0
			$0
			$0
			$0
			$0
			$0
	, etc.)		$0
	TOTAL DIRECT COST		**$23,218,100**
	Contingency	30%	$6,965,430
	Subtotal		**$30,183,530**
	General Conditions (mobilization, permits, bonds/insurance	10%	$3,018,353
	Subtotal		**$33,201,883**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$925,822
	Subtotal		**$34,127,705**
	General Contractor Overhead and Profit	10%	$3,412,770
	Subtotal		**$37,540,475**
	Escalation to Mid-Point	3%	$4,549,484
	TOTAL ESTIMATED CONSTRUCTION COST		**$42,089,960**
	Design, Legal & Administration Fees	15%	$6,313,494
	Construction Management	10%	$4,208,996
	TOTAL ESTIMATED PROJECT COST		**$52,612,449**

The cost estimate herein is based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo Engineers have no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo Engineers cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Thermal Drying & Pyrolysis		$71,900,000
	Equipment Installation (Applied to Equipment Cost)	10%	$6,471,000
	Electrical, Instrumentation, & Controls (Applied to New Structures and Equipment)	15%	$9,706,500
	Misc. Process Piping (Applied to New Structures and Equipment)	15%	$9,706,500
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	, etc.)		$0
	TOTAL DIRECT COST		**$97,784,000**
	Contingency	30%	$29,335,200
	Subtotal		**$127,119,200**
	General Conditions (mobilization, permits, bonds/insurance	10%	$12,711,920
	Subtotal		**$139,831,120**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$3,899,137
	Subtotal		**$143,730,257**
	General Contractor Overhead and Profit	10%	$14,373,026
	Subtotal		**$158,103,283**
	Escalation to Mid-Point	3%	$19,160,344
	TOTAL ESTIMATED CONSTRUCTION COST		**$177,263,626**
	Design, Legal & Administration Fees	15%	$26,589,544
	Construction Management	10%	$17,726,363
	TOTAL ESTIMATED PROJECT COST		**$221,579,533**

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Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Thermal Drying		$50,000,000
	NEFCO two-train rotary drum dryer configuration		
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	, etc.)		$0
	TOTAL DIRECT COST		**$50,000,000**
	Contingency	30%	$15,000,000
	Subtotal		**$65,000,000**
	General Conditions (mobilization, permits, bonds/insurance	10%	$6,500,000
	Subtotal		**$71,500,000**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$1,993,750
	Subtotal		**$73,493,750**
	General Contractor Overhead and Profit	10%	$7,349,375
	Subtotal		**$80,843,125**
	Escalation to Mid-Point	3%	$9,797,280
	TOTAL ESTIMATED CONSTRUCTION COST		**$90,640,405**
	Design, Legal & Administration Fees	15%	$13,596,061
	Construction Management	10%	$9,064,040
	TOTAL ESTIMATED PROJECT COST		**$113,300,506**

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Engineers...Working Wonders With Water®

PROJECT SUMMARY

Project:	**Biosolids Master Plan at the RWRF**	**Estimate Class:**	**5**
Client:	**City of Fresno**	**PIC:**	**ETC**
Location:	**Fresno**	**PM:**	**SAD**
Zip Code:	**93706**	**Date:**	**April 2019**
Carollo Job #	**11099A00**	**By:**	**JRW**
		Reviewed:	**CP**

NO.	DESCRIPTION		TOTAL
	Covered Aerated Static Pile (ASP) Compost Sustainable Generation Bunker system with GORE Covers		$12,500,000
	Roto-Mix 3410 Industrial Mixer (4)		$635,904
	Multistar Screen (2)		$650,000
	Equipment Installation (Applied to Equipment Cost)	30%	$1,510,771
	Electrical, Instrumentation, & Controls (Applied to New Structures and Equipment)	15%	$1,692,886
	Misc. Process Piping (Applied to New Structures and Equipment)	15%	$1,692,886
			$0
			$0
			$0
			$0
			$0
			$0
			$0
	, etc.)		
	TOTAL DIRECT COST		**$18,682,446**
	Contingency	30%	$5,604,734
	Subtotal		**$24,287,180**
	General Conditions (mobilization, permits, bonds/insurance	10%	$2,428,718
	Subtotal		**$26,715,898**
	Sales Tax (Applied to 50% of Total Direct Cost)	7.975%	$744,963
	Subtotal		**$27,460,861**
	General Contractor Overhead and Profit	10%	$2,746,086
	Subtotal		**$30,206,947**
	Escalation to Mid-Point	3%	$3,660,743
	TOTAL ESTIMATED CONSTRUCTION COST		**$33,867,690**
	Design, Legal & Administration Fees	15%	$5,080,153
	Construction Management	10%	$3,386,769
	TOTAL ESTIMATED PROJECT COST		**$42,334,612**

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Appendix 4-G

OPERATION AND MAINTENANCE COST BREAKDOWN

RWRF BIOSOLIDS MANAGEMENT ALTERNATIVES OPERATION AND MAINTENANCE COSTS	Process			Energy								Chemicals					Maintenance	Labor		Hauling			Marketing	TOTAL
				Electricity $ 0.117 /kWh						Natural Gas $ 1.26 /therm								$ 40.58 /hr						
	No. of Operating Units	No. of Standby Units	Motor Power (hp) or Power Use Factor (kWh)	Total Operating Motor Power (hp)	Operational % of Nameplate	Power input (KW)	Operation Time (hr/d)	Annual KWh	Annual power cost	Therms/day	Annual Cost	DT solids / year	Dose (lb active polymer / DT solids)	Usage (lb chemical/ yr)	Unit Cost ($/lb)	Chemical Cost ($/year)	Repair/ Replacement Cost	Labor hours (hr/d)	$/yr	wet tons per day	Unit Cost ($/wet ton)	Annual Hauling Cost	Annual Outreach ($/year)	**O&M Cost ($/year)**
Baseline: MAD with 3 New Digesters																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	16		325,000					5,200,000	$610,480															
Sludge Heating										3,000	$1,379,700													
Maintenance (New Digesters Only)																	$90,000							
Operational Labor (New Digesters Only)																		1.5	$22,218					
Dewatering																								
Power Consumption (kWh/gal)	951,298							1,997,657	$234,525															
Polymer Consumption												31,494	25	787,360	$2.89	$2,277,671								
Product End-Use (Class B Hauling)																				398	$34	$4,937,004		
Total									**$845,005**		**$1,379,700**					**$2,277,671**	**$90,000**		**$22,218**			**$4,937,004**		**$9,551,598**
Baseline: MAD with Process Optimization (Higher %TS)																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	13		325,000					4,225,000	$496,015															
Maintenance																	$14,400							
Sludge Heating										2,568	$1,181,023													
Dewatering																								
Power Consumption (kWh/gal)	951,298							1,997,657	$234,525															
Polymer Consumption												31,494	30	944,832	$2.89	$2,733,206								
Product End-Use (Class B Hauling)																				398	$34	$4,937,004		
Total									**$730,540**		**$1,181,023**					**$2,733,206**	**$14,400**		**$0**			**$4,937,004**		**$9,596,173**
Baseline: MAD with Recuperative Thickening																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	4		325,000					1,300,000	$152,620															
Sludge Heating										624	$286,978													
Recuperative Thickening Digestion (Digesters 9-12)																								
Mixers	16		10	160	85%	101	24	889,075	$177,815															
Screw Thickeners	4		15	60	85%	38	16	222,269	$44,454															
Sludge Heating										2,376	$1,092,722													
Polymer Consumption												50,942	5	254,711	$2.89	$736,826								
Maintenance																	$64,000							
Operational Labor																		3	$44,435					
Dewatering																								
Power Consumption (kWh/gal)	526,454							1,105,515	$129,787															
Polymer Consumption												31,494	25	787,360	$2.89	$2,277,671								
Product End-Use (Class B Hauling)																				398	$34	$4,937,004		
Total									**$504,676**		**$1,379,700**					**$3,014,498**	**$64,000**		**$44,435**			**$4,937,004**		**$9,944,313**
Pre-Digestion Thermal Hydrolysis																								
Pre-Dewatering																								
Power Consumption	3	1	165	495	50%	185	24	1,617,985	$189,951															
Polymer Consumption												64,477	20	1,289,545	$2.89	$3,730,391								
Pre-Digestion																								
Power Consumption (10 kWh/dry ton)	64,477		10					644,773	$128,955															
Sludge Heating										5,640	$2,593,836													
Maintenance																	$335,000							
Operational Labor																		54	$799,832					
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	6		325,000					1,950,000	$228,930															
Dewatering																								
Power Consumption (kWh/gal)	423,347							164,043	$19,259															
Polymer Consumption												30,339	18	546,102	$2.89	$1,579,761								
Product End-Use (Class A Hauling)																				251	$34	$3,121,030		
Total									**$567,095**		**$2,593,836**					**$5,310,152**	**$335,000**		**$799,832**			**$3,121,030**		**$12,726,944**

RWRF BIOSOLIDS MANAGEMENT ALTERNATIVES OPERATION AND MAINTENANCE COSTS	Process			Energy – Electricity ($ 0.117 /kWh)						Energy – Natural Gas ($ 1.26 /therm)		Chemicals					Maintenance	Labor ($ 40.58 /hr)		Hauling			Marketing	TOTAL
	No. of Operating Units	No. of Standby Units	Motor Power (hp) or Power Use Factor (kWh)	Total Operating Motor Power (hp)	Operational % of Nameplate	Power input (KW)	Operation Time (hr/d)	Annual KWh	Annual power cost	Therms/day	Annual Cost	DT solids / year	Dose (lb active polymer / DT solids)	Usage (lb chemical/ yr)	Unit Cost ($/lb)	Chemical Cost ($/year)	Repair/ Replacement Cost	Labor hours (hr/d)	$/yr	wet tons per day	Unit Cost ($/wet ton)	Annual Hauling Cost	Annual Outreach ($/year)	O&M Cost ($/year)
Post-Digestion Thermo-Chemical Hydrolysis - Onsite																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	13		325,000					4,225,000	$496,015															
Sludge Heating										3,000	$1,379,700													
Dewatering																								
Power Consumption (kWh/gal)	951,298							1,997,657	$234,525															
Polymer Consumption												32,965	25	824,124	$2.89	$2,384,024								
Post-Digestion																								
Power Consumption (61 kWh/dry ton)	31917		61					1,946,941	$228,571															
Heat Demand (1.4 MMBTU/dry ton)										1,536	$706,406													
Caustic Potash (KOH)												31,917	260	8,298,436	$0.30	$2,489,531								
Maintenance																	$187,920							
Labor																		3	$44,435					
Product End-Use (Class A Liquid Fertilizer, Lystek-owned)																				583	$24	$5,106,720		
Total									**$959,111**		**$2,086,106**					**$4,873,555**	**$187,920**		**$44,435**			**$5,106,720**		**$13,257,847**
Post-Digestion Thermo-Chemical Hydrolysis - Offsite																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	13		325,000					4,225,000	$496,015															
Sludge Heating										3,000	$1,379,700													
Dewatering																								
Power Consumption (kWh/gal)	951,298							1,997,657	$234,525															
Polymer Consumption												32,965	25	824,124	$2.89	$2,384,024								
Post-Digestion (Indirect Cost)																								
Power Consumption (61 kWh/dry ton)	31917		61					1,946,941	$228,571															
Heat Demand (1.4 MMBTU/dry ton)										1,536	$706,406													
Caustic Potash (KOH)												31,917	260	8,298,436	$0.30	$2,489,531								
Maintenance																	$187,920							
Labor																		3	$44,435					
Product End-Use (Class A Liquid Fertilizer, Lystek-owned)																				583	$24	$5,106,720		
Product Hauling (Unclassified, Lystek-owned)																				404	$15	$2,210,145		
Total									**$959,111**		**$2,086,106**					**$4,873,555**	**$187,920**		**$44,435**			**$7,316,865**		**$15,467,992**
Thermal Drying & Pyrolysis																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	13		325,000					4,225,000	$496,015															
Sludge Heating										3000	$1,379,700													
Dewatering																								
Power Consumption (kWh/gal)	951,298							2,695,816	$316,489															
Polymer Consumption												32,965	34	1,120,809	$2.89	$3,242,273								
Pyrolysis																								
Equipment Power (95 kWh/wet ton)	151,986		95					14,438,670	$1,695,100															
Sludge Heating										3,624	$1,666,678													
Bleach Consumption: Odor Control												31,917	1.0	31,917	$2.00	$63,834								
Caustic Consumption: Odor Control												31,917	0.04	1,330	$ 0.30	$399								
Maintenance (Spare Parts and Replacement)																	$1,250,000							
Maintenance Labor																	$20,290							
Labor (fully-automated)																		24	$355,481					
Product End-Use (Biochar)																				44	-$1.50	-$23,927		
Marketing																							$100,000	
Total									**$2,507,604**		**$3,046,378**					**$3,306,506**	**$1,270,290**		**$355,481**			**-$23,927**	**$100,000**	**$10,562,331**
Thermal Drying																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	13		325,000					4,225,000	$496,015															
Sludge Heating										3,000	$1,379,700													
Dewatering																								
Power Consumption (kWh/gal)	951,298							2,695,816	$316,489															
Polymer Consumption												32,965	34	1,120,809	$2.89	$3,242,273								
Thermal Drying																								
Equipment Power (660 kW per dryer train)	1	1				660	21	5,115,000	$600,501															
Sludge Heating										7,224	$3,322,318													
Bleach Consumption: Odor Control												31,917	1.0	31,917	$2.00	$63,834								
Caustic Consumption: Odor Control												31,917	0.04	1,330	$ 0.30	$399								
Maintenance																	$759,713							
Operational Labor																		64	$952,181					
Product End-Use (Granule)																				92	-$1.50	-$50,396		
Marketing																							$100,000	
Total									**$1,413,005**		**$4,702,018**					**$3,306,506**	**$759,713**		**$952,181**			**-$50,396**	**$100,000**	**$11,183,026**

RWRF BIOSOLIDS MANAGEMENT ALTERNATIVES OPERATION AND MAINTENANCE COSTS	Process			Energy: Electricity						Energy: Natural Gas		Chemicals					Maintenance	Labor		Hauling			Marketing	TOTAL
				$ 0.117 /kWh						$ 1.26 /therm								$ 40.58 /hr						
	No. of Operating Units	No. of Standby Units	Motor Power (hp) or Power Use Factor (kWh)	Total Operating Motor Power (hp)	Operational % of Nameplate	Power input (KW)	Operation Time (hr/d)	Annual KWh	Annual power cost	Therms/day	Annual Cost	DT solids / year	Dose (lb active polymer / DT solids)	Usage (lb chemical/ yr)	Unit Cost ($/lb)	Chemical Cost ($/year)	Repair/ Replacement Cost	Labor hours (hr/d)	$/yr	wet tons per day	Unit Cost ($/wet ton)	Annual Hauling Cost	Annual Outreach ($/year)	**O&M Cost ($/year)**
Composting																								
Digestion																								
Power Consumption (325,000 kWh/yr per digester)	13		325,000					4225000	$496,015															
Sludge Heating										3,000	$1,379,700													
Dewatering																								
Power Consumption (kWh/gal)	951,298							1,997,657	$234,525															
Polymer Consumption												32,965	25	824,124	$2.89	$2,384,024								
Composting																								
Power Use Factor (1.5 kWh/ton processed)	303,971		1.5					455,957	$53,529															
Mixers	8	0	56	448	100	334	23	2,789,851	$327,529															
Maintenance (Cover Replacement)																	$800,000							
Maintenance (Sensors and Equipment)																	$212,500							
Bulking Agent Amendment																				291	$0	$0		
Operational Labor																		53	$778,672					
Product End-Use (Class A Compost)																				229	-$1.50	-$125,388		
Marketing																							$100,000	
Total									**$1,111,598**		**$1,379,700**					**$2,384,024**	**$1,012,500**		**$778,672**			**-$125,388**	**$100,000**	**$6,641,106**