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Technical Memorandum

Prepared for: City of Sunnyvale, Sunnyvale, CA

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Project No: 135083

Technical Memorandum

Subject: Plant Replacement Alternatives Goals, Objectives, and Technology Screening Review

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1. INTRODUCTION

The general approach for the Strategic Infrastructure Plan (SIP) is to compare the major approach of renovating and optimizing the existing plant against the competing major approach of replacing the existing facility with a predominantly new plant. This technical memorandum is associated with the major approach of replacing the existing facility with a predominantly new plant. The purpose of this memorandum is to establish the goals and objectives of new plant alternatives and to review and screen a range of process technologies that may be candidates for inclusion in specific alternatives for the new plant approach. This technical memorandum sets the foundation for a subsequent technical memorandum that will provide detailed description and evaluation of a limited number of specific new plant alternatives.

2. GOALS AND OBJECTIVES FOR NEW PLANT ALTERNATIVES

The overall goals for new plant alternatives are generally the same as for the plant rehabilitation alternatives. Those goals have been described in another technical memorandum titled Level of Service (LOS) Measures. The LOS measures were created by a City panel to define the drivers for water pollution control plant improvements. LOS measures were classified according to regulatory and non-regulatory categories. The non-regulatory category was further broken down into the "triple bottom line" categories of social, economic, and environmental drivers. The alternatives that are associated with either the plant rehabilitation approach or the predominantly new plant approach are to be developed to best meet the overall goals that are defined by the LOS measures.

The objectives for the new plant approach relate to the defining characteristics of a new plant approach alternative as compared to an alternative that is related to the plant rehabilitation approach. The key distinction between the rehabilitation and new plant alternatives is defined by the fate of the oxidation ponds used for secondary treatment. The rehabilitation alternatives retain the oxidation ponds for their current use as the predominant form of secondary treatment. The plant replacement alternatives will not use ponds for secondary treatment, but may retain a portion of them for flow equalization. The portion of the ponds not used for flow equalization may be converted to wetlands or some other type of wildlife habitat or to some other disposition recognized by the City as in compliance with regulatory considerations and the LOS measures for the plant improvements.

For consideration of new plant approach alternatives, several assumptions were made to identify viable alternatives. Some of the key LOS measures that were considered include:

- Space allowance for beyond 2035 flows and loads or new loads from future regionalization agreements;
- Identifying existing processes worth salvaging with a new plant approach (assuming suitable rehabilitation thereof);
- And developing process robustness or buffering equivalency to the ponds (e.g., flow and load equalization).

Another technical memorandum, titled Early Execution Projects, considered the question of whether or not the new plant approach might entail construction of facilities on a site other than the City property currently owned and allocated for the water pollution control plant. For several reasons, it was concluded that the existing water pollution control plant site would be the location considered for new plant approach alternatives. Accordingly, for the new plant approach alternatives, the plant must fit on the existing site,

which means the processes must be compatible with footprint restrictions and construction phasing. An initial qualitative screening is performed for several process technology alternatives. The objective of the initial screening is to identify two general new plant approach alternatives, one utilizing conventional secondary process technology and one utilizing compact footprint secondary process technology.

For the screening, comparisons between treatment technologies were made in general terms. Parameters such as life cycle cost, energy consumption, footprint requirements and process maturity were used for comparison. Resource consumption was also included to evaluate processes. In this context, resource consumption refers to chemical use, energy requirements and associated transportation requirements. These parameters are all contributors to a facility's carbon footprint or resource consumption profile.

3. PROCESSES TO CONSIDER SALVAGING

There are several existing components of the plant that can be retained and salvaged. Table 3-1 summarizes the processes that could be retained. Of the nine potential processes, only the anaerobic digesters and tertiary filters have useful life remaining and meet the LOS criteria. The grit tanks and primary sedimentation tanks could either be replaced or repaired. The oxidation ponds would be retained, but would not be used for secondary treatment. A portion of the pond area would be converted to flow equalization basins. One basin would be used to equalize daily flows, which would reduce the size requirements of downstream processes. Another basin would be used as an overflow basin to minimize the impact of wet weather induced peak flows. The remainder of the pond area may be converted to wetlands, wildlife habitat, or other use that is in compliance with environmental regulations and in conformance with LOS measures.

Table 3-1. Analysis of Processes for Retention and Salvage

Process	Retain	Comment
Grit Tanks/Primary Sedimentation Tanks Preliminary and Primary Treatment (including raw sewage pumping, debris removal, grit removal, and primary sedimentation)	yes	Early replacement of process facilities is envisioned (see Early Execution Projects TM). Either replace or repair
Oxidation Ponds	no	Not used for a secondary treatment
Nitrifying Trickling Filters	no	Large footprint requirements when combined with secondary treatment
Dissolved Air Flotation Clarification	no	Process not suitable for liquid / solids separation in other secondary process treatment technologies.
Tertiary Filtration	yes	With equalization and rebuilding, remaining useful life
Gaseous Chlorine Disinfection	no	Minimize hazardous chemicals (LOS – Environmental/Heatlh & Safety.)
Anaerobic Digestion	yes	Core technology for stabilization of biosolids
Drying beds	no	Insufficient capacity and land needed

4. LIQUID STREAM PROCESS TECHNOLOGY SCREENING

Table 4-1 summarizes the processes that were identified for the liquid stream screening. Primary treatment, secondary treatment and disinfection technologies are presented. Preliminary and tertiary treatment processes are also required but were not evaluated in detail.

The primary treatment units would be sized for the full influent flows and loads. For the secondary and disinfection processes, it is assumed that the existing ponds would be used for diurnal and peak flow

equalization. As a result, the secondary and disinfection processes would not be required to treat the full peak wet weather flows and loads.

Table 4-1. Summary of Liquid Stream Processes

Process	Present Worth Cost	Ability to Nitrify	Energy Consumption	Footprint Requirement	Process Maturity	Resource Consumption
Debris Removal						
Grinders	Low	N/A	Low	Low	Mature	Low
Screens	Low	N/A	Low	Low	Mature	Low
Grit Removal						
Vortex Grit Removal	High	N/A	Low	Low	Mature	Low
Preaerated Grit Removal	Low	N/A	High	High	Mature	High
Primary Treatment						
Primary Sedimentation	Low	N/A	Low	High	Mature	Low
CEPT	Medium	N/A	Medium	Medium	Mature	Medium
Ballasted Sedimentation	High	N/A	High	Low	Evolving	High
Secondary Treatment						
Activated Sludge	Medium	Good	Medium	Highest	Mature	Medium
IFAS	High	Good	Medium	Medium	Evolving	High
BAF	High	Good	Medium	Lower	Evolving	High
MBR	High	Good	Highest	Lowest	Evolving	Highest
Disinfection						
Sodium Hypochlorite	Low	N/A	Low	High	Mature	Low
UV Disinfection	High	N/A	High	Low	Evolving	High

4.1 Preliminary and Primary Treatment Technologies

Preliminary and primary treatment will be required for both the new plant approach and the plant rehabilitation alternatives. Preliminary treatment would consist of: new raw sewage pumping station, debris removal, and grit removal. Currently, the plant has grinders which grind influent debris, but does not actually remove debris from the process. This can result in accumulation of material in downstream processes. For the new plant approach, influent screening will be used instead of influent grinding. For grit removal, preaerated grit basins will be used instead of vortex grit removal; preaerated grit basins are better suited for peak flow conditions.

Primary treatment would consist of new primary sedimentation tanks and some form of separate primary sludge thickening. Performing in-tank primary sludge thickening can impact clarification performance and is not recommended. Three potential primary treatment technologies that were evaluated are summarized below.

- **Primary Sedimentation.** Of all the primary treatment technologies, primary sedimentation has the lowest life cycle cost and is the most mature treatment technology. Primary sedimentation consists of sedimentation basins which are designed to settle out particulate material and produce a clarified effluent. There are no chemicals used in the process and the only energy use is for the sludge scraper

mechanisms and sludge pumping, which make energy costs low. Because chemicals are not used to improve performance, the primary sedimentation process has the largest footprint requirement associated with the necessary clarification area. The primary sedimentation process has the lowest resource consumption of all the primary treatment technologies due to its low energy requirements and lack of chemical requirements.

- **Chemically Enhanced Primary Treatment (CEPT).** The CEPT process is an established technology and is similar to the primary sedimentation process except that chemical addition makes higher surface overflow rates (SOR) possible. As a result, the CEPT process requires less clarification area than primary sedimentation, which makes its footprint considerably smaller. Chemicals that are commonly added include ferric chloride, poly aluminum chloride (PACl) and aluminum sulfate (alum). Polymer can also be added to further improve performance. The application of chemicals will also improve effluent quality due to improved solids capture. The costs attributed with chemical use increase the life cycle cost of the CEPT process. The chemical use means the process has higher resource consumption compared with primary sedimentation.

- **Ballasted Sedimentation.** The ballasted sedimentation process (Figure 4-1) is the newest of all primary treatment technologies considered. The process is commercially available as Actiflo (Veolia Water Solutions and Technology) or Densadeg (Degremont Technologies). Like the CEPT process, ballasted sedimentation uses chemicals to increase SOR, which makes the clarification requirements smaller. However, the ballasted sedimentation process also uses a ballast to increase the density of the sludge flocs so that they settle much faster making clarification requirements even less than CEPT. Sand is used for the Actiflo process, and recycled sludge is used for the Densadeg process. Lamella settling plates are used in the primary clarifier, and present a potential maintenance issue. Ballasted flocculation will have the smallest footprint requirements of all the primary treatment technologies, but will have the highest life cycle cost. High energy consumption and chemical use means the ballasted flocculation has the highest resource consumption of all the primary treatment technologies.

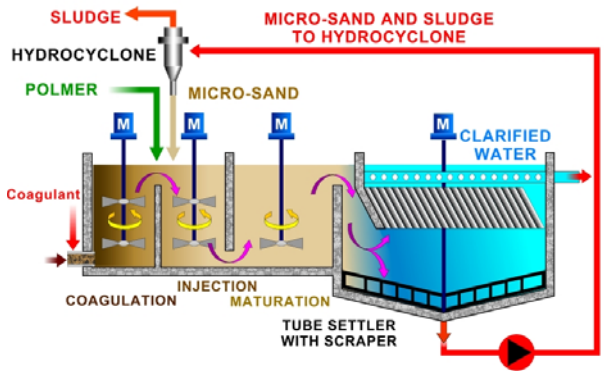


Figure 4-1. Process flow diagram of the Actiflo ballasted flocculation process.

Table 4-2 summarizes the rankings of the primary treatment technologies. For the new plant approach, preliminary treatment would consist of screening and preaeration grit removal. Primary treatment would consist of primary sedimentation due to the low life cycle costs and resource consumption.

Table 4-2. Summary of Primary Treatment Technology Rankings			
Treatment Technology	Life Cycle Cost	Footprint Requirements	Resource Consumption
Primary Sedimentation	Low	High	Low
CEPT	Medium	Medium	Medium
Ballasted Sedimentation	High	Low	High

4.2 Secondary Treatment Technologies

The secondary treatment technologies that were evaluated for the new plant approach would not require the oxidation ponds for treatment. A portion of the ponds would be used for primary effluent flow equalization. All secondary processes that were considered were capable of performing complete nitrification. The four secondary processes that were evaluated are discussed below.

- **Activated Sludge.** The activated sludge process (Figure 4-2) has been in use the longest of all the secondary processes considered. The process consists of aerated basins followed by secondary clarifiers. The aeration basins contain concentrated biomass, or activated sludge, that grows as a result of the degradation of the influent wastewater. The concentration of the activated sludge in the aeration basin, or mixed liquor suspended solids (MLSS) concentration, can range from 1,500 to 4,000 mg/L. Fine bubble aeration is typically used to provide dissolved oxygen (DO) to the activated sludge (coarse bubble aeration can also be used). The activated sludge is then sent to a secondary clarifier where the sludge settles to the bottom of the clarifier, and clarified effluent flows over the weirs as treated effluent. The settled solids are recycled back to the aeration tank to maintain the concentrated biomass. The continuous repetition of aeration and sedimentation results in the natural selection of an activated sludge that will tend to flocculate in the aeration basin and settle in the secondary clarifier. The hydraulic retention time (HRT) of the activated sludge process is typically 6 to 8 hours. The amount of time the activated sludge remains in the system before it is removed as waste sludge, termed solids retention time (SRT), will determine the concentration of the activated sludge. Operation at larger SRT values will result in an accumulation of solids in the reactor and make the tankage requirements higher. However, higher SRT values make nitrification possible by retaining nitrifying bacteria, which are slow growing bacteria relative to other heterotrophic bacteria. The SRT for nitrification is temperature dependant, with lower temperatures requiring higher SRT values. Values can range from 5 to 12 days for a nitrification system. The activated sludge process will have the largest footprint requirements of all the processes considered. To minimize the footprint requirements, the aeration basins would be constructed to be 30-ft deep (typical sidewater depth of 15 ft). The majority of the energy requirements originates from aeration and recycle pumping. Generally considered to have low resource consumption relevant to other secondary processes, the process aeration requirements and oxygen transfer efficiency will determine the actual resource consumption of the activated sludge process.

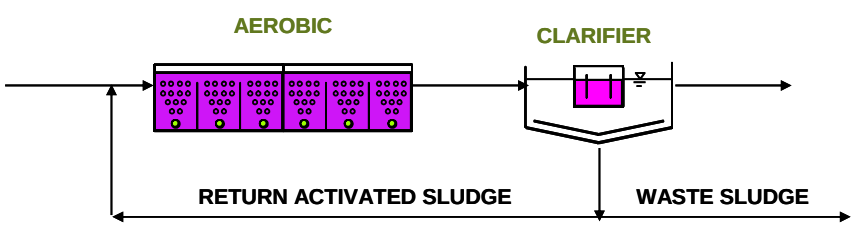
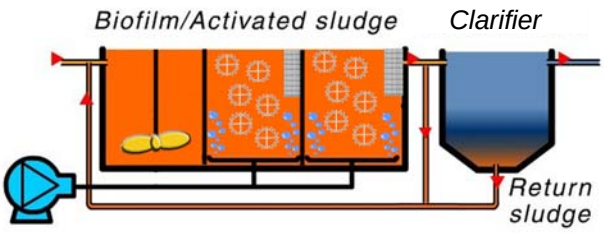


Figure 4-2. Process flow diagram of the activated sludge process for nitrification.

- **Integrated Fixed Film Activated Sludge (IFAS).** The IFAS process (Figure 4-3) is a combination of an activated sludge process and a fixed film process. Plastic carrier media are placed in the aeration

basins of an activated sludge process. The carrier media is designed to provide a site for nitrifying microorganisms to form a biofilm. Screens are installed on the discharge of the aeration basins to retain the media so that it does not flow into the secondary clarifier. The benefit of the nitrifying biofilm is that nitrifiers are retained in the aeration basin at conditions where they would normally be washed out of the system in an activated sludge process. This means that lower SRT operation is possible with the IFAS process so that it is well suited for cold climate applications where high SRT values are necessary to achieve reliable nitrification. The lower SRT of the IFAS process means that it will have lower footprint requirements than an activated sludge process and can be a viable alternative if an activated sludge process were too large. However, the addition of the media makes the process more expensive than activated sludge. In addition, coarse bubble aeration is required to keep the media suspended, which makes energy costs higher (e.g. higher resource consumption) compared with activated sludge. The leading supplier of IFAS media in North America is AnoxKaldnes (Veolia Water).



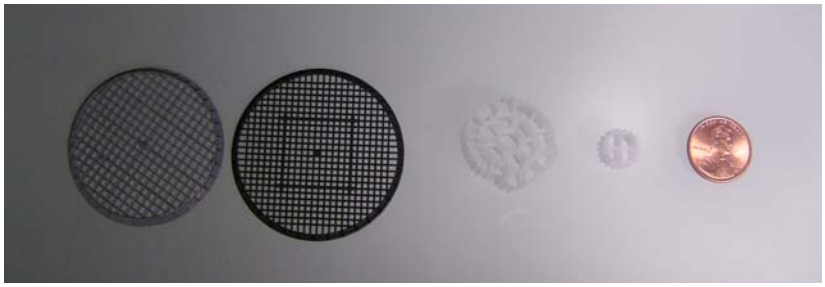


Figure 4-3. Process flow diagram (top) of the IFAS process and an example of carrier media (bottom, AnoxKaldnes media shown).

- **Biological Aerated Filter (BAF).** The BAF process (Figure 4-4) is a submerged fixed-film biological reactor in which microorganisms, attached to the reactor media, oxidize the organic content of the wastewater. The process can also be designed to nitrify. The reactors also operate as filters to removal particulate material, which eliminates the need for a secondary clarification step. To meet secondary treatment requirements, the BAF process would require primary treatment with CEPT to reduce influent loadings. The BAF process is commercially available from Kruger, Inc. (BioStyr process) and Degremont Technologies (Biofor process). The BAF process would more expensive than the IFAS process. The amount of chemical required for CEPT means the BAF will have higher resource consumption than some of the other secondary processes.

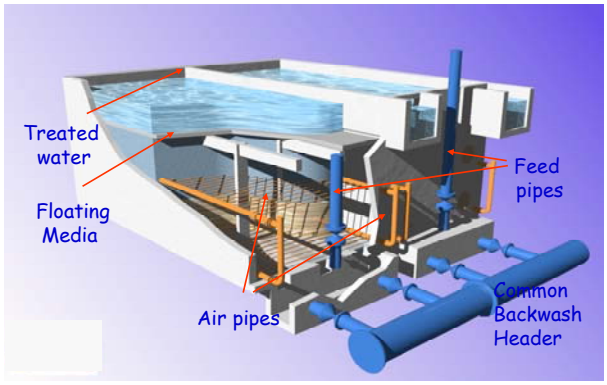


Figure 4-4. Schematic of the BAF process (Biostyr process by Kruger shown).

- **Membrane Bioreactor (MBR).** The MBR process (Figure 4-5) is an activated sludge process that uses membranes for solids separation instead of secondary clarifiers. In modern designs, the membranes are placed in the aeration tanks. An applied vacuum pressure is used to filter the biomass so that solids are retained in the reactor and a membrane filtered effluent is produced. Because membranes are used for separation, the MBR effluent represents a tertiary effluent. Coarse bubble aeration of the membrane is typically used to prevent solids from accumulating at the membrane surface, and routine backwashing (or membrane relaxing where applied vacuum pressure is stopped) is used to prevent solids accumulation. Membranes allow operation at high MLSS concentrations (8,000 to 12,000 mg/L compared to 1,500 to 4,000 mg/L for activated sludge). As a result, the MBR has the smallest footprint requirements of all the selected technologies. The MBR process is typically operated at high SRT values that promote nitrification to minimize biological fouling of the membranes. Fouling is inevitable in a MBR causing increased operating pressures, and routine chemical cleanings are performed to restore the membrane permeability. Although not necessary, primary clarification is commonly used for larger installations to reduce the organic loading. There are several MBR vendors and most North American installations are Enviroquip Inc., Zenon (GE Water and Process Technologies) and Siemens (U.S. Filter). The high energy requirement due to membrane operation and the chemical requirements means the MBR process will have the highest resource consumption of all the secondary processes.

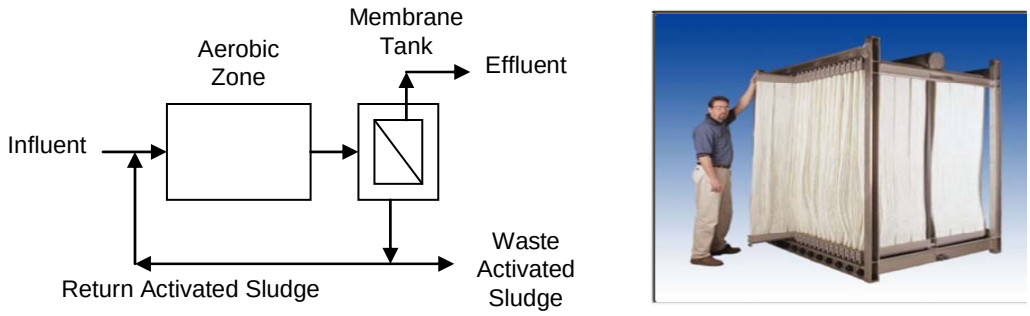


Figure 4-5. Process flow diagram of the MBR process (left) and picture of a membrane (right, Zenon membrane shown).

Table 4-3 summarizes the rankings of the secondary treatment technologies. For the new plant approach, both activated sludge (representing a conventional technology) and MBR (representing a compact technology) were selected for further evaluation. For the activated sludge alternative, the existing multimedia filters would be retained to produce tertiary effluent. For the MBR alternative, the multimedia filters would not be necessary since the MBR produces tertiary effluent. If upon further evaluation, the activated sludge process footprint is determined to be too large, the IFAS process will be used in its place. Although not

conventional, the IFAS process is similar to the activated sludge process and has a lower life cycle cost and lower resource consumption than the BAF and the MBR.

Table 4-3. Summary of Primary Treatment Technology Rankings

Treatment Technology	Life Cycle Cost	Footprint Requirements	Resource Consumption
Activated Sludge	Low	Highest	Lowest
IFAS	Medium	Medium	Medium
BAF	High	Low	High
MBR	Highest	Lowest	Highest

4.3 Disinfection

Currently, the plant uses gaseous chlorine (compressed into liquid form), which is a significant health and safety concern. For the plant replacement alternative, gaseous chlorine would no longer be used. Two disinfection technologies were considered and are summarized below.

- **Sodium Hypochlorite**. Sodium hypochlorite is a liquid solution at atmospheric conditions. Sodium hypochlorite would be delivered by truck and would be stored in tanks, where it would be metered into the filter effluent, upstream of the chlorine contact chamber. Dechlorination would still be necessary before discharge. The existing sulfur dioxide system will eventually be replaced with a sodium bisulfite (SBS) system. The life cycle cost of sodium hypochlorite is low, because of the existing chlorine contact chamber. It represents the technology with the lowest resource consumption due to the low energy cost, and despite the chemical requirements.

- **Ultraviolet (UV) Disinfection**. The UV disinfection process (Figure 4-6) uses UV light, generated by bulbs, to inactivate pathogens. The process is commercially available from Trojan Technologies, Inc. and Wedeco (ITT Industries). Use of this technology eliminates the need for chlorination and dechlorination, which complies with the LOS objective to reduce the use of harmful chemicals on site. The technology also offers reduction of non-compliance risks associated with disinfection by-products that form with chlorination practices. There would only be minimal chemicals needed to perform routine cleaning of UV bulbs. UV disinfection has significant energy requirements to power the UV bulbs means it will have higher resource consumption. Because UV disinfection has more installed equipment compared with sodium hypochlorite, it will have higher maintenance requirements associated with the lamps and ballast.

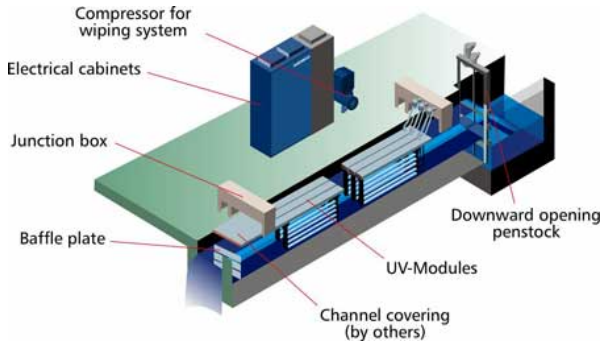


Figure 4-6. Schematic of the UV disinfection process (Wedeco process shown).

Table 4-4 summarizes the rankings of the disinfection technologies. For the conventional treatment alternative, sodium hypochlorite was selected for disinfection. For the compact footprint alternative, UV disinfection was selected for disinfection.

Table 4-4. Summary of Disinfection Technology Rankings			
Treatment Technology	Life Cycle Cost	Footprint Requirements	Resource Consumption
Sodium Hypochlorite	Low	High	Low
UV Disinfection	High	Low	High

5. SOLIDS STREAM PROCESS TECHNOLOGY SCREENING

Table 5-1 summarizes the solids stream processes that were evaluated. Solids thickening, solids stabilization and solids dewatering technologies were evaluated.

Table 5-1. Summary of Solids Stream Processes						
Process	Life Cycle Cost	Regulatory Class	Energy Use	Biosolids Reuse	Process Maturity	Resource Consumption
Solids Thickening						
DAFT	Medium	N/A	High	N/A	Mature	High
GBT	Low	N/A	Medium	N/A	Mature	Medium
RDT	Low	N/A	Lowest	N/A	Evolving	Lowest
Centrifuge	Highest	N/A	Highest	N/A	Mature	Highest
Solids Stabilization						
Mesophillic Digestion	Medium	B	Low	Medium	Mature	High
TPAD	High	A	Medium	High	Evolving	Medium
Cambi/Digestion	High	A	High	High	Evolving	Low
Solids Dewatering						
Centrifuge Dewatering	High	N/A	High	N/A	Established	High
Screw Press	Medium	N/A	Low	N/A	Evolving	Low
Belt Press Dewatering	Medium	N/A	Medium	N/A	Established	Medium

5.1 Solids Thickening

Solids thickening is necessary prior to solids stabilization to reduce the volume of the sludge. By reducing the volume of the sludge, the solids stabilization and solids dewatering processes requirements will be smaller. Solids thickening can be performed separately on the primary and secondary sludge streams. Or, the solids streams can be combined and thickened simultaneously, termed co-thickening. All of the thickening process that were considered can produce at least 4 percent total solids (TS) sludge.

- **Dissolved Air Flotation Thickening (DAFT).** Currently, dissolved air flotation (DAF) is used to separate algae from the pond effluent. These DAF units could be used for sludge thickening in the future, termed DAFT (Figure 5-1) In the DAFT process, dissolved air is introduced to the sludge which results in the formation of air bubbles that attach to solids particles and cause them to rise to the surface. Liquid that remains behind (termed subnatant) is returned to the main liquid stream process. Polymer addition can be performed to improve thickened solids content and to improve subnatant quality. The DAFT process is an established technology that has been in use for over 30

years. The process requires minimal operator attention and can be operated 24 hours per day. Energy use and resource consumption is highest of all the thickening processes.

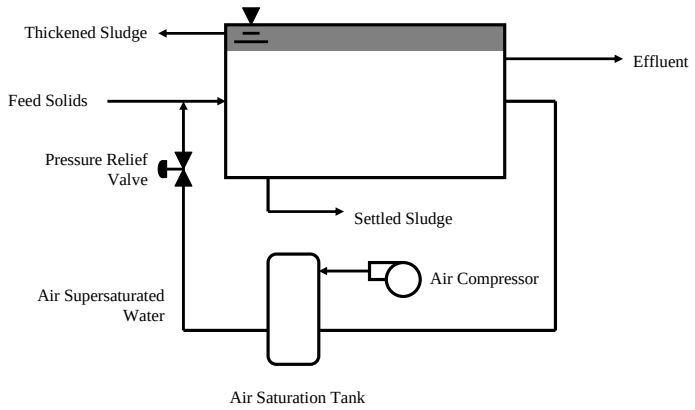


Figure 5-1. Schematic of the DAFT process.

- **Gravity Belt Thickening (GBT).** In the GBT process (Figure 5-2), sludge is dosed with polymer and is travels along a belt that is moved by rollers. As a result of the polymer addition, sludge particles flocculate and excess water drains out through the belt. Plow blades are used to furrow the sludge to improve thickening. The GBT process is commercially available from Siemens Water Technologies and Komline-Sanderson Engineering Corporation, as well as others. Energy use is minimal for a GBT, and the majority of the O&M costs are due to polymer use. The process requires operator attention for startup and shutdown, and is typically not operated without some level of continuous operator attention. Compared to the DAFT process, the GBT will have a higher life cycle cost. GBT units are typically installed in buildings, and because the belt is exposed, odor control is necessary. The odor control requirements increases the life cycle cost and electrical costs of the process.

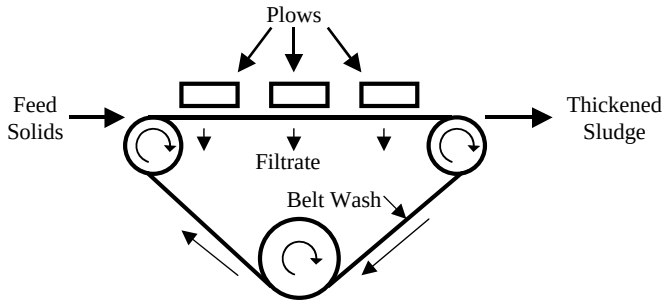


Figure 5-2. Schematic of the GBT process.

- **Rotary Drum Thickener (RDT).** The RDT process (5-3) uses a rotating cylindrical screen that retains sludge and allows excess water to drain out. Prior to the drum, polymer is added to the dilute sludge and mixed to promote floc formation. The RDT process is a low energy process, and electrical requirements are only due to polymer addition and sludge mixing, and the rotation of the drum. Unlike the GBT, the RDT process can be operated continuously with minimal operator attention. RDT units are typically installed in buildings; however, because the RDT is a contained process, the odor control requirements will be much less than for a GBT. The RDT process is commercially sold by Parkson, Vulcan Industries, Inc., and FKC Company, Ltd. The rotary screw thickener, commercially sold by Huber, is a similar technology to RDT and would have similar energy and chemical requirements, footprint requirements and life cycle costs.

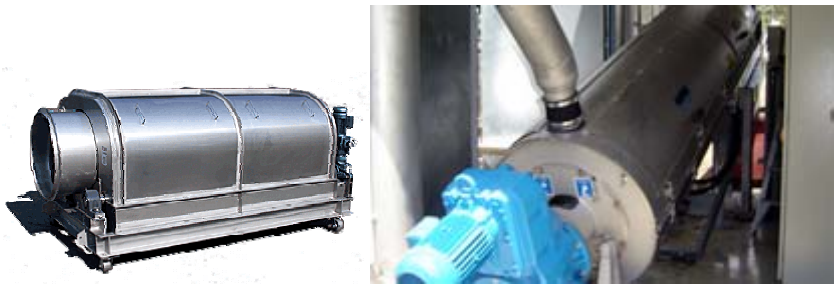


Figure 5-3. Picture of a FKC RDT (left) and a Huber rotary screw press (right).

- **Centrifuge.** The centrifuge (Figure 5-4) can be used either for thickening or dewatering. Thickening is performed using a rotating bowl that separates the solids from the liquid. Rotation produces forces of 500-3,000g which requires a significant amount of energy. The liquid, or centrate, is recycled to the liquid stream processes. The dewatered solids in the centrifuge are discharged using a screw feeder. Polymer is commonly can be used to improve solids content and minimize suspended solids in the centrate. Centrifuges are manufactured by Sharples, Komline-Sanderson and others. The higher energy requirements associated with the centrifuge mean it will have the highest resource consumption. Similar to the RDT process, the unit is contained and odor control requirements will be minimal compared to other processes.

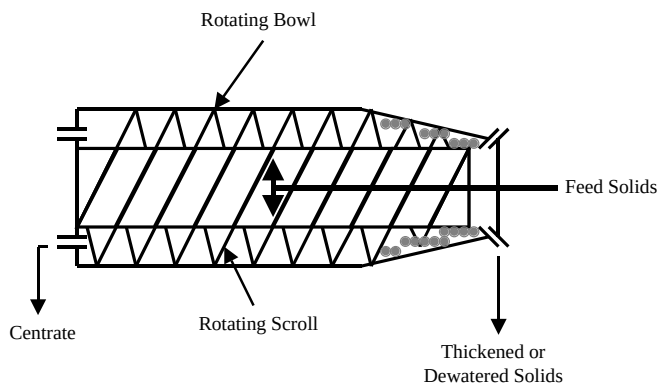


Figure 5-4. Schematic of thickening centrifuge.

Table 5-2 summarizes the rankings of the solids thickening technologies. For the new plant approach, the RDT process was selected for thickening because of its low life cycle cost and low resource consumption.

Table 5-2. Summary of Solids Thickening Technology Rankings

Treatment Technology	Life Cycle Cost	Footprint Requirements	Resource Consumption
DAFT	Medium	Highest	High
GBT	Low	High	Medium
RDT	Low	Medium	Low
Centrifuge	Highest	Low	Highest

5.2 Solids Stabilization

The solids stabilization processes considered were all variations of anaerobic digestion. The anaerobic digestion process results in the destruction of solids which decreases disposal costs. In addition, the biogas that is produced during the process contains methane, which can be used to produce electricity. Other solids

stabilization processes include alkaline stabilization, aerobic digestion and composting. These are not practical alternatives for Sunnyvale because of high energy costs (aerobic digestion), high chemical costs (alkaline stabilization) and large footprint requirements (composting).

The solids stabilization process selected will determine the quality of the biosolids. The classification of biosolids is defined by the U.S. EPA regulation, The Standards for the Use or Disposal of Sewage Sludge (Title 40 of the Code of Federal Regulations [CFR], Part 503 Rule).

- **Mesophilic Digestion.** Anaerobic digestion is performed in the absence of molecular oxygen and results in the decomposition of sludge. As a result, the overall solids in the digestion process are destroyed and converted to biogas (consisting mostly of carbon dioxide and methane). Digester contents can be mixed using pump mixing, draft tube mixing or gas mixing. The temperature of the digester contents will determine the rate of solids destruction, and the mesophilic digestion process is operated at temperatures from 30 to 38 degrees C. The hydraulic retention time (HRT) of the digester will determine the degree of solids destruction, with higher solids destruction occurring at higher HRT values. The mesophilic digestion process is commonly operate at HRT value of 15 days or greater. Mesophilic digestion can be operated to produce Class B biosolids. It will have the lowest energy requirements and the lowest life cycle cost of all the stabilization processes and is considered the to have the lowest resource consumption.

- **Temperature Phased Anaerobic Digestion (TPAD).**The TPAD process is a solids stabilization process where two digesters are operated in series. One version of this process involves operating the first digester at thermophilic temperatures (50 to 57 degrees C) and the second digester at mesophilic temperature. Operation at elevated temperatures increases biological activity so that lower HRT conditions can be used (3 to 5 days), making the digester smaller. The thermophilic digester is followed by a mesophilic digester that is operated at a HRT of approximately 10 days. The TPAD process produces a higher overall volatile solids (VS) destruction, because of the use of the thermophilic digester. However, thermophilic digesters require additional energy to heat the process to thermophilic temperatures. The high energy costs associated with digester heating can be reduced by feeding the digester a more concentrated (or thickened) sludge. The TPAD process can be operated to produce Class A biosolids. To prevent the possibility of short circuiting through the thermophilic digester, a batch pasteurization step can be placed before mesophilic digestion. The TPAD process will have higher energy costs and life cycle cost than mesophilic digestion and is considered to have higher resource consumption. Operation at higher temperatures will mean the TPAD process will have an overall lower HRT than mesophilic digestion and will make the footprint smaller.

- **Cambi/Digestion.** The Cambi thermal hydrolysis process is a high-pressure steam pre-treatment for anaerobic digestion. Sludge fed to the Cambi unit is dewatered to approximately 15 percent TS. In the first stage (termed pulper), the sludge is heated to 100 degrees C using steam. Sludge is then sent to reactors where thermal hydrolysis is performed at 165 degrees C using steam. The excess steam is sent back to the pulper for pre-heating. The hydrolyzed sludge is then sent to a flash tank where a rapid pressure drop occurs that causes cell destruction. Sludge is then cooled before being fed to a mesophilic digester. The Cambi process allows the digester to be fed at higher concentrations and higher solids destruction is possible because the hydrolysis releases additional degradable material. In addition, solids dewatering is also improved (e.g., >30 percent TS is possible). The process was included in the evaluation because it may be applicable for disrupting resistant algae cell material, which could improve digestion efficiency. The thermal hydrolysis step makes the process compliant with Class A regulations for pathogen reduction. The elevated sludge feed concentration means the Cambi/digestion process will have the smallest footprint. However, energy costs can be higher due to the steam production, unless costs are offset by additional gas production

not possible with TPAD or mesophilic digestion. The additional gas production will determine the resource consumption of the process, however it is assumed to have the highest resource consumption of the solids stabilization processes.

Table 5-3 summarizes the rankings of the solids stabilization technologies. For the new plant approach, the TPAD process was selected for solids stabilization because it can provide higher VS destruction than mesophilic digestion, can produce Class A biosolids and has a lower life cycle cost than Cambi/Digestion.

Table 5-3. Summary of Solids Dewatering Technology Rankings

Treatment Technology	Life Cycle Cost	Footprint Requirements	Resource Consumption
Mesophilic Digestion	Low	High	Low
TPAD	Medium	Medium	Medium
Cambi/Digestion	High	Low	High

5.3 Solids Dewatering

Table 5-4 summarizes the solids dewatering technologies that were evaluated. Solids dewatering is discussed in detail in the technical memorandum titled Evaluation of Dewatering Technologies. Three technologies were considered: centrifuge, belt filter press (BFP) and screw press. For the new plant approach, the screw press was selected because of its low life cycle cost and resource consumption relative to the other two technologies. Like the RDT process, the screw press has lower odor control requirements than the BFP (which is similar to a GBT).

Table 5-4. Summary of Solids Stabilization Technology Rankings

Treatment Technology	Life Cycle Cost	Footprint Requirements	Resource Consumption
Centrifuge	High	Low	High
Belt Press	Low	High	Medium
Screw Press	Low	Medium	Low

6. PROCESS TECNOLOGY SCREENING SUMMARY SELECTION

The initial screening identified several processes for liquid stream and solids stream treatment. These processes were narrowed down to two treatment schemes for liquid stream and one treatment scheme for solids processing. For the liquid stream, one conventional and one compact footprint treatment scheme was selected.

6.1 Liquid Stream Process

A process flow diagram of the liquid stream conventional treatment flow scheme is shown in Figure 6-1. The existing tertiary filters would be retained for this alternative. A process flow diagram of the compact footprint flow scheme is shown in Figure 6-2. For this alternative, the existing filters would not be necessary since the MBR produces tertiary effluent water.

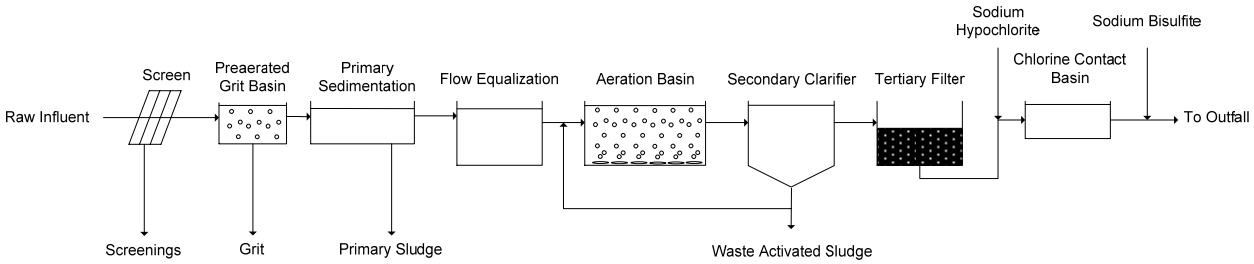


Figure 6-1. Process flow diagram of conventional treatment alternative for the liquid stream.

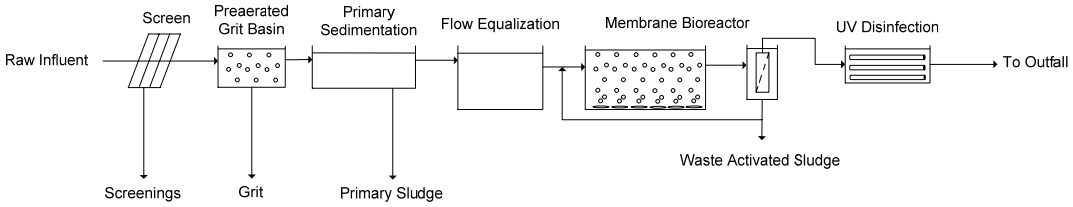


Figure 6-2. Process flow diagram of compact footprint alternative for the liquid stream.

6.2 Solids Stream Process

A process flow diagram of the solids stream treatment flow scheme is shown in Figure 6-3. The existing digesters would be upgraded to TPAD and primary and secondary sludges would be cothickened in a RDT.

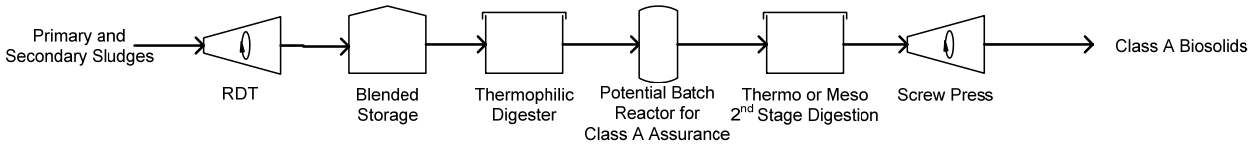


Figure 6-3. Process flow diagram of solids stream..