occur causing the thickened sludge blanket to rise to the surface as gas is produced. EPA's 1979 "*Process Design Manual – Sludge Treatment and Disposal*" indicates that "several researchers have related overflow rates to odor control, but odor is due to excessive retention of solids and can be better controlled by removing the thickened sludge from the thickener at an increased frequency." Several design references indicate that to maintain aerobic conditions and minimize odors associated with gravity thickeners, final overflow rates should be in the range of 400-800 gal/day-ft^2 (16.7-33.3 gal/hr-ft^2). The overflow rate will be discussed in this report in terms of gal/hr-ft^2 since wasting to the thickener will not be continuous over a 24 hour period.

If the feed sludge volume does not allow for an adequate overflow rate, provisions should be made for adding treated wastewater to the feed sludge to achieve an acceptable overflow rate. If the primary clarifier waste sludge pumping capacity is changed to 25 gpm (1,500 gallons per hour), the overflow rate to the thickener will be 2.8 gal/hr-ft^2 for a thickener with a surface area of 531 ft^2. This overflow rate is approximately 17% of the minimum overflow rate of 16.7 gal/hr-ft^2 recommended in the literature. Therefore provisions should be included for adding a minimum of 14-18 gal/hr-ft^2 (125-160 gpm) of secondary clarifier effluent (or other make-up water) to the gravity thickener when sludge is being fed to the unit. As indicated in the EPA design manual, less make-up water can be utilized if a constant sludge retention time (SRT) can be achieved in the thickener. A maximum SRT recommended for design purposes, which does not promote the premature onset of anaerobic digestion in the settled and thickened sludge, is 24 hours.

Other make-up water should be incorporated into the design through a spray bar system mounted to the thickener bridge. The water spray would allow any foam or solids that do float to be dispersed. Spray nozzles should be spaced approximately 24-inches apart, and should be capable of delivering 0.2 – 0.5 gpm per nozzle at a pressure of 40 pounds per square inch (psi). At a 24-inch spacing, a minimum of 12 nozzles would be required for the spray system allowing 2.5-6 gpm of spray water to be applied to the surface of the gravity thickener.

The current side wall depth of the existing digester tank is approximately 18 feet, and the floor has a 1V:3H side slope. Most gravity thickeners are designed with floor slopes of 1V:4H and with a sidewater depth of 12-15 feet deep. Correspondence with a gravity thickener mechanism representative indicated that a thickener stirring/rake assembly with pickets can be installed utilizing the existing floor slope of the digester basin. A full-bridge thickener assembly is recommended with a bridge supported thickener drive and stirring/rake mechanism. Torque on the circular drive is expected to range between 3,380 and 5,070 ft-lb. Supernatant from the thickener should be removed from the thickener basin utilizing a circular overflow weir similar to that on the primary clarifier. Supernatant would be returned the WWTP headworks. The existing depth of the unit will provide additional free board than what is required, however, this is not detrimental to the operation of the gravity thickening process.

Anaerobic Digester Sizing

Recommended design criteria for an anaerobic digestion sludge stabilization facility for Woodland's WWTP (assuming the existing treatment process continues to be utilized) is shown in Table VII-28. The anaerobic digestion facility preliminarily sized in this section is to stabilize primary and secondary sludge generated by the existing primary and fixed film treatment process. Anaerobic digestion is not recommended to be utilized if the liquid treatment process is changed to activated sludge without primary clarification due to: 1) increased operational factors associated with thickening WAS; 2) increased hazards compared to aerobic digestion associated with methane gas production; and 3) high BOD_5 and ammonia concentrations in digester supernatant returned to the liquid treatment process which can adversely affect plant performance.

Table VII-28 Anaerobic Digester Design Criteria			
Design Parameter	*1998*	*2009 (Phase I)*	*2023 (Phase II)*
Population	3,570	6,111	12,089
Solids Wasted from Clarifier (lbs/cap/day)	0.26	0.26	0.21[1]
Solids Wasted from Thickener (lbs/day)	928	1,589	2,577
Volatile Solids Content of Solids Wasted (%)	80	80	80
VSS Wasted from Thickener (lbs/day)	742	1,271	2062
Solids Concentration (%)	4	4	4
Sludge Volume (gpd)	2,782	4,763	7,724
Minimum Sludge Retention Time (days at 95 deg. F)	20	20	20
VSS Reduction (%)	50	50	50

1: Lbs/Capita/Day is reduced for 2023 population based on reduced influent loading associated with City enforcing sewer billing ordinance and developing a pre-treatment ordinance for high strength dischargers.
2: Digester volume required will be provided through the construction of two tanks, rather than a single tank.

Based on a VS loading rate of 0.10 lbs/day-ft^3 ultimate digester capacity required is 20,620 ft^3 or 154,248 gallons. Based on the minimum sludge retention time of 20 days, the ultimate digester capacity required is 154,480 gallons (20,651 ft^3). Based on volume per capita of 2.6 ft^3/person, the ultimate digester capacity required is 31,431 ft^3 (235,123 gallons). The volume per capita sizing guideline is often utilized as a "first-cut" when limited or no solids data exists, and is therefore more conservative than the VS loading criteria or the SRT sizing criteria. All of the sizing criteria above are for heated and mixed digester tanks operated at approximately 95 deg. F. For Woodland, the minimum ultimate digester capacity recommended is 200,000 gallons (26,736 ft^3), 100,000 gallons (13,368 ft^3) per tank.

The most common anaerobic tank design is a low, vertical cylindrical tank with diameters ranging from 20 to 125 feet. Side water depths range between 20-45 feet. Gas lift mixing is most effective when the ratio of tank radius to water depth is between 0.7 and 2.0. The floor of the digester tank is usually conical with the bottom sloping to the sludge withdrawal in the center. Minimum floor slopes are typically 1V:4H.

Recommended anaerobic digester tank dimensions for the proposed Woodland facility are 30 foot diameter by 20 foot side water depth. This yields a ratio of tank radius to water depth of 0.75.

The anaerobic digesters should be designed with multiple sludge inlets and draw-offs. In addition, multiple recirculation suction and discharge points are recommended to provide flexible operation and mixing of the tank contents. Multiple withdrawal levels should also be provided for supernatant sampling and withdrawal. Supernatant will be returned to the headworks of the WWTP.

The tanks should also be completely mixed with the mixing system sized so that a complete tank volume turnover occurs at least once every 30 minutes. Each tank should be insulated so that heat loss to the surrounding environment is minimized. External heat exchangers should be included in the facility design to allow for maintaining sludge digestion at approximately 95 deg. F. Due to the production of methane gas during the anaerobic digestion process, precautions must be taken during design to insure that adequate gas safety and handling equipment is included in the gas system piping to minimize the risk of explosion. It is also recommended that floating covers with gas draw-off equipment be utilized if anaerobic digestion is utilized for solids stabilization.

Aerobic Digester Sizing

Since implementation of the *503 Regulations* in 1993 the most convenient way for aerobic digestion to meet Class B biosolids requirements (pathogen reduction to less than 2,000,000 colony forming units per gram and VSS reduction of at least 38%) is to hold the sludge for at least 60 days at 15 degrees C (59 degrees F). In areas of the country, such as Western Washington, where winter temperatures are often below 15 degrees C for extended periods additional detention time (up to 90 days total) is often necessary to ensure compliance with the Class B requirements. To provide 60-90 days of detention time requires that tank volumes be significantly increased or that the solids concentration be increased in the feed sludge. Often thickening the feed sludge to 4-6% solids concentrations is the preferred alternative due to the capital cost associated with construction of large digestion basins, however, this can create an entirely new set of operational challenges if the digester facility is not specifically designed to handle a thickened feed sludge. Notably air requirements are significantly higher for thickened sludge due to higher oxygen uptake rates and mixing can be adversely affected due to higher sludge viscosity.

Pathogen and VSS reductions required to produce Class B biosolids can also be satisfied by optimizing process control in place of simply providing additional digester volume to provide longer detention times. It is possible to design an aerobic digestion facility that can be properly controlled with minimal operator attention to routinely achieve these stabilization parameters.

It is important to note that the aeration system must be designed with enough flexibility to ensure the oxygen profile in the basin matches the oxygen demand. If this is not done then anaerobic conditions can develop in parts of the digester and odors and ammonia release can occur. Air requirement calculations should be based on providing 2 lbs O_2/ lb VSS applied with sufficient air also provided to ensure that 2 mg/l of oxygen is maintained during aeration to enable nitrification to take place. While nitrification is desirable it should not be allowed to continue unchecked due to the associated pH drop and subsequent upset conditions in the digester basin. To control this the design should allow for the air to be cycled on and off or an anoxic zone should be incorporated into the design so that denitrification can occur. Including the ability to denitrify in the process can allow up to 50% of the alkalinity lost during nitrification to be recovered as nitrates are converted to nitrogen thereby minimizing variation in process pH. In addition, oxygen will be released during the nitrate conversion which can reduce the oxygen requirement in the digestion process by up to 17%. Optimum digester performance occurs with pH in the range of 6.8-8. If the pH drops to less than 6.8 the air should be turned off, while the volume of air supplied should be increased if pH rises above 8. The ability to nitrify and denitrify allows for the production of stabilized biosolids with a low nitrogen content. A low nitrogen content can be very attractive when land application rates are controlled by allowed agronomic nitrogen loading (pounds of nitrogen per acre).

Another element that is critical for successful aerobic digestion is the temperature of the sludge being digested. When the temperature drops to 10 degrees C (50 degrees F) or less biological activity is severely reduced and volatile solids reductions of as little as 20-25% typically occur. Above 37 degrees C (99 degrees F) nitrification will be adversely affected due to the effects of high temperature on the nitrifying bacteria. Optimum digester performance occurs if temperature can be maintained in the range of 20 degrees C (68 degrees F) to 35 degrees C (95 degrees F). Since the temperature in Woodland during winter months is between 10-15 degrees C it is recommended that covers be provided on the digestion basins. Covers will also help to mitigate any odors which could occur if the digesters experience an upset or anaerobic condition. Due to the aeration and digestion capacity of the proposed facility odors are not anticipated to be concern therefore the estimated costs do not include odor control equipment. If odors should be a concern an odor control system can be incorporated into the facility design.

Enviroquip, a manufacturer of wastewater treatment equipment, has developed an aerobic stabilization process called Pre-Thickened Aerobic Digestion (PAD). This process has been developed specifically to meet the needs of WWTP's treating between 0.5-3.0 MGD. The PAD process is comprised of four basins including two digesters, a pre-mix basin, and a gravity thickener. The stabilization process consists of two phases. Phase 1 of the process consists of the pre-mix basin, the gravity thickener and Digester No. 1 operating in a re-circulating looped flow pattern. The sludge in Digester No. 1 is constantly recycled through the gravity thickener, the pre-mix basin and the digester. This constant re-circulation through the gravity thickener allows the sludge solids concentration to gradually increase to 3-3.5%. Digester No. 2 receives no new feed sludge but is continuously aerated and mixed. At the end of Phase 1, the stabilized biosolids in Digester No. 2 are removed and the digester is incorporated into the looped flow pattern with the pre-mix basin and gravity thickener. Digester No. 1 is isolated from the pre-mix and gravity thickener and continuously aerated and mixed. Each phase lasts for approximately 20 days, therefore sludge undergoes stabilization in a 40 day time period. Typically most of the required VSS reduction occurs during the phase when a digester is receiving feed sludge and is part of the flow loop. When a digester is isolated in the next phase volatile reductions continue at a slower rate, however, the real advantage to isolating the digester is for improved pathogen reduction. Isolation of the digester ensures that the stabilized biosolids are not contaminated by incoming feed sludge thereby ensuring that significant pathogen reduction can occur in the basin. Fecal coliform counts of less than 500 colony forming units 100 per milliliters have been reported for this process which is significantly less than the required 2,000,000 required to comply with Class B requirements. The aerobic digestion alternative evaluated for Woodland as part of a proposed SBR WWTP utilizes the PAD process. Recommended design criteria for an aerobic digestion sludge stabilization facility for Woodland's WWTP (assuming an SBR treatment process without primary clarification is utilized for liquid treatment) is shown in Table VII-29.

Table VII-29
Aerobic Digester Design Criteria

Design Parameter	*1999*	*2009 (Phase I)*	*2023 (Phase II)*
Population	3,570	6,111	12,089
Total WAS to digester (lbs/day)	947	1,634	2,455[1]
VSS to digester (lbs/day)	691	1,193	1,792
Solids concentration range to digester (%)	0.5-1.0	0.5-1.0	0.5-1.0
Sludge Volume to Digester (gpd)	11,354-22,707	19,590-39,180	29,433-58,866
VSS Reduction (%)	40-50	40-50	40-50
Diffused-air mixing (ft^3/1,000 ft^3 basin volume-min)	30	30	30

1: Lbs/Capita/Day is reduced for 2023 population based on reduced influent loading associated with City enforcing sewer billing ordinance and developing a pre-treatment ordinance for high strength dischargers.
2: Tank volume shall provide a minimum of 40 days HRT at ultimate design conditions
3: Digester volume will be provided through the construction of two tanks.

The PAD facility as preliminarily sized by Enviroquip would consist of the following: two aerobic digesters each 43' W x 30' L x 24' SWD with an air bridge aeration system; a 35' diameter gravity thickener with standard weirs, trough, baffle and skimmer; a 5.5' W x 35' L x 21.5' SWD pre-mix thickener basin with aeration equipment; two thickened sludge airlift pumps; two scum airlift pumps; and required weir plates for the looped flow pattern. Three blowers, each with a capacity of 1,100 SCFM (82 BHP) would also be required. Two blowers would be in operation with the third unit providing redundant standby capacity. Stabilized biosolids could be transferred to the existing aerobic digestion tank for interim storage and for transfer to haul trucks.

PRESENT WORTH COST COMPARISON OF WWTP ALTERNATIVES

A cost estimate for the Phase I WWTP upgrade for each treatment plant alternative is included in Appendix I of this report. The estimated cost for the upgrade based on designing and constructing additional SBC/RBC treatment capacity and associated processes is approximately $7.0 million dollars including land acquisition, construction contingency, tax, administration, engineering, legal, and survey. The estimated cost for the upgrade based on designing and construction of SBR treatment capacity and associated processes is approximately $7.4 million dollars including land acquisition, construction contingency, tax, administration, engineering, legal, and survey. While the Phase I upgrade is approximately 5.6% higher in terms of initial capital cost if SBR capacity is designed and built the City will realize a significant capital savings when the Phase II upgrade is required. The cost to increase SBR WWTP capacity to meet the projected Phase II needs is approximately $0.8 million dollars including all of the above listed components, while the total capital cost to increase SBC WWTP capacity to meet Phase II needs is estimated to be slightly more than $5.5 million. All estimated costs are based on March 1999 dollars and capital costs have a March 1999 ENR Construction Cost Index (20-City) of 5985.65.

A present worth analysis was performed on the estimated capital cost, annual operation and maintenance (O&M) cost, and projected salvage value of project components for both Phase I and Phase II improvements. Assumptions utilized in the present worth analysis include the following: A 15-year useful life for electrical components, a 20-year useful life for mechanical components, a 50-year useful life for structural components, an interest rate of 5.75% and an inflation rate of 0% (both per federal guidelines) and straight line depreciation of all costs with the exception of land (no depreciation of land). Table VII-30 presents the estimated total present worth value of Phase I and Phase II WWTP upgrades for both treatment process alternatives.

Table VII-30
Estimated Present Worth of Woodland WWTP Upgrade Alternatives

	Capital Cost Present Worth ($, millions)	*O&M[1] Present Worth ($, millions)*	*Salvage[2] Present Worth ($, millions)*	*Total Present Worth ($, millions)*
SBR Alternative				
Phase I Upgrade	$ 7.378	$ 3.974	($ 1.244)	$ 10.108
Phase II Upgrade	$ 0.791	$ 2.880	($ 0.092)	$ 3.579
TOTAL	$ 8.169	$ 6.854	($ 1.336)	$ 13.687
SBC Alternative				
Phase I Upgrade	$ 6.967	$ 3.750	($ 1.206)	$ 9.511
Phase II Upgrade	$ 5.511	$ 2.718	($ 0.853)	$ 7.376
TOTAL	$ 12.478	$ 6.468	($ 2.059)	$ 16.887

1: Present Worth of Phase I O&M is for the first 10 years.
Present Worth of Phase II O&M is for the second 10 years.
2: Salvage value in year 2023.

As shown in Table VII-30 there is approximately $3.2 million (19%) in savings (1999 dollars) to the City of Woodland over the next 24 years if the WWTP is converted to an SBR treatment process. Most of the savings is due to significantly reduced capital construction costs associated with Phase II. Additional mixing and aeration equipment and UV disinfection capacity would be required for the SBR but no additional basin volume would be required as part of Phase II for the SBR/PAD alternative. In contrast the SBC alternative would require construction of large capital cost items including two additional primary clarifiers, three secondary clarifiers, and an SBC basin.

Due to the significant savings available to the City of Woodland and due to the increased capability of the SBR process for nutrient removal it is recommended that the City of Woodland convert the community's wastewater treatment plant to an SBR process with UV disinfection and a pre-thickened aerobic digestion (PAD) facility for solids treatment. The recommended improvements to serve the projected 2023 population will provide the City of Woodland with a wastewater treatment system that is capable of consistently meeting all anticipated treatment and water quality standards. The improvements when implemented will provide the City with conservatively sized and responsive treatment processes that will be flexible and tolerant when high flow or loading occurs. A more detailed discussion of the recommended alternative is provided in Section VIII of this report.