FLORIDA RURAL WATER ASSOCIATION

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DRAFT

FRWA Whitepaper

Wastewater Treatment Recommendations for Small & Medium Sized Utilities

(under 1.0 Million gallons per day)

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What is the best type of wastewater treatment facility for small and medium sized utilities in Florida?

In a word – **it depends**. The objective of this whitepaper is to identify the best, most reasonable, cost effective, and reliable wastewater treatment plant for your community and ratepayers. We provide this for your consideration and without regard to favoritism, special interest, or hope of future design fees. Please be careful when choosing a treatment plant because you're going to have to live with that decision for a long-long time – long after the consultant is gone.

FRWA circuit riders and engineers work all around the state and we see everything – everything that works and doesn't. We see some pretty big disasters and are willing to help you avoid them. Our advice and assistance is a FREE membership benefit, we are available anytime you want to talk. We will be around to assist you long after the plant is constructed and you are operating it. Plus FRWA engineering staff has considerable experience designing, permitting, constructing, and operating all types of treatment plants.

Wastewater Treatment Processes Ranking. The ranking of wastewater treatment processes recommended by FRWA is as follows, beginning with highest recommendation and moving to lowest:

1. **Oxidation Ditches** (a.k.a. Carousels) has many options for biological nutrient removal treatment and surge capacity.

2. **Conventional or Extended Aeration** Suspended Growth Systems (including nitrification, Denitrification, and proprietary schemes).

3. **Contact Stabilization** Suspended Growth System (limited nutrient removal capability)

4. **Fixed-Film Treatment Processes**, Trickling Filters, Biotowers, Rotating Biological Contactors (RBC), etc.

5. **Aerated Lagoons, Facilitative Lagoons,** etc.

6. **Sequence Batch Reactors** (SBRs).

7. **Other state-of-the-art Treatment Schemes** (typically these are not appropriate for medium and small size systems).

Table 1 ~ Rankings of Wastewater Treatment Processes under 1.0 MGD [1]

☺☺ Excellent | ☺ Good | ○ Okay | ⊙ Fair | ◎◎ Poor

Ranking	**Basic Treatment Processes** (as defined herein)	Reliability of Operation & Treatment for Small & Medium WWTPs	Ability to Handle Surges & Toxic Shocks	Low Cost & Ease of Operation	Consistently Maintain Secondary Treatment Stds.	Consistently Maintain Reuse Quality Effluent Stds.	Construction Costs
1	Oxidation Ditches (Carousels)	☺☺	☺☺	☺☺	☺☺	☺☺	☺
2	Extended Aeration	☺☺	☺	☺☺	☺☺	☺☺	☺☺
3	Contact Stabilization	○	○	○	○	⊙	☺☺
4	Fixed-Film Treatment	☺	⊙	☺	☺	⊙	☺
5	Aerated & Facilitative Lagoons	☺	☺	☺☺	☺☺	○	○
6	Sequence Batch Reactors (SBRs)	◎◎	◎◎	⊙	○	⊙	☺☺
7	Other Schemes (MBRs, etc)	⊙	○	⊙	☺	☺	◎◎

Description Ranking Criteria. The six categories used by FRWA to evaluate and rank the different treatment processes are:

1. **Reliability of Operation and Treatment for small and medium sized systems.** Reliability of your facility is a primary goal – this is where you will save the most money in the long run when the plant produces a consistent effluent and all units operate up to marketing claims. Would you buy a car if you knew it did not perform as promised? The same goes with treatment plants and they are more complex and costly. Computer operated controls may look good on paper but one lightning strike or bad component can make the whole plant inoperable – any cost savings goes right out the window as the operator has to baby-sit a plant 24/7 for weeks while the special parts come in.

2. **Ability to Handle Surges and Toxic Shocks.** Wastewater treatment plants are expected to take all kinds of abuse and anything that can be flushed down the drain. It's a case of out of sight, out of mind. Not all treatment processes are able to handle these abuses and toxic shocks without significant operator intervention (such as Sequence Batch Reactors). It is not unusual to have these events occur on a Friday night. Some substances are toxic to biological organisms in the wastewater. It is not uncommon for the treatment plant biomass to die in these events and cause problems meeting the FDEP effluent requirements. A good operator can save the situation by nursing the plant back to a healthy balance – but he or she spends the next 48-hours (burning over-time) trucking the bad stuff to another plant that can handle the toxic load. The other major issue that WWTPs must be able to handle is large sewage flows that

[1] MGD is million gallons per day.

occur just after a rainstorm – infiltration into sewer lines, cleanouts and manholes. Infiltration dilutes the wastewater; microbes are starved from the food necessary to keep them alive. Some of the same concerns are meeting the FDEP effluent requirements. The best overall treatment scheme to handle these scenarios is oxidation ditches, the second best is extended aeration with surge tanks, and the worst are SBRs.

3. **Low Cost and Ease of Operation.** Small communities cannot always afford to staff the plant full time with certified operators and often rely on contract operations to supplement or completely run the plant. This means that any problems with operation, reliability, or variability of flows directly impact your budget. This is not a case of making it easy for the operator; it is a concern that any decision maker must weigh.
4. **Consistently Maintain Secondary Treatment Standards.** Secondary treatment and basic disinfection is adequate for most sprayfields and percolation ponds -- slow-rate land application; restricted public access (Rule 62-610, FAC, Part II and table 2 below).
5. **Consistently Maintain Reuse Quality Effluent Standards**. Effluent quality standards for public access reuse require secondary treatment plus filtration, and high-level disinfection. This is designated as slow-rate land application; public access areas, residential irrigation, and edible crops (Rule 62-610, FAC, Part II and table 2 below).
6. **Construction Costs.** The cost of construction is always a consideration, but should be carefully considered against the long-term cost of operation and reliability of the system. For this reason FRWA recommends oxidation ditches and extended aeration and strongly discourages sequence batch reactors (SBRs) and other state-of-the-art schemes such as membrane bioreactors (MBRs). Let the larger systems try out these new technologies, work out the "bugs", and absorb the costs of experimentation.

Effluent Standards Drive the Selection of Treatment Process. The most important element in selecting the treatment process for your plant is the effluent limitation and disposal method. Because of recent implementation of the EPA's proposed numeric nutrient criteria[2] for Florida we strongly recommend: (1) **sprayfields** or effluent reuse by agricultural customers (seed crops, pastures, commercial nurseries, sod farms, and so forth); or (2) **percolation ponds** (rapid infiltration basins) – and no discharge to surface waters[3].

A third option is effluent reuse in areas with public access, such as golf courses, cemeteries, parks, landscaped areas, hotels, motels, highway medians, and so forth – however the capital costs for this type of system is very expensive. Public access reuse is allowed only for systems over 100,000 gpd (permitted capacity). In addition to treatment and high level chlorination the system must install a network of reuse transmission and distribution piping, such that it is not cost effective for small and most medium sized communities.

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[2] The Numeric Nutrient Criteria Rule (NNC) is driven by over-zealous environmental groups NOT actual science or rational consideration of the detrimental impact on Florida's wastewater treatment plants with surface discharge. The expected costs for compliance are estimated by FRWA at increasing individual wastewater bills $50 to $100 per month. This new draconian regulation is slated to be effective on November 15, 2010 (yes that's correct) and will require total nitrogen limits as low as 0.5 mg/L and total phosphorous limits as low as 0.01 mg/L. <u>None</u> of the wastewater treatment methods listed in this paper can meet these limits. The only practical way to obtain these unusually low and unrealistic standards will require a reverse osmosis unit to be installed at the end of the pipe and before the effluent touches surface waters of the state. FRWA has several whitepapers available on this subject.

[3] Surface waters of the state include any canal, stream, river, lake, wetland, marsh, estuary, or coastal water.

Table 2 ~ Effluent Standards Drive the Selection of Treatment Process [4]

Reuse System Type	Reuse Activities	Part in Chapter 62-610	Treatment and Disinfection Requirements[5]
Slow-rate land application systems; restricted public access	Irrigation of pastures, trees, feed, fodder, fiber, or seed crops	Part II	Secondary treatment and basic disinfection
Slow-rate land application systems; public access areas, residential irrigation, and edible crops	Residential, golf course, other landscape irrigation, Toilet flushing, Fire protection, Dust control, Aesthetic features (ponds and fountains), Irrigation of edible crops (direct contact only with crops that will be peeled, skinned, cooked, or thermally processed)	Part III	Secondary treatment, filtration, and high-level disinfection
Rapid-rate land application systems	Rapid Infiltration Basins (RIBs) and Absorption Fields	Part IV	Secondary treatment,[6] basic disinfection, < 12 mg/L NO_3-N [7]
Groundwater recharge and indirect potable reuse	Salinity barriers and Augmentation of surface waters	Part V	Principal treatment and disinfection or full treatment and disinfection (depending on use) [8]
Overland flow systems		Part VI	Low-level disinfection
Industrial uses of reclaimed water	Cooling water, Wash water, and Process water (not to include food processing for human consumption)	Part VII	Secondary treatment and basic disinfection (additional treatment may be needed to meet needs of a particular application)

Did you know that most wastewater systems in Florida serve less than 10,000 persons?

According to the FDEP[9] about 80-percent of Florida's facilities have capacities less than 100,000 gallons per day – serving a population of about 1,250 persons. These facilities however, account for only about 2-percent of the total permitted capacity in the state.

Most wastewater systems in Florida, about 88-percent have facilities under 1.0 MGD capacity – these small and medium systems are the focus of this paper.

Only about two-thirds (64-percent) of Florida's population is served by central sewer systems and treatment facilities. The remaining one-third uses septic tanks (on-site sewage treatment and disposal).

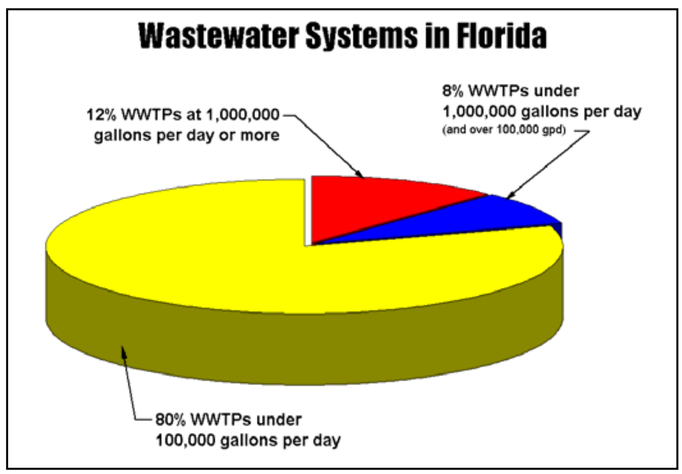

Figure 1~ Florida's Wastewater Treatment Plants by Size

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4 From *"Reclaimed Water and Florida's Water Reuse Program."* Martinez, C.J. & Clark, M.W. http://edis.ifas.ufl.edu/ae448

5 See FDEP Chapter 62-610 F.A.C. for specific treatment and disinfection requirements.

6 Secondary treatment is NOT allowed in nutrient sensitive areas, such as the springs, estuaries, Florida Keys, and so forth.

7 Nitrate as nitrogen.

8 See FDEP Chapter 61-610 F.A.C. for specific treatment and disinfection descriptions.

9 FDEP wastewater facts, see http://www.dep.state.fl.us/water/wastewater/facts.htm

About 44-percent of Florida's domestic wastewater from centralized treatment systems is disposed through surface water outfalls and 22-percent through deep aquifer injection wells. The remainder is managed through other groundwater disposal systems, such as percolation ponds, Rapid Infiltration Basins (RIBs), and sprayfields. Six (6) facilities use Atlantic Ocean outfalls for wastewater effluent disposal. Approximately 260 facilities discharge to other surface waters. Nearly 50 facilities use deep aquifer injection.

Small and medium systems (88-percent and under 1.0 MGD capacity) face problems of economies of scale and more frequently struggle with system reliability, cost-effectiveness, manpower shortages, financial sustainability and regulatory compliance.

WWTP Ranking No. 1 ~ Oxidation Ditches (a.k.a. Carousels, CLR) [10]

FRWA recommends oxidation ditches over all other treatment schemes because of the reliability of treatment; ability to achieve effluent regulations; ease of operation; low cost to operate and maintain; and ability to handle hydraulic surges and toxic shocks.

Oxidation ditches (a.k.a. Carousels, Closed Loop Reactors) are a type of modified activated sludge biological treatment process that utilizes long solids retention times (SRTs) to remove biodegradable organics and microbes. Oxidation ditches are typically complete mix systems with 24-hours of detention times, but they can be modified to approach plug flow conditions.

Typical oxidation ditch treatment systems consist of a single or multi-channel configuration within a ring, oval, or horseshoe-shaped basin. Horizontally or vertically mounted aerators provide aeration, circulation, and oxygen transfer in the ditch.

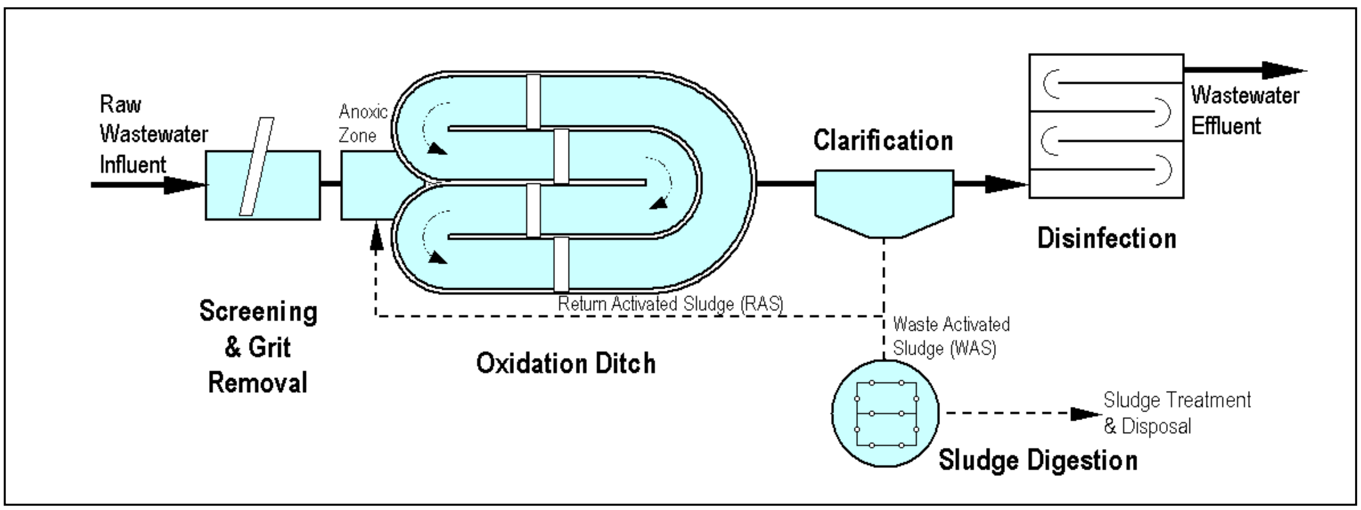

Figure 2 ~ Oxidation Ditches Process Flow Schematic

Raw wastewater is first screened before entering the oxidation ditch. Depending on the system size and manufacturer type, a grit chamber may be required. Once inside the ditch, the wastewater is aerated with mechanical surface or submersible aerators (depending on manufacturer design) that propel the mixed liquor around the channel at velocities high enough to prevent solids deposition. The aerator ensures that there is sufficient oxygen in the fluid for the microbes and adequate mixing to ensure constant contact between the organisms and the food supply.

[10] USEPA (2000) *Wastewater Technology Fact Sheet -- Oxidation Ditches*, EPA 832-F-00-013, http://www.epa.gov/OWM/mtb/index.htm

Figure 3 ~ Oxidation Ditches with Lakeside Aerators

Figure 4 ~ Oxidation Ditches with EIMCO Aerators

Oxidation Ditch Advantages

- Main Advantage - ability to achieve removal performance objectives with low operational requirements and operation and maintenance costs.

- Oxidation ditches tend to operate in an extended aeration mode consisting of long hydraulic and solids retention times, which allow more organic matter to break down. Treated sewage moves to the settling tank or final clarifier, where the biosolids and water separate. Wastewater then moves to other treatment processes while sludge is removed. Part of it is returned to the ditch as return activated sludge (RAS), while the rest is removed from the process as the waste activated sludge (WAS). WAS is wasted either continuously or daily and must be stabilized prior to disposal or land application.
- Flexibility of operation for biological nutrient removal and reliable treatment to advanced wastewater treatment (AWT) standards for reuse and surface water discharge with tertiary filtration.
- Added measure of reliability and performance over other biological processes owing to a constant water level and continuous discharge, which lowers the weir, overflow rate and eliminates the periodic effluent surge common to other biological processes, such as SBRs.
- Long hydraulic retention time and complete mixing minimize the impact of a shock load or hydraulic surge.
- Produces less sludge than other biological treatment processes owing to extended biological activity during the activated sludge process.
- Energy efficient operations result in reduced energy costs compared with other biological treatment processes. Ratio 2.0 to 4.5 lbs O_2/HP-hr in comparison to diffused air aeration of 1.2 to 1.8 lbs O_2/HP-hr.
- Little or no chemical expense

Oxidation Ditch Disadvantages

- Oxidation ditches can be noisy due to mixer/aeration equipment, and tend to produce odors when not operated correctly.
- Biological treatment is unable to treat highly toxic waste streams.
- Requires a larger land area than other activated sludge treatment options. This can prove costly, limiting the feasibility of oxidation ditches in urban, suburban, or other areas where land acquisition costs are relatively high.
- Effluent suspended solids concentrations are relatively high compared to other modifications of the activated sludge process requiring well-designed circular clarifiers.

Oxidation Ditch Comments

- Oxidation ditch surface mixers come in a high variety of arrangements – common suppliers are (beginning with lower energy requirements and progressing to higher) is the Lakeside Rotor (highest efficiency); moderate cost and efficiency is the Orbal Disk; and highest is the EIMCO EWT Surface Aerator

Proprietary Oxidation Ditch Designs [11]

There are dozens of proprietary designs that attempt to enhance or improve oxidation ditch treatment and operation. While these designs include automatic controls, computer analysis, and instrumentation which typically raises the cost of construction a good wastewater plant operator (well educated in these schemes) can run the oxidation ditch to achieve excellent biological nutrient reduction and produces effluent concentrations low in BOD, nitrogen and phosphorus with little or no costly chemical addition.

It is FRWA's opinion that the wastewater treatment plant operators, which rely on their own ability to monitor, adjust and tweak the treatment process, provide a superior effluent! These men and women are true professionals and unsung heroes in safeguarding public health, safety and the environment.

WWTP Ranking No. 2 ~ Conventional or Extended Aeration Suspended Growth Systems (including nitrification, denitrification, and proprietary schemes)

Conventional Activated Sludge. In a conventional (plug-flow) activated sludge plant the primary-treated wastewater and acclimated micro-organisms (activated sludge or biomass) are aerated in a basin or tank.

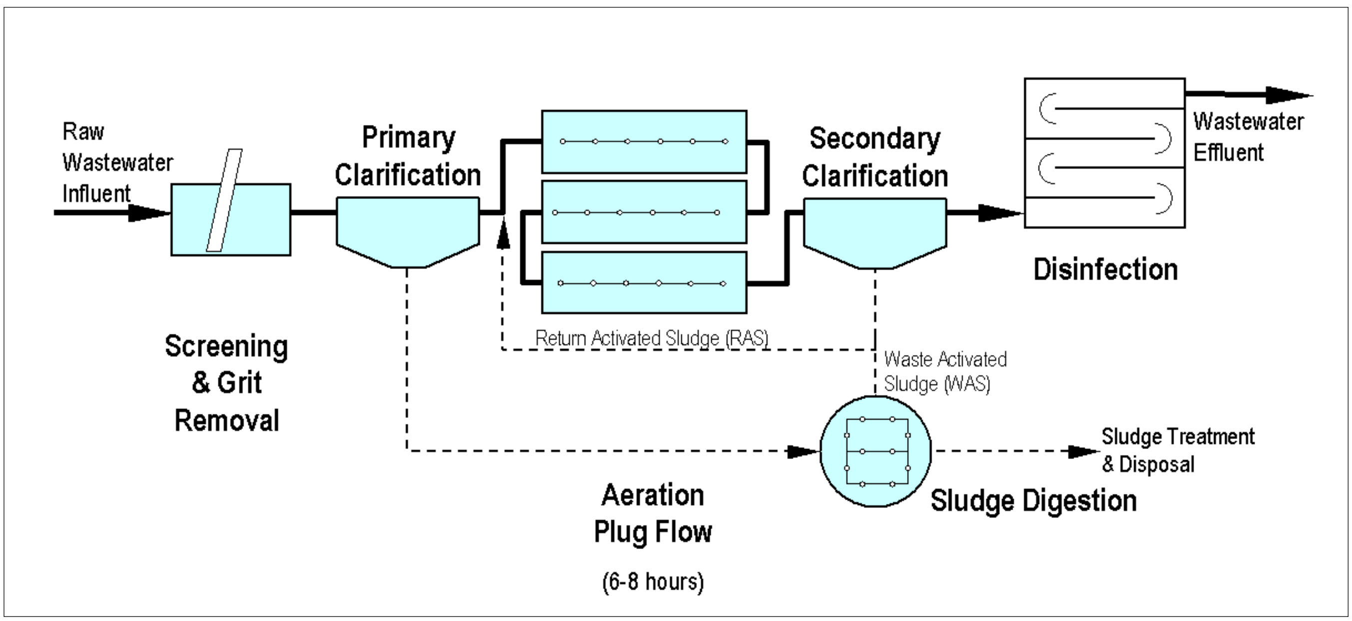

Figure 5 -- Conventional Activated Sludge Process Flow Schematic

After a sufficient aeration period, the flocculent activated sludge solids are separated from the wastewater in a secondary clarifier. The clarified wastewater flows forward for further treatment or discharge. A portion of the clarifier underflow sludge is returned to the aeration basin for mixing with the primary- treated influent to the basin and the remaining sludge is wasted to the sludge-handling portion of the treatment plant. The portion recirculated is

[11] Siemens has several design products and processes for oxidation ditches and supply the Orbal Disk. Orbal has Vertical Loop Reactor (VLR) and VertiCel processes. www.water.siemens.com; Kruger is another supplier of oxidation ditch technologies and offers Double Ditch (D-Ditch), Triple Ditch (T-Ditch), BioDenitro and BioDenipho processes. The author has researched and extensively studied the Kruger process for other design applications under 1.0 MGD. http://www.veoliawaterst.com/oxidationditch/en/?org=kruger.en; EIMCO Water Technologies provides several products including the Carrousel denitIR System designed to provide a simple, cost-effective method of biological nitrification and denitrification without the need for expensive internal recycle pumps. The author has been involved in the design of about eight plants using the EIMCO mixers and carrousel design. http://www.glv.com/WATER/Municipal_Wastewater/Biological_Treatment/EWT_Carrousel_denitIR__System/ProductDescription.aspx

determined on the basis of the ratio of mixed liquor volatile suspended solids (MLVSS) to influent wastewater biochemical oxygen demand, which will produce the maximum removal of organic material from the wastewater. Recirculation varies from 25 to 50 percent of the raw wastewater flow, depending on treatment conditions and wastewater characteristics.

Extended Aeration Plants

The extended aeration process is one modification of the activated sludge process, which provides biological treatment for the removal of biodegradable organic wastes under aerobic conditions. Air may be supplied by mechanical or diffused aeration to provide the oxygen required to sustain the aerobic biological process. Mixing must be provided by aeration or mechanical means to maintain the microbial organisms in contact with the dissolved organics. In addition, the pH must be controlled to optimize the biological process and essential nutrients must be present to facilitate biological growth and the continuation of biological degradation.

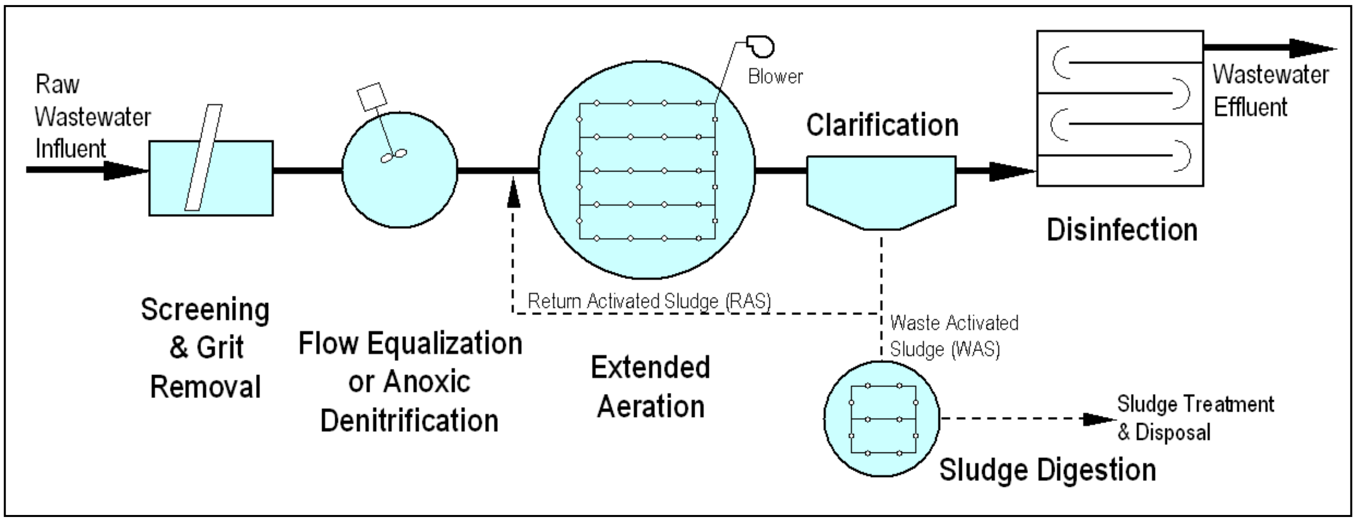

Figure 6 -- Extended Aeration Activated Sludge Process Flow Schematic

Proprietary Activated Sludge Process Designs. There are several proprietary activated sludge process designs available, but not covered in this whitepaper. One biological nutrient removal process, which is commonly used, is known as the Five Stage Bardenpho Process. The Bardenpho Process consists of an initial anaerobic contact zone followed by four alternating stages of anoxic and aerobic conditions. In the anaerobic zone, all of the raw wastewater is mixed with the return sludge. The anaerobic conditions in the initial contact zone is necessary to effect phosphate removal. The first anoxic zone follows the anaerobic zone. Nitrates and nitrites (NOx) are supplied to the anoxic zone by recycling nitrified mixed liquor from the following aerobic zone. The organic material in the raw wastewater is used as a carbon source by the denitrifying bacteria in the first anoxic zone to reduce NOx to elemental nitrogen or nitrous oxide. The first aerobic (oxic) zone is followed by a second anoxic zone where any remaining NOx in the mixed liquor is reduced by the endogenous respiration of the activated sludge. The final stage is aerobic where the mixed liquor is reaerated before reaching the final clarifier. The dissolved oxygen of the wastewater effluent is increased to prevent further denitrification in the clarifier and to prevent the release of phosphates to the liquid in the clarifier.

The Bardenpho Process and several others are capable of achieving a high percentage of nitrogen compound removal as well as phosphate removal. These types of processes require substantially larger tank volumes than conventional activated sludge systems, which means higher capital outlays. Additionally, they rely on endogenous respiration in the second anoxic reactor, which is a relatively slow process. Thus, use is limited to small plants.

Extended Aeration Plants Advantages

- Plants are relatively easy to operate, when compared to other treatment schemes.
- Extended aeration processes are good at handling organic loading and flow fluctuations, as there is a greater detention time for the nutrients to be assimilated by microbes.
- Systems have reduced odors over contact stabilization and SBRs, can be installed in most locations, have a relatively small footprint, and can be landscaped to match the surrounding area.
- Extended aeration systems have a relatively low sludge yield due to long sludge ages, can be designed to provide nitrification, and do not require a primary clarifier.

Extended Aeration Plants Disadvantages

- Extended aeration is inferior to oxidations ditch treatment ability, which have a long hydraulic retention time and complete mixing that minimize the impact of a shock load or hydraulic surge.
- Extended aeration plants do not achieve denitrification or phosphorus removal without additional unit processes. The addition of a flow equalization / anoxic denitrification basin and injecting return activated sludge can correct this issue, but is costly.
- Extended aeration plant has limited flexibility in adapting to changing effluent requirements resulting from regulatory changes. However a tertiary filter can correct this issue.
- A longer aeration period requires more energy than contact stabilization, but better effluent quality is obtained.
- Systems require a larger amount of space and tankage than other "higher rate" processes (contact stabilization and SBRs), which have shorter aeration detention times.

WWTP Ranking No. 3 ~ Contact Stabilization Suspended Growth System
(limited nutrient removal capability)[12]

The contact stabilization activated sludge process is characterized by a two-step aeration system. Aeration of short duration (½ to 2 hours) is provided in the contact tank where raw or primary-settled wastewater is mixed with the activated sludge in the contact tank. The effluent from the contact tank is then settled in a final settling tank. The settled activated sludge to be recycled from the final clarifier is drawn to a separate re-aeration in a stabilization basin for 3 to 8 hours of aeration time. It is then returned to the contact aeration basin for mixing with the incoming raw wastewater or primary settled effluent. In addition to a shorter wastewater aeration time, the contact stabilization process has the advantage of being able to handle

[12] USEPA (1999) *Wastewater Technology Fact Sheet -- Fine Bubble Aeration*, EPA 832-F-99-065, http://www.epa.gov/OWM/mtb/index.htm

greater shock and toxic loadings than conventional systems because of the buffering capacity of the biomass in the stabilization tank. During these times of abnormal loadings, most of the activated sludge is isolated from the main stream of the plant flow. Contact stabilization plants should NOT be used where daily variations in hydraulic or organic loadings routinely exceed a ratio of 3:1 on consecutive days or for plants with average flows less than 0.1 MGD. [13]

Contact Stabilization Plant Disadvantages

- Contact stabilization is inferior to other treatment schemes, and has limited ability to handle shock loads or hydraulic surges.
- Contact stabilization plants do not achieve denitrification or phosphorus removal without additional unit processes.
- Contact stabilization plants have limited flexibility in adapting to changing effluent requirements resulting from regulatory changes.

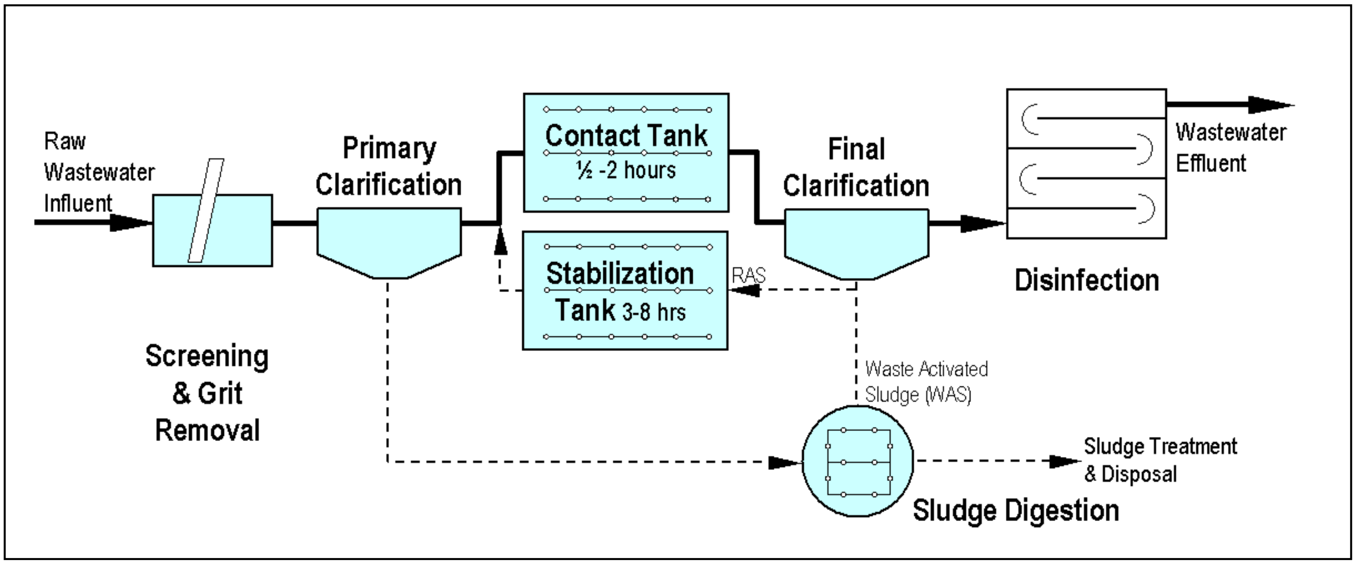

Figure 7 -- Contact Stabilization Suspended Growth Process Flow Schematic

WWTP Ranking No. 4 ~ Fixed-Film Treatment Processes -- Trickling Filters, Biotowers, Rotating Biological Contactors (RBC), etc.[14] [15]

Fixed-Film Treatment is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater. This type of system is common to a number of technologies such as rotating biological contactors and packed bed reactors (biotowers). These systems are known as attached-growth processes. In contrast, systems in which microorganisms are sustained in a liquid are known as suspended-growth processes.

Fixed-Film Treatment enables organic material in the wastewater to be adsorbed by a population of microorganisms (aerobic, anaerobic, and facultative bacteria; fungi; algae; and protozoa) attached to the medium as a biological film or slime layer (approximately 0.1 to 0.2 mm thick). As the wastewater flows over the medium, microorganisms already in the water gradually attach themselves to the rock, slag, or plastic surface and form a film. The organic

[13] USEPA (2000) *Wastewater Technology Fact Sheet* -- Package Plants, EPA-832-F-00-016, http://www.epa.gov/OWM/mtb/index.htm

[14] USEPA (2000) *Wastewater Technology Fact Sheet -- Trickling Filters*, EPA-832-F-00-014, http://www.epa.gov/OWM/mtb/index.htm

[15] USEPA (2000) *Wastewater Technology Fact Sheet -- Trickling Filter Nitrification*, EPA-832-F-00-015, http://www.epa.gov/OWM/mtb/index.htm

material is then degraded by the aerobic microorganisms in the outer part of the slime layer. As the layer thickens through microbial growth, oxygen cannot penetrate the medium face, and anaerobic organisms develop. As the biological film continues to grow, the microorganisms near the surface lose their ability to cling to the medium, and a portion of the slime layer falls off the filter. This process is known as sloughing. The sloughed solids are picked up by the underdrain system and transported to a clarifier for removal from the wastewater.

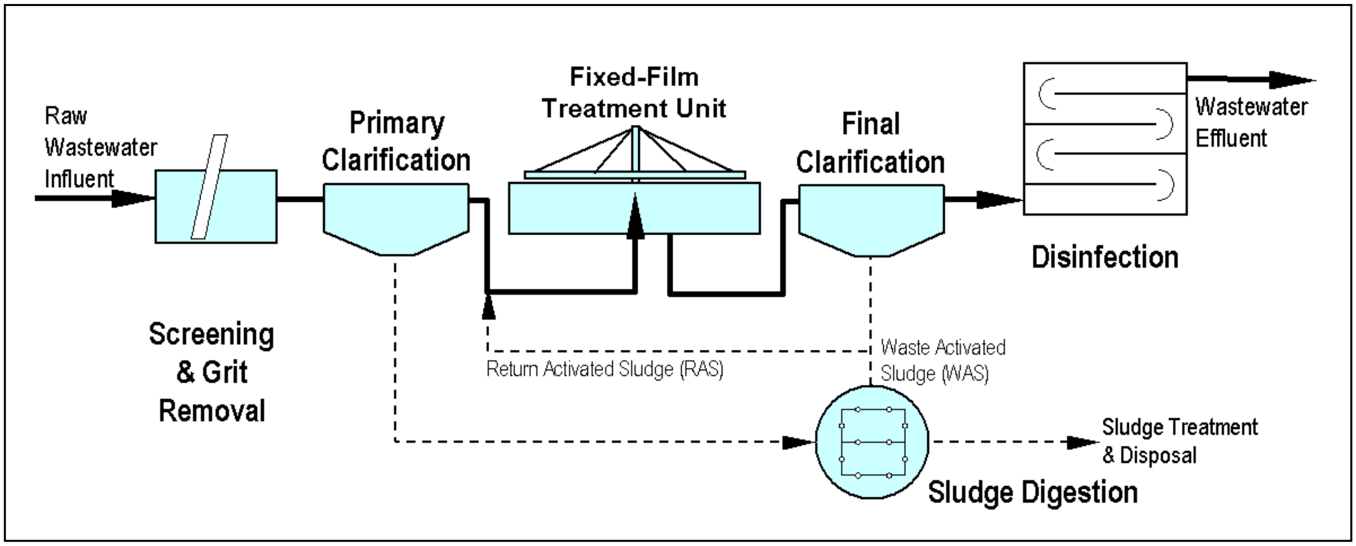

Figure 8 – Fixed Film Process Flow Schematic

<u>Fixed-Film Treatment Advantages</u>

- Simple, reliable, biological process.
- Suitable in areas where large tracts of land are not available for land intensive treatment systems.
- May qualify for equivalent secondary discharge standards.
- Effective in treating high concentrations of organics depending on the type of medium used.
- Appropriate for small- to medium-sized communities.
- Rapidly reduce soluble BOD_5 in applied wastewater.
- Efficient nitrification units.
- Durable process elements.
- Low power requirements.
- Moderate level of skill and technical expertise needed to manage and operate the system.

<u>Fixed-Film Treatment Disadvantages</u>

- Additional treatment may be needed to meet more stringent discharge standards.
- Possible accumulation of excess biomass that cannot retain an aerobic condition and can impair fixed film treatment performance (maximum biomass thickness is controlled by hydraulic dosage rate, type of media, type of organic matter, temperature and nature of the biological growth).

- Requires regular operator attention.
- Incidence of clogging is relatively high.
- Requires low loadings depending on the medium.
- Flexibility and control are limited in comparison with activated-sludge processes.
- Vector and odor problems (snails, flies, and roaches)

WWTP Ranking No. 5 ~ Facilitative Lagoons, Aerated Lagoons, etc. [16]

The rationale behind inserting these treatment schemes into this document is to demonstrate three basic truths:

1. These schemes are more reasonable and reliable for medium to small utilities than those racked below as sixth or even seventh.
2. Even though these reliable treatment schemes are not extensively used in Florida they provide adequate secondary treatment and in some cases with additional filtration and chlorination tertiary treatment. Discussions of treatment options should include these schemes.
3. Inexperience, lack of education or exposure to these schemes does not diminish their efficacy or probable application for Florida.

Facultative waste stabilization ponds, sometimes referred to as lagoons or ponds, are frequently used to treat municipal and industrial wastewater in the United States. The technology associated with facultative lagoons has been in widespread use in the United States for at least 90 years, with more than 7,000 facultative lagoons in operation today. These earthen lagoons are usually 4 to 8 feet in depth and are not mechanically mixed or aerated. The layer of water near the surface contains dissolved oxygen due to atmospheric reaeration and algal respiration, a condition that supports aerobic and facultative organisms. The bottom layer of the lagoon includes sludge deposits and supports anaerobic organisms. The intermediate anoxic layer, termed the facultative zone, ranges from aerobic near the top to anaerobic at the bottom.

Waste stabilization pond systems are simplistic in appearance, however, the reactions are as complicated as any other treatment process. Typical equipment used in facultative lagoons includes lining systems to control seepage to groundwater (if needed), inlet and outlet structures, hydraulic controls, floating dividers, and baffles. A multiple-cell system with at least three cells in series is recommended, with appropriate inlet and outlet structures to maximize effectiveness of the design volume. Most states have design criteria that specify the surface organic loading (lbs/acre/d) and/or the hydraulic residence time. Typical organic loading values range from 13 to 71 lbs/acre/d. Typical detention times range from 20 to 180 days depending on the location.

Partial mix lagoons are commonly used to treat municipal and industrial wastewaters. This technology has been widely used in the United States for at least 40 years. Aeration is provided by either mechanical surface aerators or submerged diffused aeration systems. The submerged systems can include perforated tubing or piping, with a variety of diffusers attached. In aerated lagoons, oxygen is supplied mainly through mechanical or diffused

[16] USEPA (2002) *Wastewater Technology Fact Sheet -- Aerated, Partial Mix Lagoons*, EPA-832-F02-008, http://www.epa.gov/OWM/mtb/index.htm, and USEPA (2002) *Wastewater Technology Fact Sheet -- Facultative Lagoons*, EPA-832-F02-014, http://www.epa.gov/OWM/mtb/index.htm

aeration rather than by algal photosynthesis. Aerated lagoons typically are classified by the amount of mixing provided. A partial mix system provides only enough aeration to satisfy the oxygen requirements of the system and does not provide energy to keep all total suspended solids (TSS) in suspension. Detention times range from 10 to 30 days, with 20 days the most typical (shorter detention times use higher intensity aeration). The design of aerated lagoons for BOD removal is based on first-order kinetics and the complete mix hydraulics model. Even though the system is not completely mixed, a conservative design will result.

Effluent BOD_5 under 20 mg/L can easily be achieved, while effluent TSS may range higher depending on the algal concentrations and design of discharge structures. The addition of a final clarification and filtration can achieve much higher treatment levels.

Lagoon Advantages

- Moderately effective in removing settleable solids, BOD, pathogens, fecal coliform, and ammonia. Easy to operate.
- Require little energy, with systems designed to operate with gravity flow.
- The quantity of removed material will be relatively small compared to other secondary treatment processes.
- Sludge disposal may be necessary but the quantity will be relatively small compared to other secondary treatment processes.

Lagoon Disadvantages

- Settled sludges and inert material require periodic removal.
- Difficult to control or predict ammonia levels in effluent. Aerated lagoons are not as effective as facultative ponds in removing ammonia nitrogen or phosphorous, unless designed for nitrification.
- Mosquitos and similar insect vectors can be a problem if emergent vegetation along dikes and berms is not controlled.
- Requires relatively large areas of land.
- Strong odors occur when the aerobic blanket disappears and during spring and fall lagoon turnovers. Burrowing animals may be a problem.

WWTP Ranking No. 6 ~ Sequence Batch Reactors (SBRs) [17]

A sequencing batch reactor (SBR) is a variation of the activated sludge process. As a fill and draw or batch process, all biological treatment phases occur in a single tank. This differs from the conventional flow through activated sludge process in that SBRs do not require separate tanks for aeration and sedimentation. SBR systems contain either two or more reactor tanks that are operated in parallel, or one equalization tank and one reactor tank. The type of tank used depends on the wastewater flow characteristics (e.g. high or low volume). While this setup allows the system to accommodate continuous influent flow, it does not provide for disinfection or holding for aerated sludge.

There are many types of SBR systems, including continuous influent/time based, non-continuous influent/time based, volume based, an intermittent cycle system (a SBR that utilizes

[17] USEPA (1999) *Wastewater Technology Fact Sheet -- Sequencing Batch Reactors*, EPA 832-F-99-073, http://www.epa.gov/OWM/mtb/index.htm

jet aeration), and various other system modifications based on different manufacturer designs. The type of SBR system used depends on site and wastewater characteristics as well as the needs of the area or community installing the unit. Package SBRs are typically manufactured to treat wastewater flow rates between 0.01 and 0.2 MGD; although flow rates can vary based on the system and manufacturer.

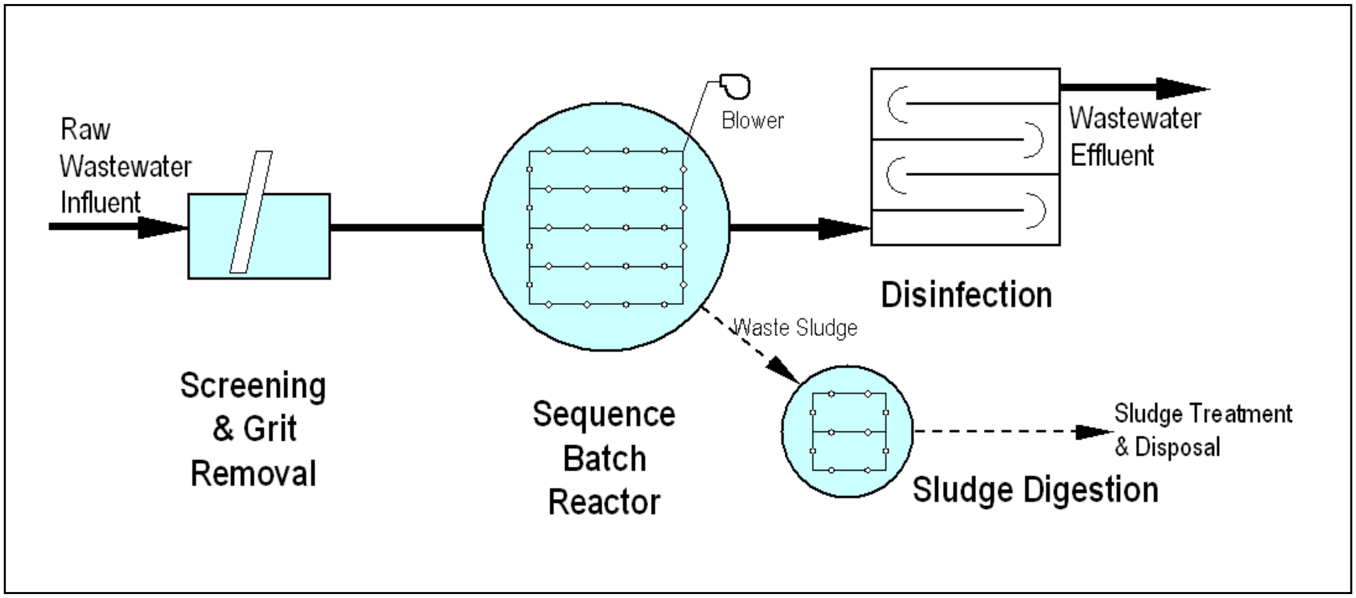

Figure 9 – Sequence Batch Reactors (SBRs) Process Flow Schematic

As seen in Figure 10, the influent flow first goes through a screening process before entering the SBR. The waste is then treated in a series of batch phases within the SBR to achieve the desired effluent concentration. The sludge that is wasted from the SBR moves on to digestion and eventually to solids handling, disposal, or land application.

The treated effluent then moves to disinfection. An equalization tank is typically needed before the disinfection unit in batch SBRs in order to store large volumes of water. If the flow is not equalized, a sizable filter may be necessary to accommodate the large flow of water entering the disinfection system. In addition, SBR systems typically have no primary or secondary clarifiers as settling takes place in the SBR.

SBR Advantages

- SBRs have lower capital costs to construct than extended aeration plants of equal capacity
- SBRs can fit on smaller site because of smaller footprint and is relatively easy to expand by adding tanks
- No separate clarifiers are required, but clarification is inefficient.

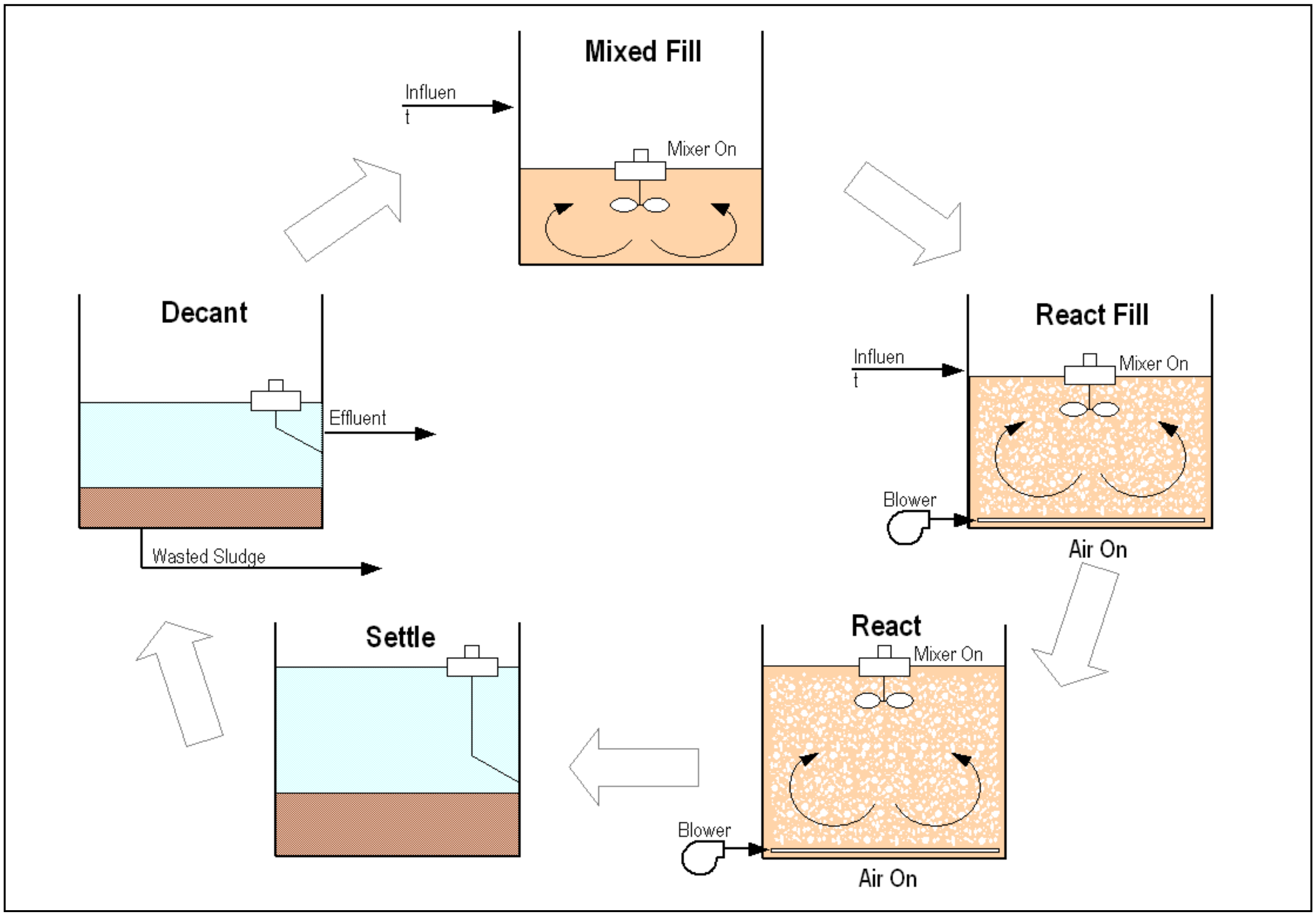

Figure 10 –SBR Batch Operation Sequence

- Cycle times and operation strategies are easily adjusted in response to changes in waste flow, strength, and treatment requirements.
- May be designed to act to a degree as its own equalization basin attenuating peak influent flows.
- Hydraulic shock resistance is also improved because the SBR utilizes one tank for solids separation eliminating the need for a separate clarifier and removing a major source of operational problems
- SBRs can consistently perform nitrification as well as denitrification and phosphorous removal.
- Since all the unit processes are operated in a single tank, there is no need to optimize aeration and decanting to comply with power requirements and lower decant discharge rates.
- The system allows for automatic and positive control of mixed liquor suspended solids (MLSS) concentration and solids retention time (SRT) through the use of sludge wasting.

SBR Disadvantages

- SBR aeration uses blowers which produce noise and specific energy consumption is high
- Operation and maintenance requirements are higher than other plants of equal capacity

- Operation is dependent upon computer actuated controls to operate pumps and close/open valves.
- When computer operated controls go down the plant must be manually operated, which is difficult and requires constant around the clock attention.
- SBRs are **one lightning strike from system failure** (*Florida leads the nation in lightning strikes per square mile with an average of 1.5 million lightning bolts each year = 26 every square mile*)
- Operators must have specialized knowledge of electronic control systems.
- SBRs are vulnerable to toxic / BOD loading shocks and requires emergency procedures or removal when active biomass expires.
- It is hard to adjust the cycle times for small communities.
- Post equalization may be required where more treatment is needed.
- Sludge must be disposed frequently.

WWTP Ranking No. 7 ~ Other state-of-the-art Treatment Schemes

Based on FRWA's considerable experience, Florida's small to medium sized utilities should avoid cutting edge state-of-the-art treatment schemes for several compelling reasons:

1. Beware of the "Newest Technology." New technologies often promise dramatic savings in capital and operating costs. They may sound thrilling, sexy and cutting edge, but experience has shown that they are typically more expensive (per gallon) to construct and operate than tried and tested systems. Sometimes construction costs are double or triple conventional treatment plants.
2. Newer technology may still have "bugs" to be worked out. We suggest that larger utilities with deeper pockets may be more able to absorb the additional costs attendant with glitches, faults and start-up problems than smaller systems. Should a small to medium sized utility act as a guinea pig for a new technology? Can the design be built and function as intended / promised? The technology may not have worked for larger systems but they are able to hide the fault and work around the flaws. [18]
3. Operation and maintenance (O&M) costs can often be optimistically small or even severely under estimated. The manufacturer, vendor and design engineer can easily under project O&M costs. How will ratepayers react when a rate hike is mandated by O&M costs for a new facility that is double or triple the old system costs?
4. Beware of the inexperienced engineer. New technologies can be risky particularly if the engineering firm or your project manager has never completed this type of project before. Don't let them experiment on you! Instead pick a team of experienced professionals. Technologies with little operating history often experience unanticipated problems and can cost several times more in the long-term than proven technologies. If you consider a new technology, insist that a reference list of similar operating facilities be provided. [19]

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[18] Based on the author's interviews and discussions with system managers about industry problems related to new technology, equipment and controls.

[19] Carroll, S.L., P.E., *How do I Choose the Right Engineering Firm for my Project?,* Water Writes, Spring 2007, official publication of Florida Rural Water Association, p. 5

5. Do not listen to the vendor promoting a product, instead contact those utilities that are actually operating the technology and ask relevant questions about the treatment efficiencies experienced and problems that have occurred. If nothing else it will save you from reinventing the wheel.

Reverse Osmosis / Membrane Bioreactor (MBR).[20] Reverse Osmosis / Membrane Bioreactors are a costly option with attendant increased operation and maintenance costs that small and medium sized communities should avoid.

The membrane bioreactor is a technology that is significantly more expensive than rehabilitating existing facilities and will cost more to operate than more common and cost-effective filtration methods. However the advantage is that the bioreactor will produce a higher quality effluent. These type of systems should be reserved for the Florida Keys and high density coastal areas in Southern Florida where reuse is a necessity.

For new installations, the use of MBR systems allows for higher wastewater flow or improved treatment performance in a smaller space than a conventional design, i.e., a facility using secondary clarifiers and sand filters. The high quality effluent produced by MBRs makes them particularly applicable to reuse applications and for surface water discharge applications requiring extensive nutrient (nitrogen and phosphorus) removal.

The technologies most commonly used for performing secondary treatment of municipal wastewater rely on microorganisms suspended in the wastewater to treat it. Although these technologies work well in many situations, they have several drawbacks, including the difficulty of growing the right types of microorganisms and the physical requirement of a large site. The use of reverse osmosis / membrane bioreactors (MBRs), a technology that has become increasingly used in the past 10 years, overcomes many of the limitations of conventional systems. These systems have the advantage of combining a suspended growth biological reactor with solids removal via filtration. The membranes can be designed for and operated in small spaces and with high removal efficiency of contaminants such as nitrogen, phosphorus, bacteria, biochemical oxygen demand, and total suspended solids. The membrane filtration system in effect can replace the secondary clarifier and sand filters in a typical activated sludge treatment system. Membrane filtration allows a higher biomass concentration to be maintained, thereby allowing smaller bioreactors to be used.[21]

Final Effluent Filtration [22]

We strongly recommend the installation of traveling-bridge filters for tertiary filtration. Traveling bridge filters provide excellent effluent removal equivalent to more expensive devices without extensive operator attention. Two identically sized traveling-bridge filters should be provided, each able to carry the filtration load.

Traveling Bridge Filters.[23] Traveling bridge filters are continuously in service and backwashing. The bash washing bridge moves back and forth across the media to remove sediment. The traveling bridge filter is a gravity filter divided up into several individual filter

[20] USEPA (2002) *Wastewater Technology Fact Sheet -- Membrane Bioreactors*, EPA-832-F-07-015, http://www.epa.gov/OWM/mtb/index.htm

[21] Copeland, A., Cole, K., Barrows, R., Pyne, J., (2007) *The Design Elements of State of the Art Treatment Technology: MBR Wastewater Treatment Systems*, Presented at 2007 Virginia AWWA/WEA Water JAM

[22] USEPA (2007) *Wastewater Technology Fact Sheet -- Denitrifying Filters*, EPA-832-F-07-014, http://www.epa.gov/OWM/mtb/index.htm

[23] Unified Facilities Criteria (UFC) (2003) *"Army Filtration of Liquids"* U.S. Army Corps of Engineers, www.tpub.com/content/UFC1/ufc_3_280_04/ufc_3_280_040045.htm

cells. A hood travels horizontally along the cells, backwashing individual cells while the other cells continue to filter water. The influent floods the bed to a depth of 2 ft, flows via gravity through the media and exits through effluent ports. Typically, the media bed ranges from approximately 12 to 24 inches deep and may consist of single or dual media.

Traveling bridge filters offer the advantage of gravity filtration, plus the additional advantage of not periodically shutting down the system for backwash. In addition, no backwash holding tanks are required, as backwash water is obtained from the effluent chamber and the filter can use a single medium.

Influent Parameters.

Design Flow: .... greater than 30 gpm

Dosing Rate: .... 2 gpm/sqft

.... 30 mg/L TSS average

Peak Flow Rate: .... 5 gpm/sqft

.... 50 mg/L TSS peak

Effluent Parameter. .... 5 to 10 microns

Backwash. .... 3 to 5% of design flow. Controlled by timer, max level. Minimum once/day 25 gpm/sqft for 90 sec/cell

Traveling Bridge Filter Advantages.

- Low head.
- No clear well and no mud well.
- Small Footprint.
- Air scour available (requiring auxiliary air supply).

Traveling Bridge Filter Disadvantages.

- Cannot have high level of solids or oil and grease.
- Not as high removal efficiency as gravity up pressure filters.
- Backwash disposal required.
- High capital and operating cost.
- Medium labor cost.
- Susceptible to upset.
- Complex control and maintenance

Traveling Bridge Filter Manufacturer. We recommend the Infilco Degremont, ABW Automatic Backwash Filter. This filter has many advantages and is a reliable and robust design. However the design engineer should check installations and references of each type before settling on a configuration and specification.[24]

Upflow Continuous Backwash Filters (DynaSand®).[25] These filters are not recommended because of inconsistent performance and inability to maintain advanced wastewater treatment

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[24] Based on FRWA engineering and circuit rider experience

[25] Unified Facilities Criteria (UFC) (2003) *"Army Filtration of Liquids"* U.S. Army Corps of Engineers, www.tpub.com/content/UFC1/ufc_3_280_04/ufc_3_280_040045.htm

effluent standards at all times.[26] They rely on filtration media that is suspended and expanded by the upflow of water and air to provide particle removal. Water enters the lower part of the filter tank and moves upward, contacting the media. Each manufacturer has its own influent dosing mechanism, by which the influent stream is introduced to the filter bed. Generally, effluent is discharged over an effluent weir. Concurrent to filtration, the media are constantly moving downward, through the dirty sand hopper, to be removed from the filtration zone for washing, and returned to the top of the filtration zone when clean. The media are removed from the filter bed through an eductor pipe. The eductor pipe provides sufficient suction to the media bed to draw the filter sand from the system. Compressed air is generally introduced at the bottom of the pipe, causing the media to be drawn from the bed upward to the washer unit. In addition to providing transport, the eductor tube, or airlift system, scours the media with air.

Influent Parameters.

Design Flow: .... greater than 40 gpm (can operate at lower flow)

Dosing Rate: .... 30 mg/L TSS average

Effluent Parameter. .... 10 to 30 microns

Backwash. .... 10 to 25% of design flow. Continuous.

Upflow Continuous Backwash Filter Advantages.

- Continuous; no shutdown.

Upflow Continuous Backwash Filter Disadvantages.

- TSS removal is not as high / consistent removal as traveling bridge or pressure filters.
- Auxiliary air required – blowers require more energy than traveling bridge filters.
- Higher capital cost than traveling bridge filters.
- More susceptible to upset.
- All proprietary systems, which provides higher profits for vendors and manufacturers.

Conclusion – Deep Bed Traveling Bridge versus Upflow Continuous Backwash Filters. Deep bed (or multimedia) traveling bridge filters are rated at 5 to 10 microns while upflow continuous backwash filters can only provide 10 to 30 microns effluent. If the facility is required to maintain advanced wastewater treatment (AWT) effluent the best choice is traveling bridge filters as it has more advantages and is more reliable. Supporting this assessment of operational problems with upflow continuous backwash filters are the characteristic and periodic turbidity excursions – in other words these filters sporadically burp TSS, not consistently maintaining AWT standards.[27]

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[26] Based on a review of FDEP records for wastewater systems with DynaSand® filters and interviews with personnel that regulate these systems.

[27] Based on considerable FRWA engineering and circuit rider experience with upflow continuous backwash DynaSand® filters.