Appendix M

Centralized Wastewater Collection and Treatment Technology Descriptions

APPENDIX M

(All Figures appear at the end of this Appendix and are referenced as Figure J-1 through J-14)

CENTRALIZED WASTEWATER COLLECTION AND TREATMENT TECHNOLOGY DESCRIPTIONS

1.0 INTRODUCTION

A. **Purpose.** The purpose of this Appendix is to identify the various decentralized wastewater treatment and discharge technologies evaluated as part of Chapter 6. Wastewater collection, treatment and discharge alternatives are divided into the following groups:

- Large Centralized Wastewater Treatment Facilities
- Effluent Disinfection
- Residuals Management
- Collection Systems

Each group of technologies is presented and screened in a separate section of Chapter 6.

2.0 WASTEWATER TREATMENT TECHNOLOGIES

A. **Moderate Level of Performance (6 – 10 mg/L TN on a maximum daily basis). Biological Nitrogen Removal (BNR) Processes.**

1. **Activated Sludge/Modified Ludzack-Ettinger (MLE) Process.** The activated sludge process is a suspended growth biological treatment process which utilizes a high concentration of microorganisms suspended in the wastewater flow. An aerobic environment is maintained in the reactor tank through either diffused or mechanical aeration. In addition to

supplying oxygen, aeration provides mixing of the suspended solids and microorganisms. The mixture of wastewater and microorganisms passes from the reactor tank to a settling tank where the microorganisms are settled from the treated effluent. The settled microorganisms are then recycled and combined with influent wastewater to maintain the desired concentration in the activated sludge basin. A portion of settled microorganisms are periodically wasted as sludge.

The oxidation of organic matter and the conversion of ammonia to nitrates (nitrification) are aerobic processes and the activated sludge process can accomplish both within the same basin. Activated sludge processes can also be modified to achieve nitrogen removal by creating anoxic zones in the reactor tank which force microorganisms to use nitrate-nitrogen as an oxygen source and, with an adequate supply of carbon, remove the nitrogen as nitrogen gas which is released to the atmosphere in a process known as denitrification. The Modified Ludzack Ettinger (MLE) activated sludge process can remove nitrogen to the 6 to 10 mg/L range. A diagram of an activated sludge/MLE process is included as Figure J-1. The Chatham WWTF currently uses the MLE process in two of its existing tanks.

Activated sludge / MLE processes have the following advantages:

- Moderate capital and O&M costs.
- Does not always need to be preceded by primary treatment (but often are).
- Shown to be highly effective for nitrogen removal as well as secondary treatment.
- Provides flexibility in operation and process control.
- Traditional technology with long record of proven performance

They have the following disadvantages:

- Requires final settling tanks.
- Requires skilled operation.
- Higher energy costs for diffused aeration vs. lagoons, RBCs, and some SBRs.
- High process control requirements to optimize performance.
- Internal recycle required.
- Higher sludge production.

2. **Activated Sludge / Extended Aeration**. The extended aeration type of activated sludge process simply refers to an activated sludge process with a longer hydraulic retention time as compared to a conventional complete-mix or plug-flow type activated sludge processes. There are a number of versions of this type of process but they are generally able to achieve a high level of treatment and to incorporate nitrogen removal. Three different types of extended aeration process will be presented because of their common application in the field.

The extended aeration processes are described as follows:

- <u>Oxidation Ditch.</u> The activated sludge basin is configured in a circular track that is typically oblong and sometimes referred to as a continuous-loop reactor. Aeration and mixing is typically provided by brush aerators but diffused aeration with submerged mixers can also be utilized. An oxidation ditch can be operated for BNR by either controlling the DO level such that at some point downstream of the aerators, the system becomes anoxic thus promoting denitrification. The system operates with very high recirculation rates and thus can be quite efficient at denitrification assuming the system is nitrifying. See Figure J-2.

- <u>Biolac Lagoon.</u> This is a patented process that maintains an activated sludge in a lagoon with either internal or external final clarifiers. A "wave oxidation" system is used to create alternating periods of aerobic and anoxic treatment thus achieving both nitrification and denitrification. The process is actually capable of more stringent permit limits depending on the characteristics of the wastewater and the design criteria. See Figure J-3.

- <u>Schreiber.</u> The Schreiber process is an activated sludge system built in a circular tank with counter current aeration. This aeration system operates with fine bubble diffusers mounted on abridge that rotates around the tank. This method separates the functions of mixing and oxygen transfer and creates alternating periods of aerobic and anoxic conditions to achieve nitrification and denitrification. The systems can be optimized for even greater levels of treatment efficiency. See Figure J-4

Activated Sludge / Extended Aeration processes have the following advantages:

- Reliable and more forgiving operation (handles peak flows better)
- Reduced quantity of sludge production

They have the following disadvantages:

- Large site area requirements
- Larger tanks required
- Cost associated with large tank volume

3. **Rotating Biological Contactors (RBC).** Rotating biological contactors are attached growth processes which utilize disc-shaped plastic media mounted to a rotating shaft. The plastic media is partially submerged in a tank and provides a growing surface for microorganisms. The rotating shaft brings the microorganisms in contact with both the organic matter in the wastewater and oxygen in the atmosphere. As a result, aerobic bacteria metabolize solids and nutrients in the wastewater. Additional microorganisms are produced and are removed from the treated effluent in a settling tank.

When RBC's are used for nitrogen removal, a separate submerged (anoxic) RBC follows the partially submerged (aerobic) RBC to provide denitrification and remove nitrogen to the 6 to 10 mg/L range. Methanol must be added to the anoxic RBC to assist nitrogen removal. A process diagram of a RBC is included as Figure J-5.

RBC's have the following advantages:

- The technology is used extensively and is well accepted by MassDEP.
- Energy requirements are lower.
- Operational requirements are low.

They have the following disadvantages:

- Shallow tanks require larger land area.
- Must be preceded by primary treatment.

- Must be followed by a final settling tank.
- Capital costs are high.
- Cold weather performance is a concern and the tanks must be covered.
- There is minimal process control and flexibility for high seasonal flows.
- Limited application in denitrifying systems.

4. **Sequencing Batch Reactors (SBR).** Sequencing batch reactors are batch-type treatment processes. Aerobic and anoxic reaction times (for nitrogen removal), and settling are accomplished in a single basin Parallel treatment units can be provided. The phases of the SBR process include fill, react, settle, draw, and idle. Wastewater is added during the fill cycle. During the react phase which is alternating aerobic and anoxic, nitrogen removal will occur. The next phase is settling, followed by decanting of clarified effluent in the draw phase. Sludge is collected and removed during the idle phase. A process diagram of an SBR is included as Figure J-6.

Nitrogen removal with SBR's can be enhanced by modifying the length of the cycle times, monitoring the reactor contents to achieve the desired degree of treatment, and adding methanol. SBR's can remove nitrogen to the 5 to 10 mg/L range.

SBRs have the following advantages:

- Batch operation allows reactor contents to be retained longer to improve effluent quality.
- Settling occurs under totally quiescent conditions with no influent flow.
- All phases are provided in a single basin, reducing the need for additional tanks such as final settling tanks.
- Highly flexible operation with ability to adjust cycle times.

They have the following disadvantages:

- Control is often SCADA based and traditional operators find it complex.
- Limited process control because multiple processes are performed in a single tank.
- Potential for solids carry over during decant cycle.

- Flow equalization typically required downstream of SBRs for efficient operation of disinfection and filtration systems.

5. **Higher Level of Performance (3 mg/L TN on average with a maximum daily limit of 10 mg/L).** When BNR Systems are upgraded by adding treatment units to achieve higher levels of treatment they are often referred to as Enhanced Nitrogen Removal (ENR) Systems. However, there are other processes that would be considered if the level of treatment required approached 3 mg/L TN which is considered the Limit of Technology (LOT) for nitrogen removal. This level of treatment is obtainable using proven technologies but requires typically greater safety factors in the design for reliable performance and the systems are more expensive to build and operate. A summary of processes to be considered for this level of nitrogen removal are discussed below.

a. **Activated Sludge / Plug Flow Systems.** The MLE process discussed previously can be upgraded for higher levels of treatment by adding a post-denitrification zone just downstream of the MLE process. In this zone, which would operate anoxically, the remaining nitrates passing through the MLE would be denitrified. However, an external source of carbon would be required since the wastewater carbon has already been consumed. Thus, methanol addition would be required. An effluent filter would be required for reliable performance at a level of 3 mg/L TN.

The Bardenpho system is another activated sludge system capable of very low levels of nitrogen and it basically resembles an MLE process with a downstream denitrification zone. However, with the Bardenpho process, the second or post anoxic zone is sized to use endogenous carbon rather than have to rely on an external carbon source. The detention times and reactor sizes therefore are grater than with an MLE with post-denitrification using methanol. The Bardenpho would have a lower operating cost however. An effluent filter would most likely be required to achieve consistently a level of 3 mg/L TN.

b. **Sequencing Batch Reactor (SBR).** An SBR can be sized to treat to a level of 3 mg/L TN. An external carbon source would be required during a portion of the anoxic react phase. Effluent filtration would be required which means flow equalization must be provided after the SBR and before the filters.

c. **Activated Sludge / Extended Aeration.** Extended aeration activated sludge processes were discussed previously. There are several extended aeration processes, however that are capable of achieving LOT treatment. These include the Carrousel process and Orbal® process as discussed below.

- Carrousel. The Carrousel process by Eimco is a multi-stage continuous loop reactor. Carbon removal and nitrification occurs in the main loop reactor. A sidestream from the loop reactor is diverted into a pre-anoxic zone for denitrification. Very high recycle rates are achieved with this system. Downstream of the loop reactor is a post anoxic zone which can use either endogenous carbon or an external source of carbon to denitrify the remaining nitrates. See Figure J-7.

- Orbal®. The Orbal® process by Siemens is comprised of three concentric ditches that flow in series. A very low DO is maintained in the first ditch and the DO increases toward the effluent. Aeration and mixing energy is provided by disc aerators. A great deal of simultaneous nitrification /denitrification occurs at the minimal DO levels maintained in the process. See Figure J-8.

Extended air systems have the following advantages:

- Typically lower power requirements than a plug-flow diffused aeration system despite larger tank volume and MCRT.
- Less equipment and valves to maintain than a system with diffused aeration.
- Typically less support building space requirements than a system with diffused aeration.
- Better resilience to shock loadings than a plug-flow system.
- Better ability to handle sudden flow changes than a plug-flow system
- Typically lower sludge production than a conventional BNR process following primary clarifiers.
- Does not require internal nitrate recycle pumps.
- Longer aerobic MCRT (and HRT) for improved nitrification under cold weather conditions.
- Longer total MCRT will result in more stable (potentially less odorous) waste sludge.
- Primary clarifiers are rarely required

- Neither would require a fine bubble aeration system. Both eliminate the need for fine bubble diffusers, aeration piping, aeration blowers and a blower building.

Disadvantages of these types of systems include:

- Biological reactors: The Carrousel® system and Orbal® system would require the use of specially designed concrete tanks and would thus not be able to reuse the existing aeration tanks in any way. Nitrate recycle pumps are not required for the Carrousel because of the system design; they are required for Orbal®.
- It is understood that these tanks could require cleaning only once every 8-10 years or so (because there are no primary clarifiers preceding them and grit that passes through the headworks and settles out). In a side by side comparison with Carrousel and Orbal® often requires a smaller footprint, but may have more complex system, more complex influent structure with brush aerators (6 locations after Phase II) and nitrogen recycle pumps. Orbal® can allow operation in contact stabilization mode allowing greater operator control.
- Aeration System: The Carrousel® system uses mechanical aerators provided with the system to introduce DO to the wastewater. The Orbal® system uses brush aerators and as stated before require a greater number of mechanical systems than Carrousel.
- Secondary Clarifiers are required with both the Carrousel® system and the Orbal® system unlike a SBR type system where no secondary clarifiers are required.
- Methanol: Is likely required for both systems.
- Systems often require a second anoxic reaeration tank to achieve higher nitrogen removal which adds to capital and O&M costs with the addition of more tanks and aeration requirements.

In comparing two of the proprietary technologies that would be considered for Chatham:

- <u>Carrousel</u>

    - Less equipment and valves to maintain than the Orbal® system.

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Orbal®

- Fewer tanks, as expansion done in rings instead of parallel trains
- Slightly greater process flexibility
- Can achieve wastewater treatment under low flow/startup conditions

d. **Membrane Biorector (MBR).** With an MBR, the final clarifiers are replaced by a membrane filtration system. Both microfiltration and ultrafiltration type membranes have been used and they are installed either directly in the mixed liquor of an activated sludge system or external to the system. If installed within the mixed liquor, the clarified effluent is pulled through the membrane (outside –in) by a vacuum pump. If installed externally, then the mixed liquor is pumped to the membranes under pressure and the clarified effluent flows through the membrane is inside-out. There is no return activated sludge since the mixed liquor suspended solids are retained within the process. Sludge wasting is direct from the mixed liquor. The systems typically operate at very elevated MLSS concentrations (8 to10 g/L) and thus are able to operate at very high sludge ages. The high level of performance is obtained through the operation at high sludge ages plus the ability of the membranes to remove essentially all of the solids. An MBR can be configured in most different types of activated sludge flow schemes such as are typically used for nitrogen removal. There are number of equipment manufacturers offering MBR systems; a few are discussed below.

1) Zenon MBR**.** The Zenon process utilizes hollow-fiber ultrafiltration membranes mounted in modules. The modules are immersed in the mixed liquor and operate under a vacuum. A diagram of the vertically mounted Zenon reactor tank is included as Figure J-9.

2) Enviroquip MBR. The MBR manufactured by Enviroquip utilizes Kubota flat plate microfiltration membranes. In most other respects, the system is similar to Zenon. The membranes are installed within the mixed liquor and operate under a slight vacuum. See Figure J-10.

In general, the MBR process has the following advantages:

- Small foot print required and can be retrofit in existing processes
- Effluent can be reused for non-potable applications and is suitable for RO treatment
- Process achieves almost 100% virus removal

MBR processes have the following disadvantages:

- Capital costs are high (but decreasing)
- Membrane replacement costs are high.
- Few installations in Massachusetts to verify performance.
- Significant membrane cleaning requirements
- Higher degree of pretreatment (screening) required

e. **Fixed Film Systems.** Biological Aerated Filters (BAFs).Biological Aerated Filters (BAFs) are a fixed film system where biomass is grown on a granular media such as sand. The wastewater flows either upward or downward through the media bed. The BAFs are high rate systems and can achieve a high level of treatment with some degree of solids filtration. The Biofor BAF by Ondeo Degremont is an upflow system that uses a non buoyant media. Wastewater and air are introduced at the bottom of the filter and flows upward. The Biostyr BAF by Kruger is another upflow filter that utilizes a floating media. The systems can be designed for carbon removal, nitrification and denitrification. See Figure J-11.

1) Denitrification Filters. Denitrification filters can be added downstream of any process that is capable of complete nitrification to provide separate-stage denitrification. A high level of nitrification would be necessary prior to the filters to achieve a low level total nitrogen discharge in the effluent because denitrification filters can only denitrify effluent that has already been nitrified. Two general types of denitrifying filters are available: downflow packed bed systems and upflow fluidized beds. Downflow packed bed systems are deep bed sand filters operated to encourage attached microorganisms to denitrify. Methanol addition is added to provide a carbon source for denitrification. Packed beds provide adequate detention time and surface area to maintain anoxic conditions for denitrification to occur. The packed beds also

act as effluent filters to remove suspended solids and improve effluent quality. Periodically, the beds must be backwashed and must be “bumped” with backwash water for a few seconds to release nitrogen gas which accumulates in the filter media and increases headloss through the media. Figure J-12 presents a schematic for denitrifying filters.

Denitrifying filters are a proven technology and are capable of achieving a high level of nitrogen removal to meet a total nitrogen limit of 2 to 5 mg/L, provided a high level of nitrification is provided in preceding steps.

Upflow fluidized beds consisting of columns containing sand have been used for denitrification. Denitrifying microorganisms attach to the sand as nitrified effluent flows upward through the column. This type of process is considered an attached growth and suspended growth process. Fluidized beds have seen limited applications and have been used mostly for industrial wastewater treatment.

Fixed film systems have the following advantages:

- Well-proven and reliable technology to meet a total nitrogen limit of 2 to 5 mg/L.
- No significant environmental or public acceptance concerns.
- Potential for air emissions is minimal, as filters are enclosed in a building.

They have the following disadvantages:

- Moderate capital costs for new facilities and building enclosure.
- Typically follow conventional secondary treatment
- High O& M Costs.
- Effluent pumping is typically required due to large headlosses.
- Methanol addition and stripping required.

3. **Natural Systems.**

a. **Constructed Wetlands.** Constructed wetlands consist of an artificial receiving water body with vegetation to treat surface and subsurface water flow. Vegetation must be harvested on a regular basis to effectively manage the system, and disposal of wetlands vegetation is a significant consideration in the design and operation of wetlands systems. Treatment performance in northern climates may be subject to seasonal weather variations, and large storage basins may be required to effectively manage wastewater flow. Nitrogen removal is typically accomplished through plant uptake and denitrification which can occur in anoxic regions of the wetland. These systems are generally regarded as emerging technology and may require pilot testing prior to being approved by MassDEP for installation. They may best be utilized as a polishing step to remove some of the remaining nitrogen. A diagram of a constructed wetland system is shown on Figure J-13.

Constructed wetlands systems have the following advantages:

- Very little process control required.
- Relies on use of natural systems.

Wetlands treatment systems have the following disadvantages:

- Large land area requirements due to long wastewater retention times.
- Cold weather performance is questionable.
- Systems have limited number of full-scale installations, particularly for nitrogen removal.
- Design information and performance data are limited.
- Removal efficiency is not readily predictable or controllable.
- Harvesting and disposal of vegetation is required.
- Usually requires an additional treatment process prior to or following the system to achieve permit limits.

b. **Solar Aquatics.** A variety of solar aquatics systems are available ranging from homemade greenhouses to systems located inside living space where plant material is used for decoration. Some systems use just plants, while others utilize organisms such as snails and fish. Wastewater is first allowed to settle to remove large solids. The wastewater is then treated by a series of stages with different types of living organisms, usually plants or algae. The effluent then moves to a unit which uses wastewater nutrients as a food source. Sunlight is required to supply light to the plants and heat for the overall system. The final effluent is then discharged to a leaching area. Again, these systems may best be utilized as a final polishing step for nitrogen removal. A diagram of a solar aquatics system for large wastewater flows is included as Figure J-14.

Solar aquatics systems have the following advantages:

- Process operations can be flexible, with ability to adjust cycle times.
- Pumping and energy requirements are minimal.
- The process is very interesting and can be a tourist attraction.

They have the following disadvantages:

- The process is very labor intensive.
- Performance data is limited for larger installations (greater than 1 mgd)
- The system has a large space requirement due to the long wastewater retention time required for proper treatment.
- Requires frequent maintenance and a knowledge of biological and ecological systems for proper operation.
- Requires energy to maintain relatively high operating temperatures.
- Requires disposal of accumulated biomass generated in the system.
- Plant death and low treatment rates may occur during low-temperature months in winter impacting effluent quality.

4. **Reuse Technologies.** Additional treatment can be provided downstream of most of the technologies discussed previously, to obtain an effluent quality suitable for a variety of water reuse options.

a. **Reverse Osmosis (RO).** Reverse osmosis, also known as hyperfiltration, is a process to remove dissolved salts and small particles from a solution. During the reverse osmosis process, only the fluid to be purified will pass through the semi-permeable membrane, while the undesired contaminants, such as dissolved organics, bacteria, salts, sugar, proteins, will be rejected. Larger particles are more likely to be rejected by the membrane. The driving force required to push fluid through the membrane increases as the concentration of rejected items increases.

Advantages of Reverse Osmosis:

- Effective in particulate nitrogen and phosphorus removal and, to a minor degree, the removal of some large organic soluble forms
- Able to remove dissolved organics that are less selectively removed by other demineralization methods
- Able to meet stringent water quality standards

Disadvantages of Reverse Osmosis

- High capital costs
- Limited experience in domestic wastewater treatment
- Demands a high degree of pretreatment to avoid excessive backwashing requirements

b. **Ultrafiltration.** Ultrafiltration is used to remove dissolved and colloidal materials and large molecules with molecular weights over 5000. It utilizes porous membrane driven by relatively low pressure. Ultrafiltration can be applied alone or served as a pretreatment step to reverse osmosis. The disadvantage of ultrafiltration is the high capital costs. The mechanism of ultrafiltration is similar to reverse osmosis.

Advantage of Ultrafiltration:

- Can be applied alone or served as a pretreatment step to reverse osmosis.

Disadvantage of Ultrafiltration:

- High capital costs.
- Not a common technology used in wastewater treatment.

c. **Electrodialysis**. Electrodialysis is another membrane technology. The membranes used in electrodialysis are semi-permeable and ion-selective. During the electrodialysis process, electrical potential is applied to the two electrodes, as a result, electrical current is produced and passed through the solution. Cations migrate toward the negative electrode while anions move towards the positive electrode. Since the cation- and anion-permeable membranes are arranged in an alternate manner, regions of concentrated and dilute salts are formed.

Advantages of Electrodialysis:

- 100% of suspended organic nitrogen can be removed
- Certain levels of ammonia and nitrate can be removed

Disadvantages of Electrodialysis:

- Occurrence of chemical precipitation of salts with low solubility on membrane surface
- Clogging of membrane by residual colloidal organic matter in wastewater treatment effluent
- Activated carbon pretreatment may be needed to reduce membrane fouling
- Not a common technology used for wastewater treatment

3.0 FURTHER ADVANCED / EXPERIMENTAL NITROGEN REMOVAL

A. **Introduction.** There is a significant amount of experience removing nitrogen to levels below 8 – 10 mg/L and thee is increasing experience with treatment to the Limit of Technology (3 mg/L TN) via conventional wastewater treatment means. The need to treat to levels below 3 mg/L is rare and thus there is little experience with full scale municipal systems in the application of the appropriate technologies. Technologies discussed here could be added to an ENR process to achieve less than 3 mg/L TN in the effluent.

It is important to understand why the task of removing nitrogen to levels below 3 mg/L is so difficult. The nitrogen remaining in the effluent, following biological treatment through any of the systems discussed previously, is often present in parts of three forms. They include ammonia, oxidized nitrogen (nitrate) and organic nitrogen. In a system that is fully nitrifying, the ammonia will be less than 1 mg/L and hopefully less, perhaps 0.2 – 0.5 mg/L. If the system has performed very well with denitrification, there will still be a small amount of nitrate in the effluent, again less than 1 mg/L. Both ammonia and nitrate are soluble so filtration will not reduce them further. Organic nitrogen consists of both a soluble and particulate form. The particulate form is associated with any microorganisms that escape in the effluent and is generally proportional to the level of suspended solids in the effluent. The soluble organic nitrogen is generally less than 1 mg/L but can be higher in treatment plants that receive waste from industries such as textile or dye plants or that receive a significant amount of septage. Thus, if you add the various forms of nitrogen in the effluent, the concentration approaches 3 mg/L as a limit unless some additional, more unusual treatment steps are taken to remove them.

B. **Technologies used to achieve less than 3 mg/L TN.** The technologies described below reduce the effluent Total Nitrogen (TN) by removing, in one of several ways, one of the three remaining fractions of nitrogen in the effluent.

1. **Absorption.** Activated carbon may be used to absorb soluble organics including both carbon and nitrogen compounds. There are several processes to accomplish this. Granular Activated Carbon (GAC) filters are available as either downflow gravity filters or pressure filters. Powdered Activated Carbon (PAC) can also be used and is typically added to a stage of the activated sludge process to absorb the organics while also retaining them in the process for possible further treatment biologically. The Zimpro PACT system is an example of this type of process.

2. **Advanced Oxidation Technologies**. Advanced Oxidation Technologies (AOT) work on the principle of breaking down the bonds in the organic nitrogen (and other organic compounds as well) that make it difficult for the compound to be oxidized biologically. Once these bonds, which may be ring type compounds found in dyes etc., are broken down, then the nitrogen compound may be further metabolized by natural biological processes. There are two basic AOT technologies. One relies strictly on UV light and is referred to as direct photolysis. The organic compound would absorb the energy provided by the UV light which causes the bonds to disassociate. The second type, which would be more applicable, utilizes a combination of UV light and some type of oxidant such as hydrogen peroxide or ozone. The UV light and

oxidant produce hydroxyl (OH^-) radicals which are very strong oxidants and will attack the bonds.

3. **Precipitation.** Chemical precipitation may be used to remove additional ammonia. If magnesium and phosphorus salts are added, the ammonia may be precipitated as a form of struvite.

4. **Ion Exchange.** Zeolite media has been used to remove the ammonium ion (NH_4^+) which is a cation. The media can be added as a slurry or be used in a packed column. There are several commercial applications of this technology. The media is regenerated with a salt water caustic solution.

5. **Break Point Chlorination.** Break point chlorination chemistry is well known and was applied early in the industry as a physical chemical process for nitrogen removal. The process was found to be expensive and difficult to operate as the main process for removing all of the ammonia from a waste stream. However, it is more practical when treating only the ammonia remaining in the effluent of a biological treatment plant.

6. **Membrane Filtration.** Reverse Osmosis (RO) membrane filtration was discussed previously. It is somewhat effective in removing additional organic nitrogen because the membranes capable of blocking some of the higher molecular weight organic compounds. The system would also remove any nitrogen associated with effluent particulate solids.

4.0 DISINFECTION TECHNOLOGIES

A. **Chlorination.** Chlorination can be provided by the addition of a number of chemicals, including sodium hypochlorite, calcium hypochlorite, gaseous chlorine, bromine chloride, and chlorine dioxide.

Use of either sodium hypochlorite or calcium hypochlorite for disinfection is very similar and involves storage and feeding of hypochlorites in solution form. Calcium hypochlorite is available in solid form and sodium hypochlorite is in liquid form. The disinfection mechanism and potential adverse environmental impacts are the same as those with gaseous chlorine.

Hypochlorites are hazardous and corrosive, but provide more safety in the storage and handling of chemicals than gaseous chlorine in the storage and handling of chemicals.

Gaseous or liquid chlorine is another form of chlorination, which is no longer used due to safety issues and public acceptance concerns.

Chlorine dioxide can be used for disinfection and is highly effective, but its use has been very limited. Chlorine dioxide is unstable and potentially explosive; therefore, it cannot be transported. It must be generated on site with chlorine and sodium chlorite, both of which can be dangerous. The environmental impacts of disinfection with chlorine dioxide are not well known.

Bromine chloride has also been shown to be effective in providing disinfection. One advantage of bromine chloride compared to chlorine and hypochlorite is that a shorter contact time is required for disinfection. Bromine chloride is hazardous and corrosive and requires special transportation, storage, and handling requirements. Bromine chloride is very similar to chlorine in terms of its requirements for chemical feed systems, handling, and precautions. The use of bromine chloride has been limited, and extensive data is not available.

All chlorine compounds can combine with organic material and product trihalomethanes (THM) which have been proven to be carcinogenic in small quantities. The USEPA and Massachusetts DEP have established a drinking water standard of 0.1 mg/L for THM. Testing of treatment plant effluent on Cape Cod disinfected with sodium hypochlorite does not indicate the formation of THM above 0.1 mg/L. The groundwater flow direction is normally south toward Cockle Cove Creek, away from all drinking supply wells. Groundwater modeling indicates that effluent flows exceeding the 150,000 gpd limit may push flow toward the Indian Hill Well. Studies show no migration towards the South Chatham or Town Forest Wells. At the same time, there may be the perception of a public health concern for disinfection with chlorine compounds.

Sodium hypochlorite is commonly the preferred chlorination method and has the following advantages:

- Process can be controlled for feed dosages and chlorine residual.
- Minimal energy use.
- Low O&M costs, depending of the cost of NaOCl.

It has the following disadvantages:

- A large chlorine contact tank is needed.
- Potential groundwater contamination with trihalomethanes (THM).
- Storage and handling of sodium hypochlorite can be a safety hazard.
- Limited shelf life of NaOCl.

B. **Ozone.** Ozone has been found to be highly effective in disinfection and has fewer potential adverse environmental impacts on receiving waters and water supplies. Ozone must be generated on site, which normally involves the use of high voltage electrodes and pure oxygen. Ozone is then transferred from the gas phase to the liquid phase with diffusers and closed contactors. The off-gases from the contactor must be treated thermally to destroy excess ozone, which is toxic.

Ozone presents less environmental concern than chlorination because ozone dissipates rapidly to oxygen after application, leaving no ozone residual and adding dissolved oxygen to the WWTF effluent. Ozone, however, can produce toxic mutagenic and/or carcinogenic compounds. Unlike chlorine, ozone does not produce a residual concentration which can be measured and used as an instantaneous indication of satisfactory disinfection.

The cost to produce ozone on site is high, resulting from the high capital cost of generation equipment and the high energy requirements. Ozonation is labor intensive because the system is complex and difficult to operate and maintain.

Disinfection with ozone has the following advantages:

- Ozone dissipates rapidly to oxygen, leaving no ozone residual.
- Ozone adds dissolved oxygen to the WWTF effluent.
- Fewer adverse environmental impacts compared to chlorination.
- Process is well demonstrated.

It has the following disadvantages:

- Ozone is toxic, even though it rapidly dissipates to oxygen.
- High capital costs associated with generating equipment.
- High energy usage to generate ozone.
- Complex operation and maintenance.
- High O&M costs.
- Can produce toxic mutagenic and/or carcinogenic compounds.
- Destruction of off-gases from contactors required to destroy ozone.
- Does not produce a residual that can be monitored like chlorination to verify performance.

C. **Ultraviolet (UV) Radiation.** Unlike the previous alternatives, UV radiation provides disinfection without the use of chemicals. UV light provides radiation which penetrates the bacterial cell walls and destroys the cell. Without the use of chemicals, no toxic residuals are produced. The UV bulbs are contained in racks or modules which are submerged in channels. Required contact time with the bulbs is short. Effluent suspended solids can interfere with disinfection efficiency by preventing penetration of the cell wall and by absorbing radiation; therefore, a high quality effluent is required prior to the UV disinfection. The UV bulbs do foul and must be periodically removed and cleaned, which is normally accomplished chemically by dipping the rack of bulbs in a bath. The bulbs must be replaced periodically, which adds to the O&M costs; however, UV disinfection has been found to be cost competitive with chlorination.

UV disinfection has the following advantages:

- No adverse environmental impacts.
- Minimal space requirements with short contact time.
- Ease of operation and maintenance.
- Cost competitive with other disinfection techniques.
- Well-proven effectiveness.

It has the following disadvantages:

- Suspended solids, turbidity, and color can interfere with the effectiveness of disinfection.
- High quality effluent required prior to UV disinfection which impacts overall costs.
- Periodic cleaning and replacement of bulbs is required.
- Does not produce a residual that can be monitored like chlorination to verify performance.

5.0 RESIDUALS MANAGMENT

A. Sludge Processing Technologies.

1. **Sludge Thickening.** Sludge thickening is a process to concentrate sludge by removing a portion of the liquid fraction. Sludge thickening reduces transportation and disposal costs and facilitates additional sludge treatment processes, including dewatering and stabilization. Sludge thickening can be accomplished by several processes. The simplest thickening process involves storing sludge in an aerated tank and periodically stopping aeration to allow the sludge to settle and excess liquid to be decanted. Other thickening processes are more complicated and utilize equipment such as filters, centrifuges, and rotating drums. Thickening with these types of mechanical equipment (mechanical thickening) often requires a covered process building, odor control facilities, and additional process equipment such as feed pumps and piping. Mechanical thickening also typically requires the addition of chemicals such as polymer to condition the sludge and facilitate the thickening process.

Sludge thickening has the following advantages:

- Often requires the least amount of equipment
- Is typically accomplished in a tank through settling
- Lowest costs if the facility has available existing tanks

Sludge thickening has the following disadvantages:

- The primary disadvantage is liquid sludge is the most costly to dispose of.

2. **Sludge Dewatering.** Sludge dewatering is a physical process used to reduce the water content of thickened sludge. Dewatered sludge, also known as sludge cake, has the consistency of moist sawdust and requires less volume for storage or transportation to a disposal site.

Sludge dewatering has the following advantages:

- Reduces the volume of sludge and is less expensive to dispose of
- The Chatham WWTF has existing dewatering equipment

Sludge thickening has the following disadvantages:

- Requires more energy and equipment than sludge thickening, resulting in higher O&M costs
- Is still more expensive to dispose of off site than sludge stabilization

3. **Sludge Stabilization and Composting.** Sludge is stabilized to reduce pathogens, odors, and the potential for the sludge to biologically decay (purification). Sludge stabilization processes can be used prior to or following sludge dewatering. Common sludge stabilization technologies include composting, digestion, alkaline stabilization, and heat treatment and drying.

a. **Composting.** Composting is a biological sludge stabilization process that destroys pathogens, reduces the water and organic solids content of dewatered sludge, and produces a granular, soil-like material. Sludge composting processes typically include the following three steps:

1) Dewatered sludge is mixed with a bulking agent such as wood chips, yard waste, or sawdust.

2) The mixture is aerated or regularly mixed, which increases the temperature of the mixture, killing pathogens and degrading the highly volatile solids of the sludge.

3) The composted material is cured and stored for distribution.

Finished compost can be distributed to the public if it meets criteria established by MassDEP regulations. Composting is typically most successful if the sludge to be composted has already been digested because the material is partially stabilized, there is less potential for generation of odors, and the sludge is easier to handle. Although composting provides a beneficial reuse of sludge, it is usually not cost effective for low sludge flows. Sludge composting facilities often consist of large covered structures to shelter the compost machinery and odor control facilities. Land areas and capital costs are usually relatively high for composting facilities.

b. **Digestion.** Digestion is a biological stabilization process that reduces the number of pathogens and the overall solids content of sludge through the use of microorganisms. The microorganisms feed on the organic material in the sludge and are utilized in two types of sludge digestion processes: anaerobic digestion and aerobic digestion. Digested sludge can be dewatered, composted, or disposed at a regional facility. Anaerobic digestion produces methane gas that can be used as a fuel source.

Anaerobic and aerobic sludge digestion processes typically include two or more large covered tanks. Thickened sludge is fed into the tanks where anaerobic or aerobic microorganisms decompose the sludge. Mixing and aeration equipment is required to improve the digestion process and maintain either an anaerobic or aerobic environment. The digestion process also requires covered buildings to protect process equipment and odor control facilities. Sludge digestion is not cost effective for small sludge flows.

c. **Alkaline Stabilization.** Alkaline stabilization is a process in which dewatered sludge is combined with an alkaline material such as cement kiln dust or lime to raise the pH and temperature and reduce the water content of the sludge. Raising the pH and temperature of the sludge creates an environment which is hostile for pathogen growth and reproduction. Alkaline stabilization, like composting, can produce a material that meets MassDEP's requirements for distribution to the public.

The primary market for an alkaline stabilized sludge is the agricultural industry. The alkaline stabilized sludge has alkalinity and nutrients which are useful for growing corn and other crops; however, this type of agricultural market does not exist on Cape Cod.

The facilities required for alkaline stabilization include enclosed areas for storing alkaline materials, processing the sludge-alkaline material mixture, and storing the final product. Equipment requirements include screw conveyors for transferring the alkaline materials, a mixing unit that combines dewatered sludge and alkaline material, and a drying process for the blended material. Land area requirements and capital and operations requirements are comparable to those of a composting facility. Alkaline stabilization is typically not cost effective for small sludge flows in areas where there is not a market for the final product.

d. **Heat Treatment and Drying.** Heat treatment and drying are thermal stabilization processes which involve heating sludge under pressure to disinfect and dry the sludge. The resulting material is easier to dewater and may be dried to produce a powdered or pelletized product, which can be used as a fertilizer or soil conditioner.

These processes generally have high capital costs, level of complexity, high energy usage and operation costs, and are usually poorly received by the public due to air emissions. In addition, thermal processes require a continuous flow of sludge to keep the process running and are therefore usually not cost effective for low sludge flows.

Sludge stabilization has the following advantages:

- Certain processes, such as composting and alkaline stabilization, produce a material that can be distributed to the public, providing a beneficial reuse of the sludge and potentially reducing transportation and disposal costs.
- Processes are often easily expanded to accommodate increased sludge flows.
- These processes produce a sludge that is easiest to dispose because the sludge material is biologically more stable and less likely to decompose and generate odors.
- Anaerobic digestion produces methane gas which, if produced in large volumes, can be used as a supplementary energy source.

Sludge stabilization has the following disadvantages:

- The wastewater treatment facility would be relatively small initially, depending on the area contributing wastewater flow, and may therefore not produce a steady flow of sludge, making most of these processes impractical until larger treated flows are reached.
- The demand for a composted or alkaline-stabilized product is unknown and may be minimal due to the relatively low number of agricultural areas in Cape Cod and Eastern Massachusetts.
- Stabilization processes, particularly thermal processes, generate odors and require the construction of odor control facilities.
- High land area requirements to provide space for equipment and materials.
- Composting, alkaline stabilization, and heat treatment alternatives require extensive permitting and monitoring for MassDEP and USEPA approval prior to distribution of the finished material.
- Energy use for mixing and processing equipment would be high, resulting in high O&M costs.
- Requires high level of skill for operation and maintenance of the complex machinery.

6.0 COLLECTION SYSTEMS TECHNOLOGIES

A. **Gravity Sewers and Pumping Stations.** The most prevalent type of collection system is a traditional gravity sewer. This type of system involves the installation of sewers at a constant downhill gradient. The slope is designed to maintain a sufficient velocity within the sewer line to ensure that all solids stay suspended within the waste stream. The minimum size of a typical sanitary sewer is 8 inches. The pipe size increases proportionally with the expected wastewater flow. The sewer is installed at a constant slope until its depth becomes so great that a sewage pumping station (or lift station) is needed to “lift” the flow to a wastewater treatment plant or to another gravity sewer. In flat terrain, several pumping stations may be required before the flow is pumped to a treatment facility.

In most situations, homes along a gravity sewer connect into the system with gravity service connections from the building to the collector sewer. Houses that are below the street elevation use small pumps and a small diameter force main (1 to 2 inches) for discharging to the collector sewer.

The installation cost and ease of construction of a gravity sewer depend greatly upon the topography within a particular area and on the specific soil types. In areas where topography is consistently increasing or decreasing, the sewers can be installed close to minimum depth. In very hilly areas, deep sewers and/or pumping stations may be required. This can significantly increase construction costs when compared with other options.

Advantages of gravity sewers include the following:

- A properly designed and installed gravity sewer requires little maintenance.
- A gravity system can be easily expanded to serve additional areas.
- The potential for odors in a properly designed gravity sewer is low.
- A gravity system is reliable, since it is not dependent upon electrical power for operation where no pumping stations are required. When pumping stations are used with a gravity system, electrical generators are provided to supply power during a power outage.

Disadvantages of gravity sewers include:

- Gravity sewers are installed at a constant slope, and thus can require deep excavations as the topography changes. Construction with trenchless technologies is generally difficult as constant grades are required. Construction is generally disruptive to traffic patterns and surface infrastructure, as they are often located along the centerline of roads.
- Pumping stations are required to transport the sewage out of low points in topography.
- Capital and operation and maintenance costs increase with each pumping station required.
- Pumping stations tend to increase the potential for odor emissions.
- If not installed properly, gravity sewers are prone to infiltration from groundwater, which reduces the wastewater carrying capacity of the pipe, increases pumping costs,

and can affect treatment capacity and process effectiveness at the downstream treatment facility.

- If not installed properly, there is a potential for exfiltration of sewage into the surrounding soil if any breaks occur in the pipeline.

B. **Pressure Sewers with Grinder Pumps.** A pressure sewer system requires the installation of a grinder pump to serve each building or group of buildings. Wastewater flows by gravity into a pump chamber, where the sewage is shredded and pumped into a pressure sewer, which eventually discharges to a gravity main or directly to a treatment facility. This type of technology is particularly suited to areas where there is a need to minimize excavation or in areas of rolling or hilly topography.

The typical pressure in this type of system is 5 to 40 pounds per square inch (psi). Pressure systems can be expanded to serve additional areas up to a design limit of 60 psi. Typically, systems can be expanded to serve a large number of additional homes, but the overall expansion capability tends to be less than that of a gravity sewer.

Advantages of a pressure sewer include the following:

- The collection main is installed at a relatively shallow depth and is independent of grade changes. This allows less excavation, lower piping construction costs, and less overall disruption to the area due to a shorter construction period for installation.
- A pressure sewer can serve areas of hilly terrain or marginal slope.
- A pressure sewer (beyond the pumping chamber) is not susceptible to infiltration, unlike gravity sewers.
- The shredding action of the pump eliminates the need for a larger-size collection system. Pressure sewers tend to be much smaller diameter than a typical sanitary sewer, ranging from 1-1/4 inch to 4 inch, depending upon the expected design flow.
- The pressure sewer mains can be located in road shoulders to minimize construction in roads when space is available.
- Some portions of pressures sewers could be installed with trenchless technologies, thus reducing general disruptions experienced during construction.

Disadvantages to this type of system include the following:

- Each building or group of buildings in the system would have to be equipped with a pump unit, which increases operation and maintenance requirements. Spare parts must be maintained for these units to minimize disruption of service.
- Each pump unit is dependent upon electrical power for proper operation; since the pumps are located at individual homes, municipal backup electrical power is typically not provided. Storage capacity is typically built into each pump chamber (normally 60 gallons). However, in a prolonged power outage, it would be possible for the wastewater flow to exceed this capacity and back up into the pipelines within the structures. This can be remediated by providing electrical connections on each pump unit to allow a service crew to connect a portable generator and pump out each unit during times of prolonged power outage. Another optional remedy is to install a larger unit with more capacity or a dual tank system. The additional storage would minimize inconveniences during outages.
- This system is more sensitive to seasonal flow conditions than a gravity sewer. In areas with extreme seasonal fluctuations, minimum flow conditions must be carefully quantified to be sure the sewage flow can properly travel through the system. If inadequate flow exists, solids can harden within the sewer and cause blockages.
- There is a potential for exfiltration of sewage into the surrounding soil if leaks or breaks occur in the pipeline.
- Training would be required to familiarize operating staff with maintenance of the pumps and pressure sewers.

C. Septic Tank Effluent Sewers.

1. **General.** Septic tank effluent sewers use either new or existing septic tanks and are designed to transport septic tank effluent to a treatment facility. The use of septic tanks prevents a large portion of solids and grease from entering the sewer. An effluent screen located upstream of the discharge point helps to keep solids out of the sewer.

Septic tank effluent sewer systems require septic tank maintenance, including routine pumping and treatment of septage. Each septic tank should be inspected during sewer construction to replace those tanks which provide inadequate service. Inadequate tanks include those which are prone to infiltration, are insufficient in size, have inappropriate inlets or outlets, or do not meet current Title 5 requirements.

When connecting septic tank effluent into existing gravity systems, odor control systems may be required at the discharge point and downstream pumping stations to mitigate odors caused by the hydrogen sulfide content in the effluent. Manholes at the discharge point should be protected from corrosion, which can occur as a result of the high hydrogen sulfide concentrations.

There are two types of septic tank effluent collection systems: (a) septic tank effluent pump systems; and (b) septic tank effluent gravity systems. A discussion of each system is presented in the following sections.

2. **Septic Tank Effluent Pump (STEP) System.** The STEP system involves the installation of an effluent pump immediately downstream of the septic tank (or in the septic tank), which pumps the effluent to a pressure sewer. Thus, the system is very similar to a pressure system.

The STEP system has the following advantages:

- The system can serve in areas of hilly or flat terrain.
- The pumps and piping can be installed at shallow a depth, which reduces construction costs and overall disruption associated with excavation.
- The pressure sewer (beyond the septic tank) is not susceptible to infiltration because the system is pressurized.
- Septic tank effluent pumps tend to be less expensive than grinder pumps because the need for a shredder is eliminated.
- Few solids are transported in the system, which reduces the potential for sewer blockages caused by solids deposition.

The STEP system has the following disadvantages:

- The septage must be periodically pumped from the individual septic tanks.
- The system relies on electrical power to operate the pumps and will not function during power outages. However, the pumps are frequently installed in tanks with relatively large storage capacity.
- A large number of pumps are required, which creates greater maintenance requirements of this system when compared to a gravity sewer.
- Hydrogen sulfide buildup is common within these pipelines, which increases the potential for odors and corrosion.
- There is a potential for exfiltration of sewage into the surrounding soil if leaks or breaks occur in the pipeline.
- Training is required to familiarize operating staff with maintenance of the pumps and pressure sewers.
- A treatment plant that receives flow from this type of system must be carefully designed because it will not receive the higher organic loading that is typically needed for nitrogen removal treatment processes.

3. **Septic Tank Effluent Gravity (STEG) System.** The STEG system can be used to transport effluent from septic tanks to a pumping station or treatment facility. Layout of the system is very similar to a gravity system.

Advantages of small diameter gravity sewers include the following:

- A flatter slope can be maintained in comparison with gravity sewers, because most of the larger solids have been removed in the septic tank. The flatter slope will allow the piping to be installed at shallower depths.
- The lack of solids allows smaller diameter pipes to be installed. Sizes typically range from 4 to 6 inches versus 8 inches or greater for a typical gravity sewer.
- Cleanouts can be installed instead of manholes, which reduces installation costs.
- Very little maintenance is required on this type of system versus a pressure or vacuum system unless pumping stations are used.

Small diameter gravity sewers have the following disadvantages:

- The septage must be periodically pumped from the individual septic tanks.
- Hydrogen sulfide buildup is common within these pipelines, which increases the potential for odors and corrosion.
- They are not adaptable to hilly terrain.
- A treatment plant that receives flow from this type of system must be carefully designed because it will not receive the higher organic loading that is typically needed for nitrogen removal treatment processes.

D. **Vacuum Sewers.** Vacuum sewer is considered a new technology in Massachusetts and has been installed at a limited number of locations in the State including Barnstable and Provincetown. Vacuum sewers are typically smaller than traditional gravity sewers and rely upon a vacuum created within the pipeline to draw the sewage towards a vacuum station. Vacuum pumps located at the vacuum station are used to create a vacuum inside the sewer. Sewage from individual homes typically flows by gravity to a vacuum valve pit. Flows from larger facilities, such as hotels/motels, restaurants, apartments and condo and large commercial facilities are handled by buffer tanks instead of valve pits, however the operational aspects are similar. As sewage fills a chamber in the bottom of the valve pit or buffer tank, a sensor activates an automatic vacuum valve. When the valve opens, sewage is drawn into the sewer because of the pressure difference between the sewer and atmospheric pressure outside the valve. Each subsequent opening of the valve draws the sewage further downstream until it reaches the vacuum station, where it can then be pumped to a gravity sewer or the WWTF.

Advantages of vacuum sewers include:

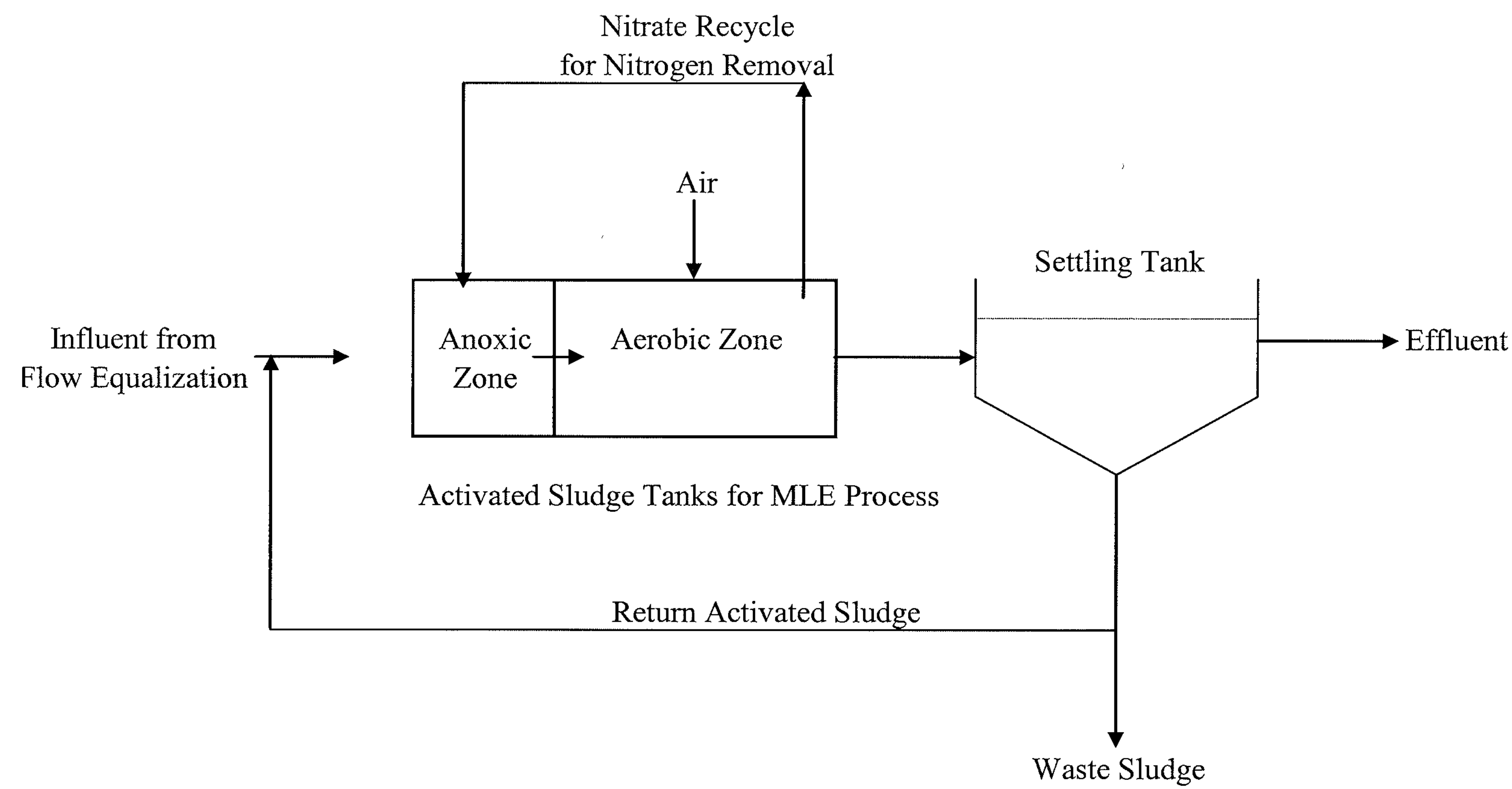
- Vacuum sewers can be installed at shallower depths than gravity, which can reduce installation costs and excavation time.
- Because the piping must be airtight to allow proper vacuum operation, the infiltration potential tends to be low. Infiltration can occur if a pipe leaks or breaks in areas where the line is completely submerged in groundwater; however, leaks are readily identified through the vacuum system operation records.
- Vacuum stations can be equipped with emergency generators, which allow the system to remain in operation during power outages.

- The vacuum sewer mains can be located in road shoulders to minimize construction in roads when space is available.
- Vacuum sewer mains are typically smaller diameter than gravity sewers

A vacuum system has the following disadvantages:

- A vacuum must be constantly maintained in the pipeline for the system to work. Malfunctions (air leaks) in the line can affect the entire system and must be fixed quickly to keep the system operational. Leaks or malfunctions may also be difficult to locate.
- The potential for odor generation at the vacuum station is greater due to the vacuum pump airflow. This air flow must be treated to minimize odors.
- Operator training would be required to gain sufficient knowledge to operate and maintain the vacuum pipelines, vacuum stations, and emergency response procedures.
- This type of system is not readily adaptable to hilly terrain.
- To design a properly operating system, the design flows must be estimated as accurately as possible, and a detailed route survey must be performed. Vacuum systems are sized for specific cases and cannot be easily expanded to serve additional homes.
- There is a potential for frozen valves, depending on the valve pit depth.
- Systems are less common in Massachusetts; therefore contractors are less familiar with the system, which has very system specific design requirements that are very different from gravity and low pressure systems.
- Headloss and length limit the application of this technology.
- System is very sensitive to the types and flow variations which can impact system performance and capacity.
- Large commercial developments (hotels, motels) typically require the use of buffer tanks, which complicate the system.
- Large flows entering vacuum systems at one location are difficult to manage and cannot be located at the ends of the collection system lines.
- Gravity and pumping stations should not be connected into vacuum systems, large flow rates from pumping stations and infiltration/inflow from gravity systems can overwhelm the vacuum valves.

- Buffer tank installations (if needed) add to operations and maintenance requirements (act as small pumping stations).
- Influent pipes to buffer tanks (if needed) are susceptible to clogging with rags and can create backups in the gravity lines feeding the system, and can impact flow splitting in these structures.



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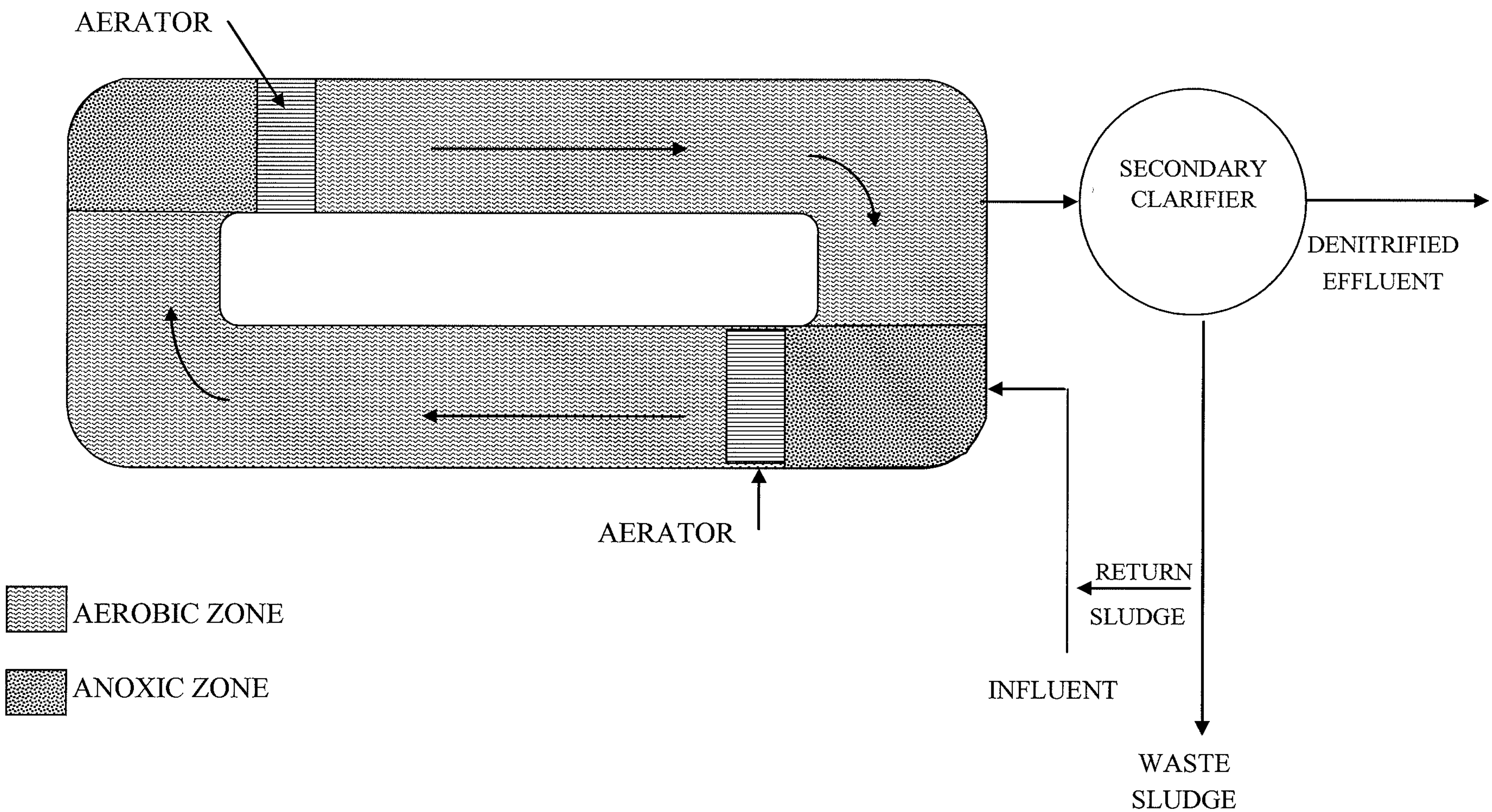
MANAGEMENT PLAN

ACTIVATED SLUDGE / MLE PROCESS

FIGURE J-1



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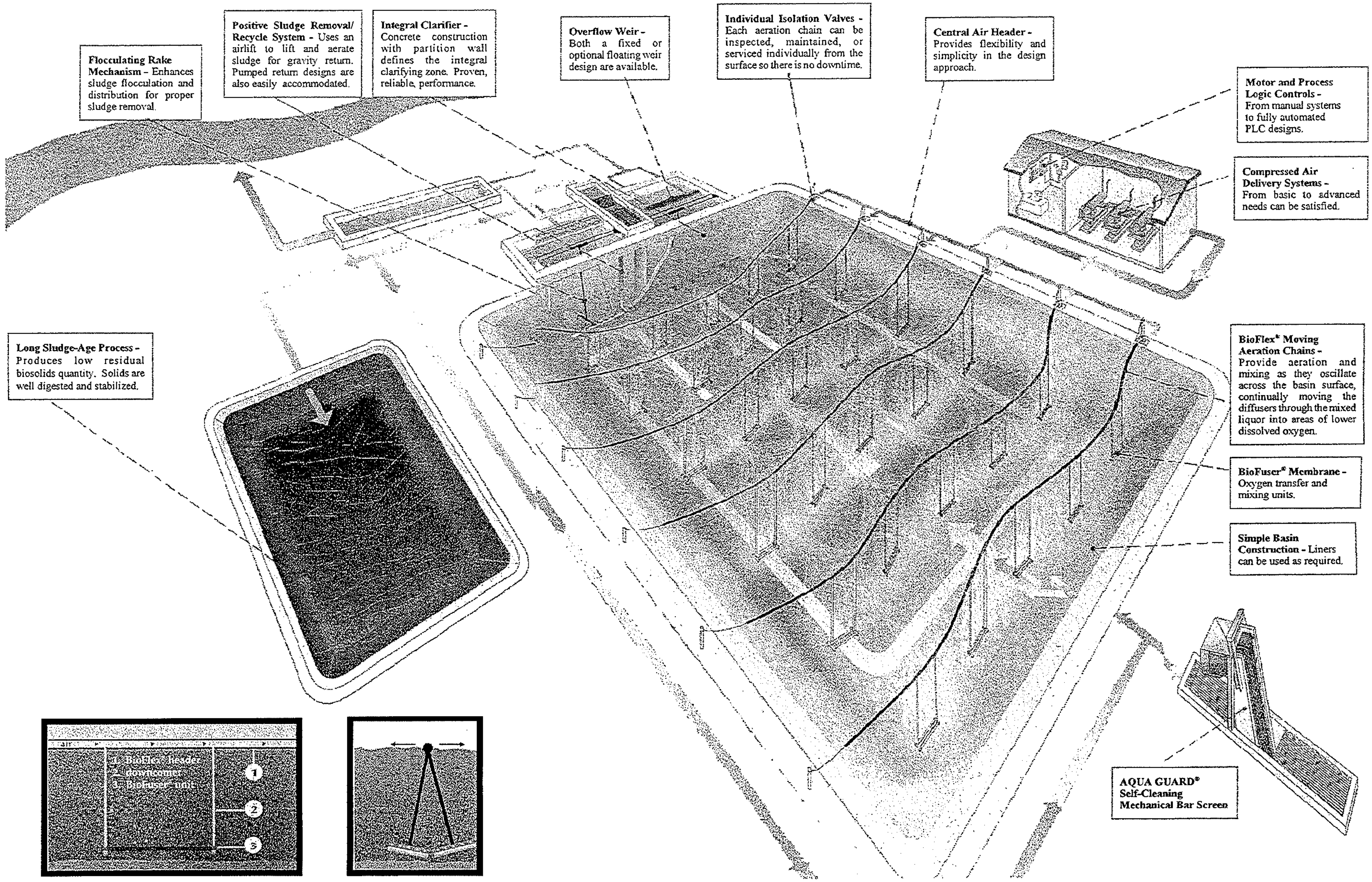
OXIDATION DITCH FOR NITROGEN REMOVAL

FIGURE J-2



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BIOLAC LAGOON

FIGURE J-3

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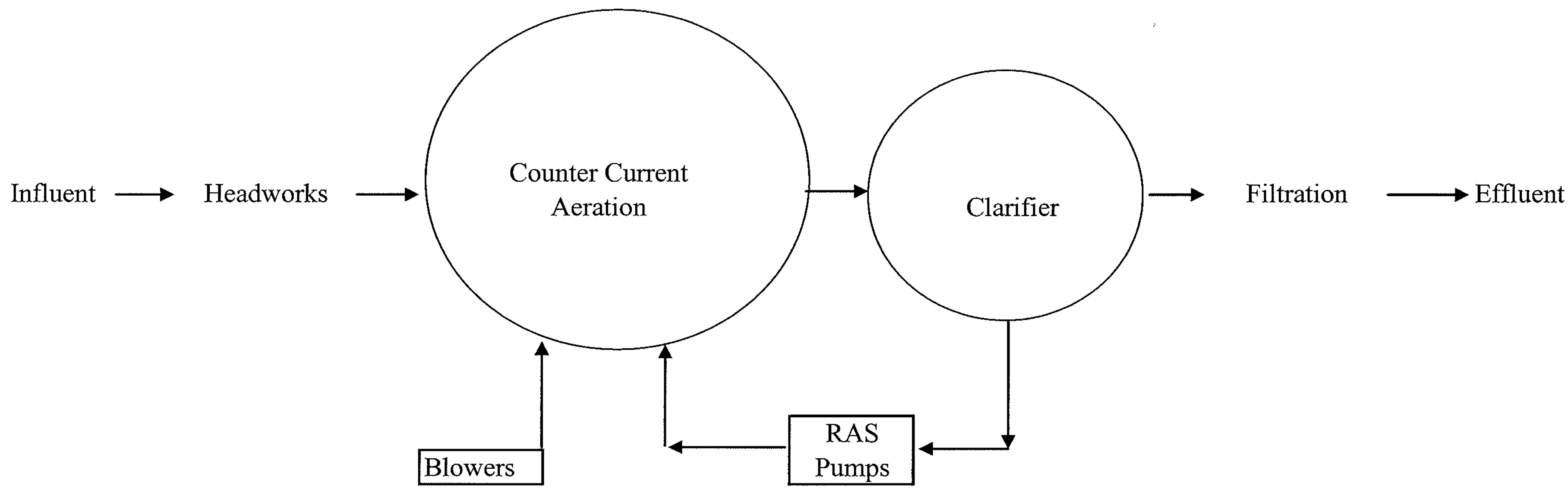

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MANAGEMENT PLAN

SCHREIBER

FIGURE J-4

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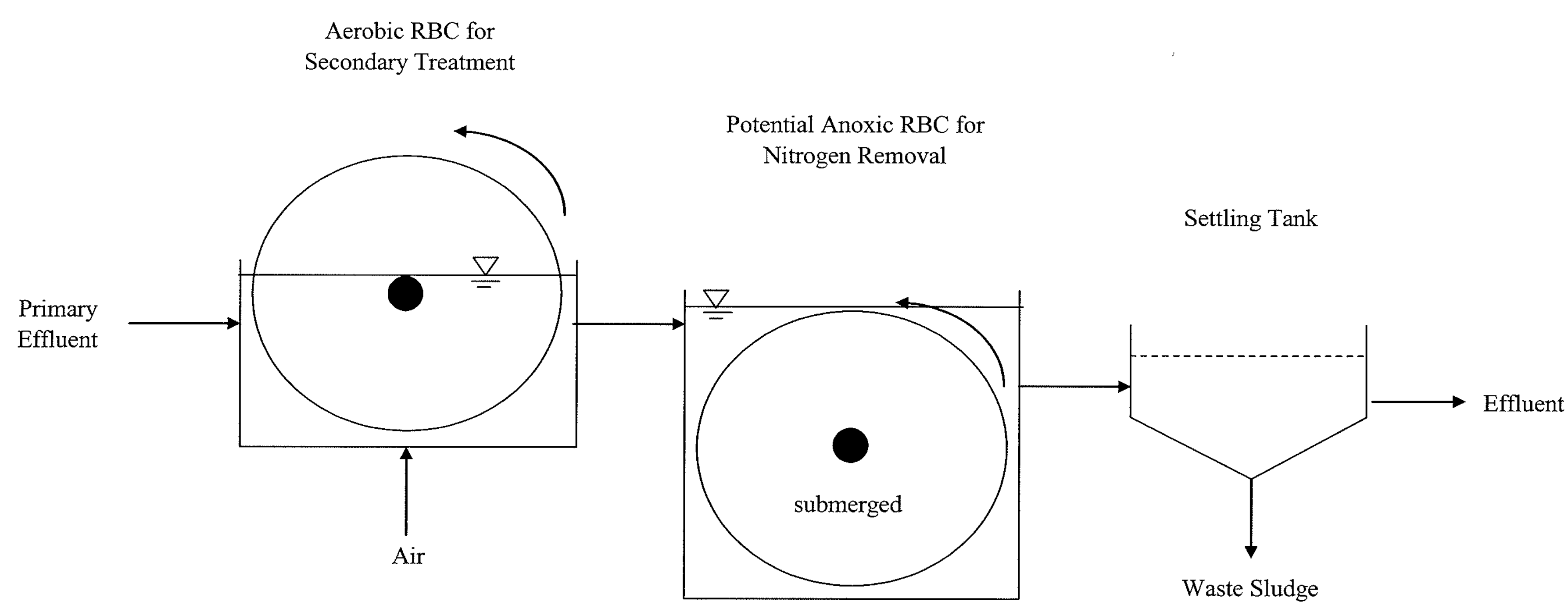

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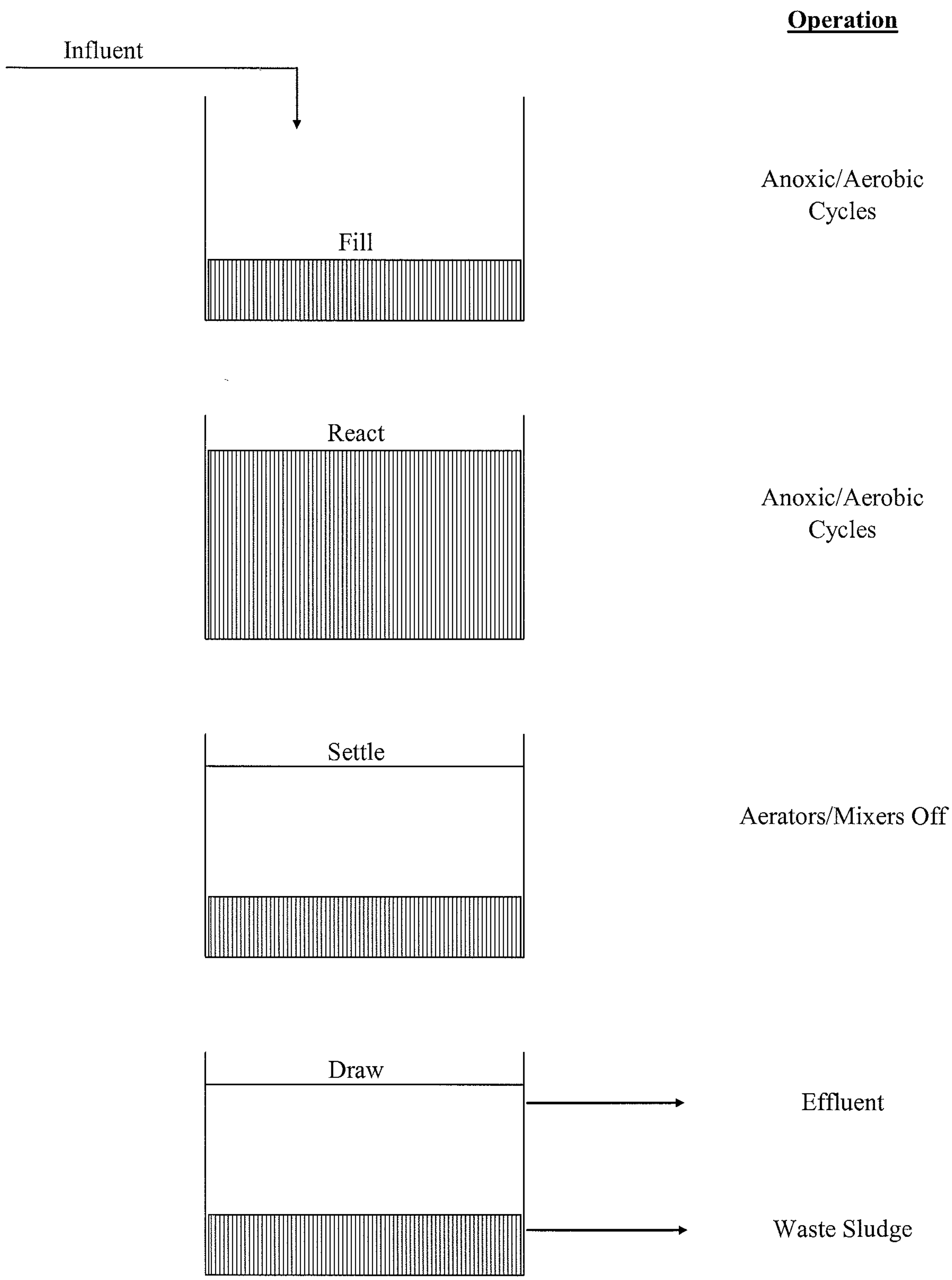
ROTATING BIOLOGICAL CONTACTOR

FIGURE J-5



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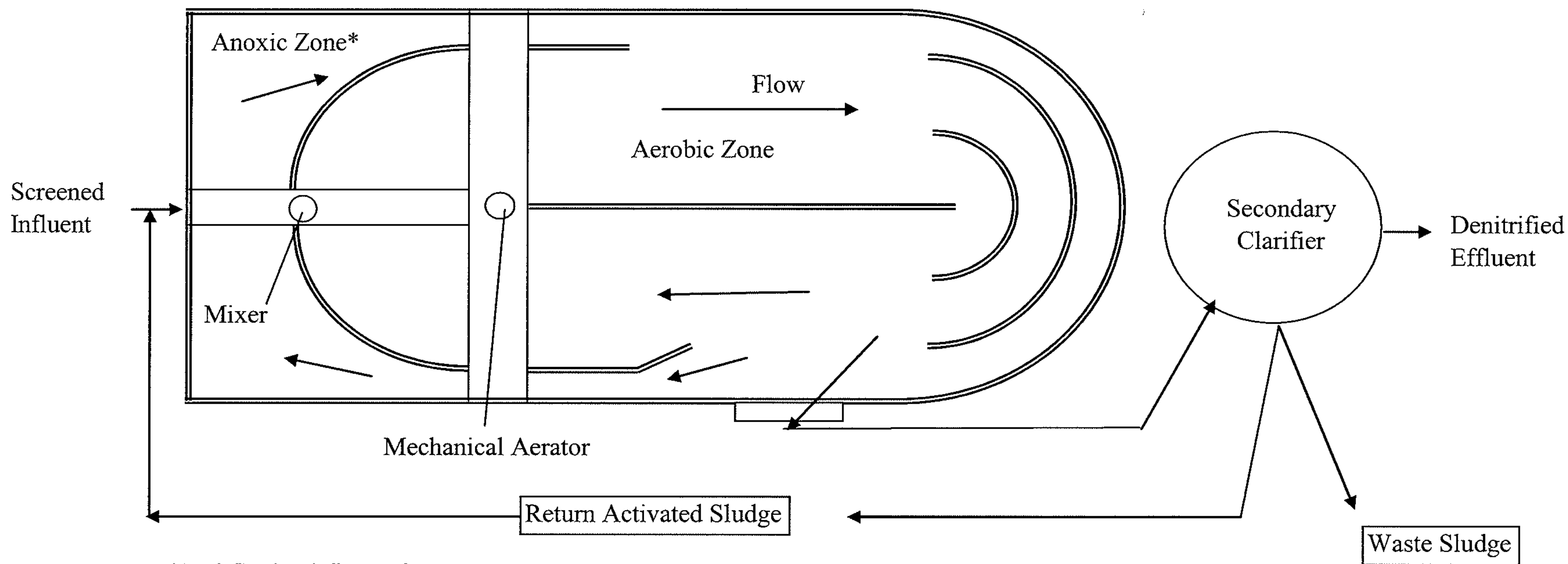
SEQUENCING BATCH REACTOR

FIGURE J-6

Carrousel



*Anoxic Zone is typically covered

Source: Eimco Water Technologies

Data Source: Mass GIS
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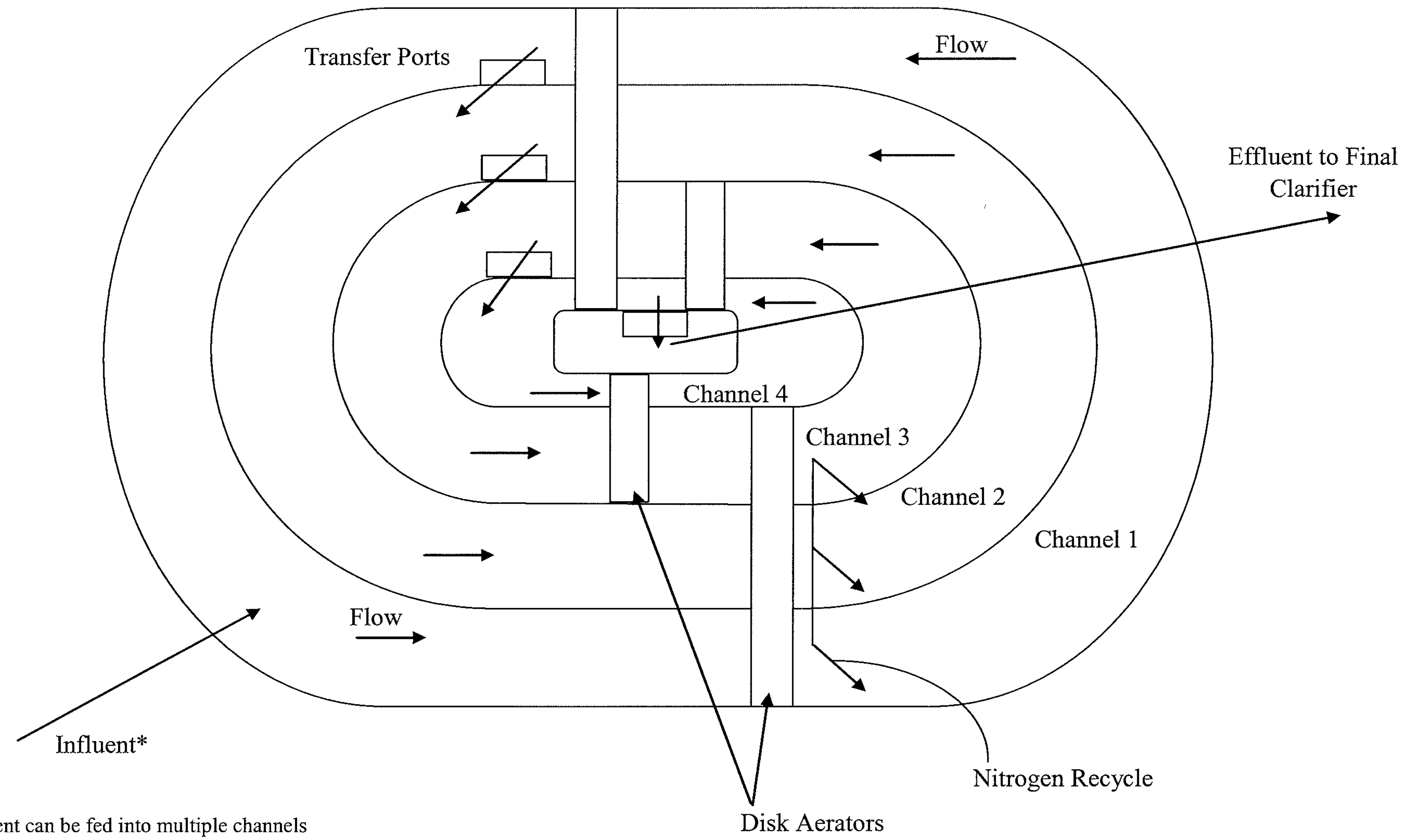
CARROUSEL

FIGURE J-7



*Influent can be fed into multiple channels

Source: USFilter

Data Source: Mass GIS
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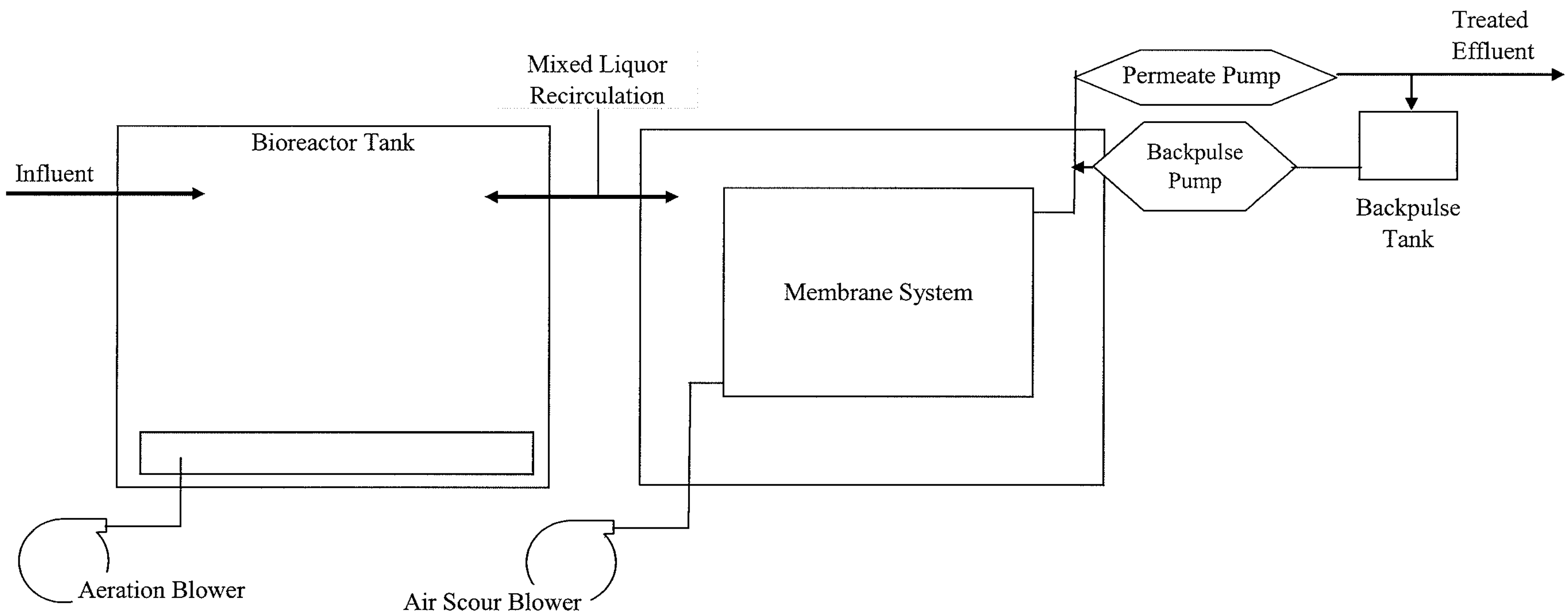
ORBAL

FIGURE J-8



Source: Zenon Environmental, Inc.

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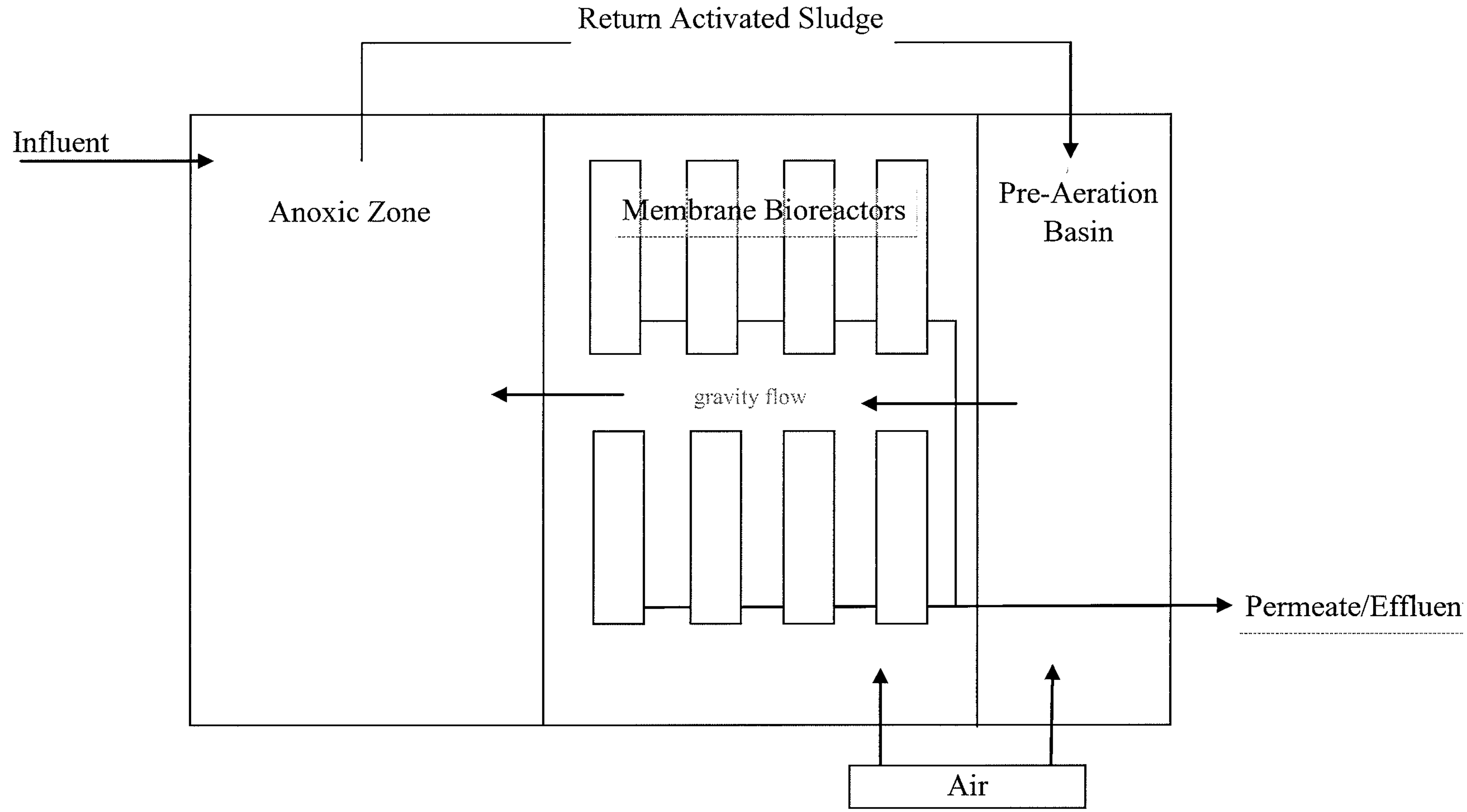
TOWN OF CHATHAM, MASSACHUSETTS
COMPREHENSVE WASTEWATER
MANAGEMENT PLAN

ZENON SYSTEM

FIGURE J-9



Source: Enviroquip, Inc.

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MANAGEMENT PLAN

ENVIROQUIP MEMBRANE BIOREACTOR

FIGURE J-10

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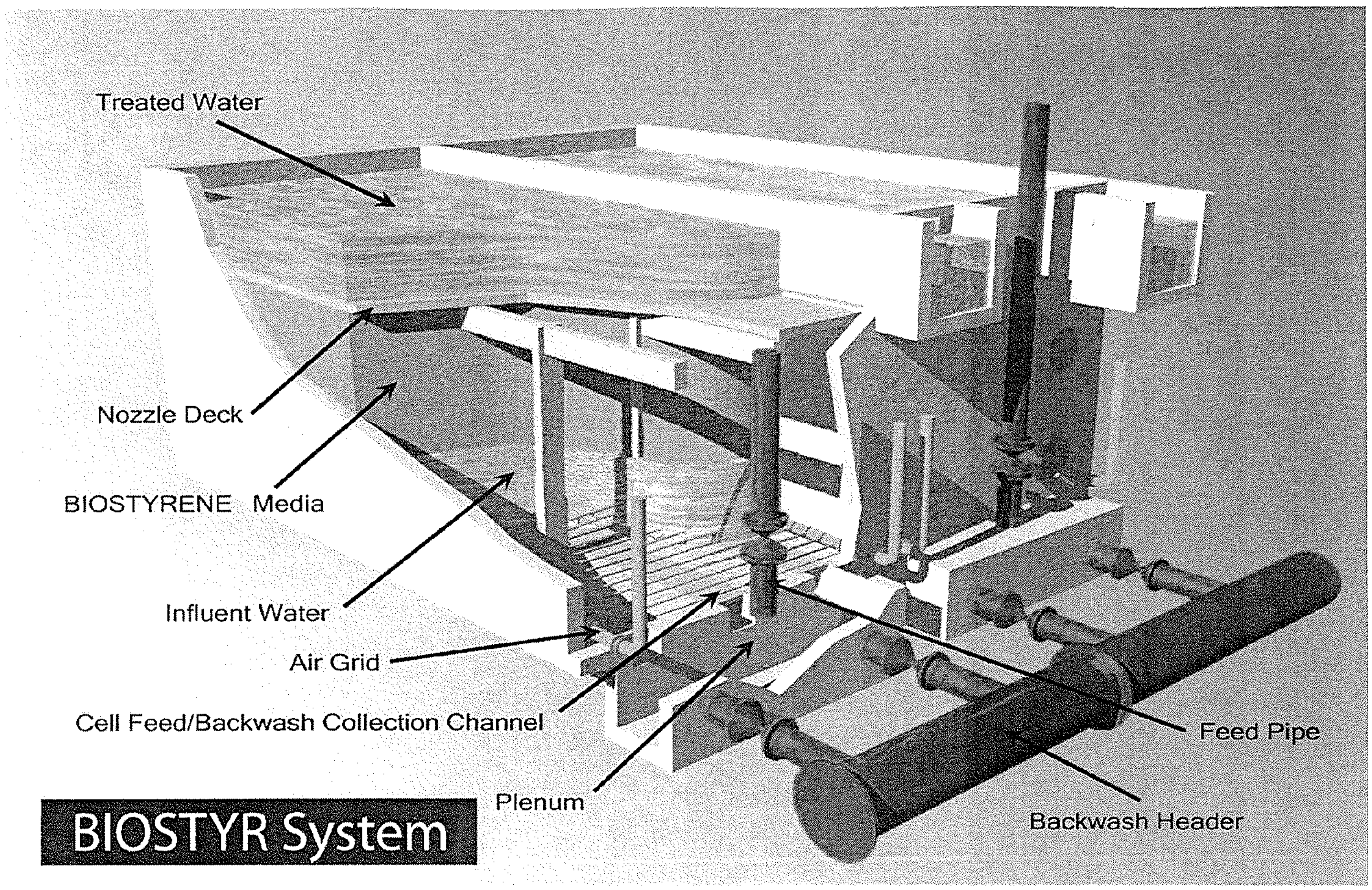

FLEXIBLE, COMPACT FOOTPRINT

Source: Kruger, Inc.

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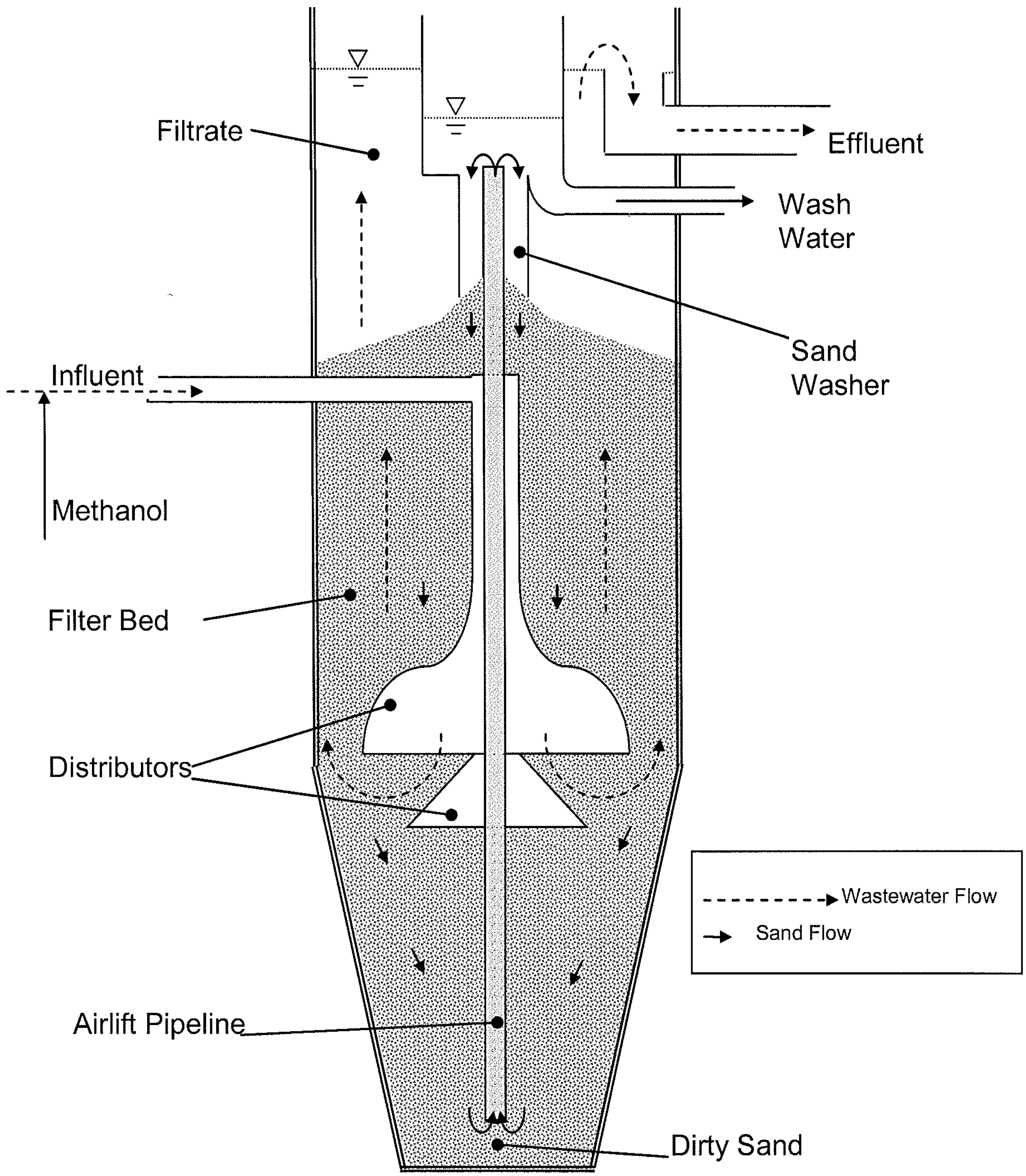
BIOLOGICAL AERATED FILTERS

FIGURE J-11



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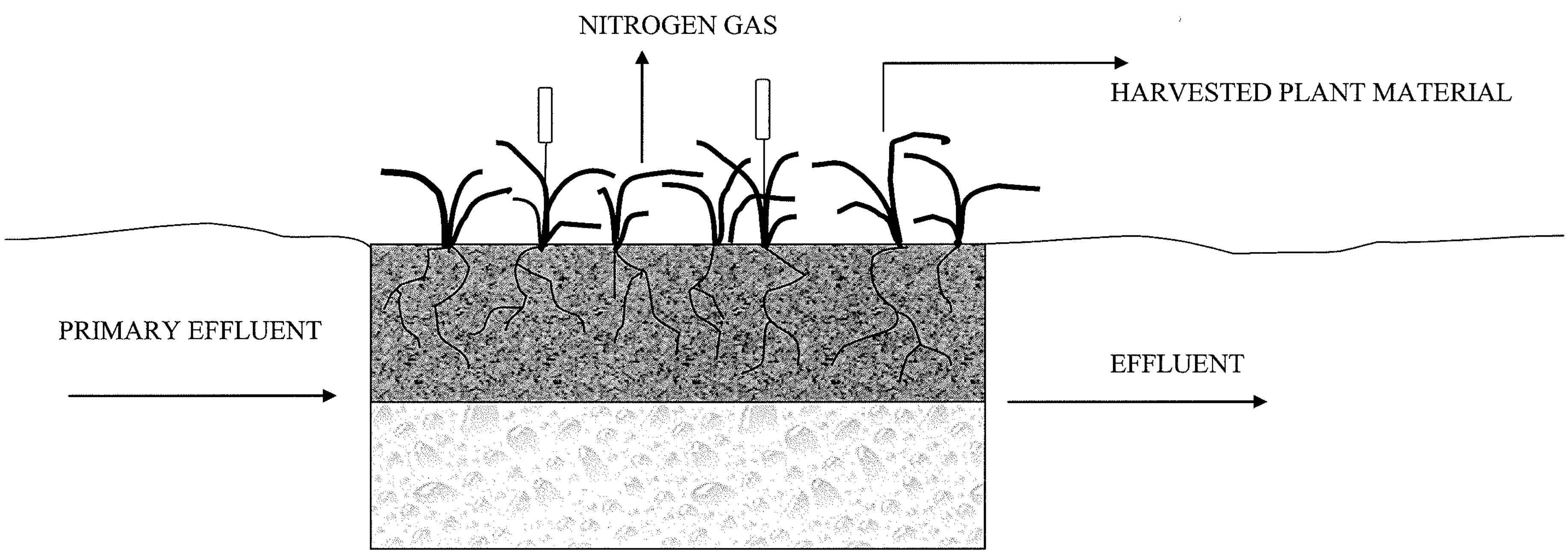
DENITRIFICATION FILTER

FIGURE J-12



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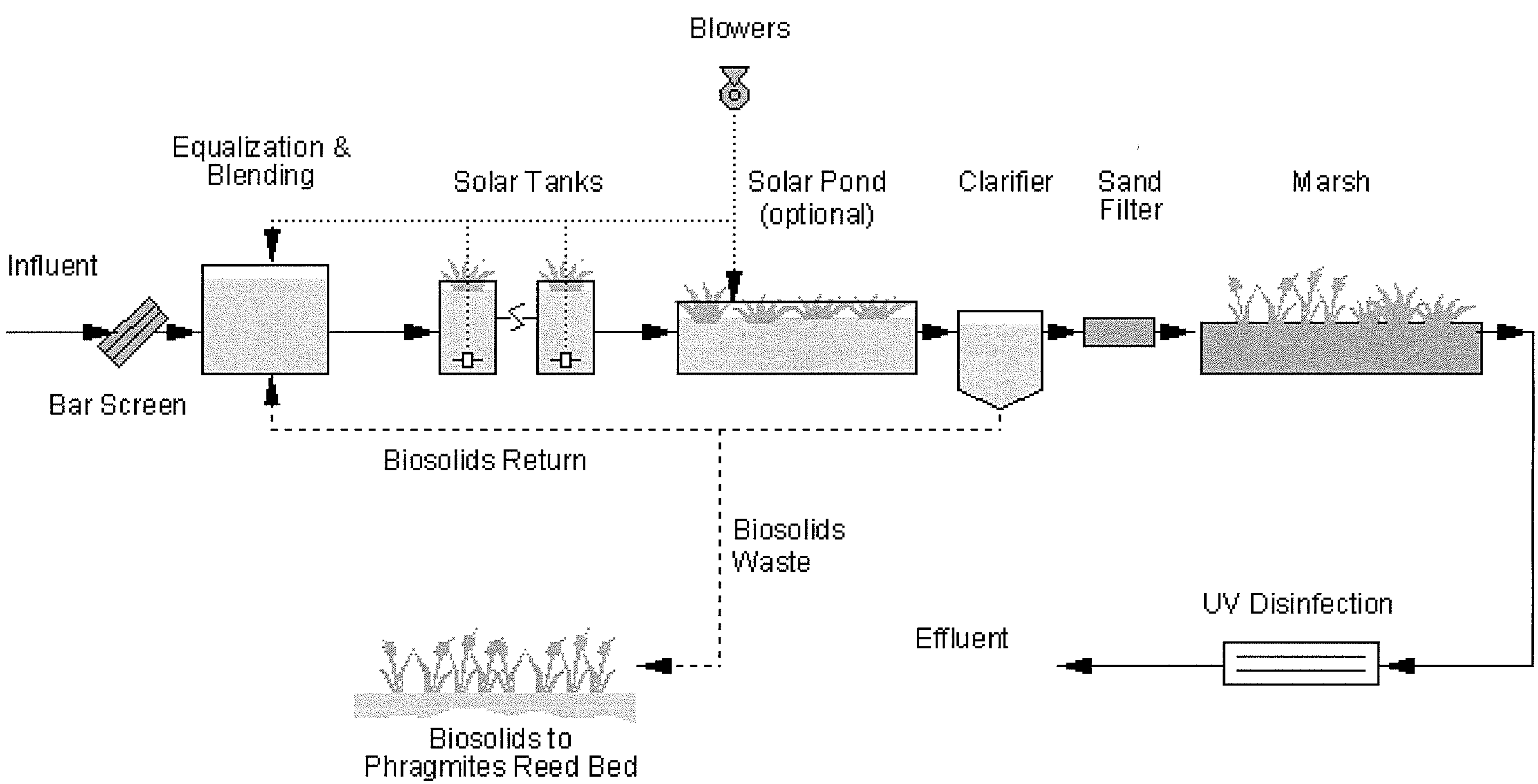
CONSTRUCTED WETLANDS

FIGURE J-13



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File Location: J:\GIS\GIS Project Folder\Job#\70098 Chatham\CWMP Figures\Report Figures\Technology Screening Report\70098FJ-14.mxd

Stearns & Wheler, LLC
Environmental Engineers and Scientists
HYANNIS, MASSACHUSETTS

Date: 7/2007 Project No. 70098

TOWN OF CHATHAM, MASSACHUSETTS
COMPREHENSVE WASTEWATER MANAGEMENT PLAN

SOLAR AQUATICS SYSTEM

FIGURE J-14