Chapter 3

Individual On-Site System and Cluster System Alternatives

CHAPTER 3

INDIVIDUAL ON-SITE SYSTEM AND CLUSTER SYSTEM ALTERNATIVES

3.1 INTRODUCTION

A. **Purpose.** The purpose of this chapter is to identify and screen Individual On-Site System and Cluster System wastewater treatment and recharge technologies which could be used to mitigate wastewater issues identified in the Draft Needs Assessment Report.

These types of wastewater management systems typically have wastewater flows less than 10,000 gallons per day (gpd) and are regulated by MassDEP and local Boards of Health under the Title 5 regulations. These systems are often called "decentralized management" systems though there is no universally accepted definition or flow range for "decentralized management" systems. Systems with flows greater than 10,000 gpd require a MassDEP groundwater discharge permit and must meet more stringent discharge requirements. These larger systems (the ones needing a groundwater discharge permit) are often called "centralized and or satellite" systems though (again) there is no universally accepted definition or flow range for these larger systems. For the purpose of this report, the following definitions are used to categorize the various types of wastewater management systems:

- Individual on-site systems serve one site and do not require a collection (sewer) system. They are privately owned and they are regulated by the Title 5 regulations.
- Cluster systems serve more than one property and require a collection (sewer) system to convey the wastewater from the properties to the treatment and recharge system. They can be privately or municipally owned. They are regulated by the Title 5 regulations and can be used for maximum-day flows up to 10,000 gpd. This maximum-day flow typically corresponds to a maximum of 30 three-bedroom houses. These types of systems are often required to obtain 50 percent nitrogen removal (19 to 25 mg/L total nitrogen, though the exact requirements depend on specific regulating factors.

- Satellite systems serve more than one property and require a collection (sewer) system. They require a MassDEP discharge permit and must provide nitrogen removal to less than 10 mg/L total nitrogen on a maximum daily basis. They may have more stringent nitrogen limits as well depending on the recharge location. They have discharge limits for other pollutant and nutrient parameters as well. They typically have flows in the 10,000 gpd to 300,000 gpd range. In Barnstable, satellite systems could be larger than 300,000 gpd and it is assumed that they would be municipally owned and managed by the Town's Water Pollution Control Division of the Department of Public Works which is centered at the Hyannis WPCF.
- Centralized systems typically treat flows greater than 300,000 gpd and need to meet stringent discharge limits (as required for a MassDEP discharge permit) for nitrogen as well as other parameters. The Hyannis WPCF is considered the centralized system in Barnstable.

These definitions are consistent with wastewater planning guidance documents prepared by the Cape Cod Water Protection Collaborative.

Individual On-Site System and Cluster System technologies are identified and screened in this Chapter based on their ability to address the wastewater needs in Barnstable. The ability of these technologies to consistently remove nitrogen from wastewater is an important factor. Individual On-Site System and Cluster System alternatives selected for further consideration will be included in the alternative plans identified as part of the next phase of this project.

B. **Comparison with Centralized Collection and Treatment.** The individual on-site system and cluster system technologies in this chapter are presented as an alternative to satellite or centralized wastewater collection and treatment. To properly evaluate decentralized collection and treatment system alternatives, it is important to understand some of the general advantages and disadvantages of centralized collection and treatment systems, as summarized below.

Centralized collection and treatment has the following advantages:

- Wastewater is removed from the sewered area, minimizing health threats and nitrogen loading to the specific sewered area.
- Individual property owners will not have the responsibility of operating their own on-site or cluster wastewater treatment system.
- Fewer treatment sites would be required within the Town.
- Centralized and satellite wastewater treatment systems are reliable, provide high quality effluent, have professional operations staff, and have regular monitoring of the recharged water.
- Expanding sewers into portions of the Town that are adjacent to existing centralized collection facilities is typically less expensive than other treatment and recharge scenarios requiring site purchase and new facilities. An "economy of scale" to treat and recharge the wastewater at one location can reduce capital and O&M costs.
- Fewer resources are required for the Town to operate one or two facility(ies) as compared to many cluster or satellite systems.

Centralized collection and treatment has the following disadvantages.

- Sewer construction can potentially disrupt traffic and have a high capital cost associated with it. (This disadvantage applies to cluster and satellite systems too.)
- Treated water recharge issues, including siting, capacity, and groundwater elevation impacts to low elevation properties, can limit the amount of treated water recharged in one location.
- Centralized facilities may be located at great distances from the areas being served, increasing costs associated with wastewater collection and transfer.

C. **Advantages/Disadvantages of Sewers and On-Site Systems.** Individual on-site systems have two major advantages as compared to cluster or centralized systems. They do not require a collection system. They also do not accumulate significant flows for groundwater recharge; therefore they tend to be easier to site. These advantages make individual on-site systems less expensive.

Individual on-site systems have the following major disadvantage that is described in following sections: long-term monitoring of the technologies approved by MassDEP for individual on-site systems has not proven their ability to consistently produce effluent with less than 19 mg/L total nitrogen (current MassDEP performance criteria for individual on-site nitrogen removal systems). This disadvantage makes individual on-site nitrogen removal systems impractical for areas where greater than 50 percent wastewater nitrogen removal is needed.

3.2 INDIVIDUAL ON-SITE SYSTEMS

A. **Introduction.** There are several new developments with individual on-site systems that may prove feasible for the Town. Also, there is much interest in individual on-site systems and in cluster systems that use decentralized treatment technologies on Cape Cod.

On-site systems are used to treat wastewater from individual lots and may utilize one of several innovative and alternative (I/A) technologies. The following is the definition of I/A technologies in accordance with Title 5 Regulations (310 CMR 15.002):

> "Alternative Systems – Systems designed to provide or enhance on-site sewage disposal which either do not contain all of the components of an on-site disposal system constructed in accordance with 310 CMR 15.100 through 15.293 or which contain components in addition to those specified in 310 CMR 15.100 through 15.293 and which are proposed to the local approving authority and/or the Department for remedial, pilot, provisional, or general use approval pursuant to 310 CMR 15.280 through 15.289."

MassDEP has identified the allowable uses for each approved I/A system and has assigned each into one of four categories: remedial, pilot, provisional, and general use. Each of these categories is defined below.

> "The purpose of a **Piloting Approval** is to provide field testing and technical demonstration that an I/A technology can or can not function effectively under relevant physical and climatological conditions at one or more pilot facilities. Although information obtained during piloting is likely to be relevant to long term operation and maintenance concerns about a particular alternative system, approval for piloting is not intended, in and by itself, to provide a full evaluation of these issues.

> **Provisional Approval** is intended to designate alternative systems that appear technically capable of providing levels of protection at least equivalent to those of standard on-site disposal systems and to determine whether, under actual field conditions in Massachusetts with broader usage than a controlled pilot setting, general use of the alternative system will provide such protection, and whether any additional conditions addressing long-term operation and maintenance and monitoring considerations are necessary to ensure that such protection will be provided.
>
> Certification for **General Use** is intended to facilitate the use, under appropriate conditions, of alternative systems that have been demonstrated to provide levels of environmental protection at least equivalent to those of standard on-site systems.
>
> The purpose of approval for **Remedial Use** is to allow for the rapid approval of an alternative system that is likely to improve existing conditions at a particular facility or facilities currently served by a failed, failing, or nonconforming system."

MassDEP has also identified I/A systems that receive nitrogen reduction credits as part of their technology approvals. For the purposes of this evaluation, the various on-site treatment system technologies are grouped as follows:

1. On-site systems approved for general use but not credited for nitrogen removal. This includes Title 5 septic systems and equivalent approved alternative systems.

2. Non-discharge systems.

   a. Tight tanks
   b. Waterless toilets
   c. Urine source separation

3. On-site nitrogen removal systems, also called I/A technologies, of which there are three types:

   a. Nitrogen removal systems approved for general use by MassDEP in nitrogen-sensitive areas, which include:
      - recirculating sand filters that comply with Title 5
      - RUCK® systems (for flows less than 2,000 gpd)

- MicroFAST®, HighStrengthFAST®, and NitriFAST® systems (for flows less than 2,000 gpd)

b. Nitrogen removal systems approved for provisional use by MassDEP in nitrogen-sensitive areas, including:

- Bioclere®
- MicroFAST®, HighStrengthFAST®, and NitriFAST®
- Modular FAST®
- Waterloo Biofilter®
- Amphidrome® Process
- AdvanTex®
- NITREX®
- SeptiTech®
- Singulair® (for flows less than 2,000 gpd)

c. Nitrogen removal systems approved for piloting use by MassDEP in nitrogen-sensitive areas, including:

- RUCK CFT®
- Cromaglass® WWT System
- OMNI® Recirculating Sand Filter
- OMNI-Cycle® System (for flows less than 2,000 gpd)
- NITREX® Plus (for flows less than 2,000 gpd)
- BioBarrier® MBR WWT System (for flows less than 2,000 gpd)

B. On-Site Systems Not Credited for Nitrogen Removal.

1. **Title 5**. Conventional Title 5 systems not credited for nitrogen removal consist of a septic tank, a distribution box, and a leaching area, as shown in Figure 3-1. Wastewater is discharged to the septic tank, as shown in Figure 3-2, where settleable solids sink to the bottom of the tank, and floatables (like grease and toilet paper) rise to the surface, forming a scum layer. The septic tank prevents the solids from flowing to the leaching area where they could plug the solids and cause a failed septic system (septic tank effluent rising to the ground surface where it could cause odors or disease; or causing the building drains to backup) Decomposition of the organic matter occurs in the septic tank and produces ammonia and other dissolved pollutants.

The liquid effluent then flows via the distribution box to a leaching area, where it percolates through stone bedding and the soil prior to reaching the groundwater. A typical leaching chamber and leaching trench are shown in Figures 3-3 and 3-4, respectively.

Septic tank effluent ammonia-nitrogen levels are generally in the range of 20 to 60 mg/L. Septic tank effluent concentrations of BOD and TSS are approximately 140 to 200 mg/L and 50 to 90 mg/L, respectively. There are large ranges in the concentrations of these parameters because different households use varying amounts of water for showers, laundry, and household cleaning. The more water that is used, the more diluted the septic tank effluent will be. When a household conserves water, these concentrations will be higher. Title 5 systems reduce bacterial contamination primarily via filtration of effluent through a biological mat and the soils beneath the leaching area. The leaching area is designed to promote aerobic conditions; therefore, nitrification will occur, converting the ammonia nitrogen (NH_3-N) to nitrate nitrogen (NO_3-N). A small amount of denitrification occurs in a leaching system and some of the nitrogen will be converted to nitrogen gas to be released to the atmosphere.

Soil characteristics are an important consideration for the leaching systems. Clay and silt in the soil will result in low infiltration capacity of the soils and require a more expensive leaching system.

There are several approved innovative and alternative technologies that have been approved by MassDEP as being "equivalent to conventional Title 5 system." Those technologies that provide nutrient removal are discussed in later sections based on the current status of their regulatory approval for nutrient removal. Those that are not specifically approved for nutrient removal should be considered to have similar advantages and disadvantages as conventional Title 5 systems, and will not be discussed further in this section due to the lack of nutrient removal ability.

Title 5 systems have the following advantages:

- Well proven, mechanically simple technology.
- No significant public acceptance concerns when they are properly sited and designed.
- Generally, no pumps are required for flows less than 2,000 gpd.
- Low maintenance cost compared to other systems.

- They are very successful at protecting against failed septic systems and protecting public health.

They have the following disadvantages:

- Septic tank requires pumping every two to five years (as do all individual on-site systems).
- The effluent from the system is not well treated, and it is high in nitrogen and phosphorus, which are causing the current impacts to coastal estuaries and freshwater ponds, respectively. These systems do not provide advanced nitrogen removal.

C. **Non-Discharge Systems.** There are several non-discharge systems that may be appropriate for specific areas of Barnstable as identified below.

1. **Tight Tanks.** Tight tanks are non-discharge systems that collect and store the wastewater until it can be removed by a septage hauler. All of the wastewater generated by the household or business goes directly into the tight tank. The storage tank typically has a level indicator with an alarm, and a signal is transmitted when the liquid level reaches a specified height. When the tank is full, a septage hauler empties the tank and transports the contents to a treatment facility.

Tight tanks have the following advantages:

- Simple technology.
- No significant environmental concerns when they are properly sited and designed.
- Wastewater is not discharged to the ground; therefore groundwater mounding or nitrogen loading is not a concern.
- Require less land area than a septic system (no leaching area).
- Water use is discouraged because most water used must be transported and disposed off site at a high cost.

They have the following disadvantages:

- MassDEP does not consider tight tanks an adequate long-term solution.

- High operational costs due to frequent pumping and disposal.
- Potential for frequent pump-truck traffic and odors that occur during pumping.
- Wastewater treatment and disposal issues are transferred to another location.

2. **Waterless Toilets.** Water consumption, wastewater flow, and pollutant loading can be reduced using waterless toilets. Waterless toilet systems operate by separating black wastewater and gray wastewater. Black wastewater is toilet waste and gray wastewater is generated from non-sanitary sources, such as washing clothes and dishes and bathtub and shower use. Black wastewater is treated in the waterless toilet unit, and gray wastewater is discharged to a septic system with potential size reductions. The two most common wastewater toilet systems are composting toilets and incinerating toilets.

Composting toilets recirculate the black wastewater over remaining solids to promote a natural decomposition process. Incinerating toilets burn black wastewater and generate a small quantity of ash and gas. Composted material and ash are periodically removed from the respective systems, and air filters and exhaust units are used to minimize odors. Public acceptance of waterless toilet systems is often low due to the composting, incinerating, and handling of human waste within living spaces. A potential use of waterless toilets is in public restrooms and convenience stations or at remote locations such as Sandy Neck area of Barnstable where they are currently approved and in use. Diagrams of composting and incinerating toilets are included as Figures 3-5 and 3-6, respectively.

Waterless toilets have the following advantages.

- Wastewater flows and loads are reduced if properly designed and installed.
- Water consumption is significantly reduced.
- Minimal environmental concerns occur when properly sited and designed.
- Composting toilets require minimal energy use.
- Size of standard septic system may be reduced to treat only gray wastewater.
- Routine maintenance is minimal and requires no special training.

Waterless toilets have the following disadvantages.

- Public acceptance is generally low.

- Incinerating toilets generally have high energy requirements.
- Handling of composting toilet contents can be objectionable.
- Incineration units are likely to generate odors if not vented properly.
- Not well suited to high seasonal peak loading which is typical in Barnstable during summer months.

3. **Urine Source Separation.** Water consumption and wastewater flow could be reduced using urine source separation technology. Urine separating toilet systems operate by separating urine from fecal content in the toilet. The idea behind the technology is that urine constitutes less than 1 percent of the wastewater volume, but contains most of the nutrients in wastewater. Approximately 80 percent of the nitrogen and 50 percent of the phosphorus in wastewater derives from urine. Urine also contains most of the micro pollutants in wastewater, such as pharmaceuticals and endocrine active compounds.

Urine source separation technology requires the use of specially designed toilets for the separate collection of urine. Urine is then stored separately in tanks, either located in the basement of the house or within a tank adjacent to the house. The tanks for urine storage would need to be water- and odor-tight and be made of a material that is resistant to urine and strong acids. Good ventilation would be necessary. A pump and possibly a stirring mechanism would need to be installed in the tank, as well as an alarm system to indicate when the tank capacity is being approached. For existing buildings, plumbing renovations would be required to convey the urine stream from each toilet to the holding tank. Significantly greater cleaning efforts are required to prevent odors, urine stains, and urine-scale build-up. To prevent introduction of other chemicals to the urine storage (and subsequent use or treatment), recommended cleaning would be done with a 10% citric acid solution and a microfiber cloth. Extensive public education would be necessary to equip the average homeowner to properly care for a urine diverting toilet.

In addition to increased cleaning requirements, higher operation and maintenance activities are required for urine diverting toilets. This is primarily due to the tendency of urine to create precipitates. The precipitates can form in both the storage tank and in the plumbing. Substantial precipitate build-up can occur after only a few thousand uses, thus requiring maintenance activities. Strong acids or caustic sodas are required to remove precipitation and blockages. Handling of these chemicals could be objectionable or even hazardous. Additionally, the question that arises is what is done with the chemicals and water used to remove the precipitate?

In order for urine diverting toilets to have a significant impact on Barnstable's water quality, they would need to be installed at every facility in the portions of Town that need nitrogen removal, including public facilities. The urine diverting technology that has been developed to date *requires* that everyone sit to use the toilet. Public acceptance by men would likely be low due to this required behavior modification. Additionally, women who find it objectionable for hygienic reasons to sit down on a public toilet may be resistant to the technology. In pilot tests, children have had problems using the toilet properly.

Urine diversion technology on a large scale basis would require significant decision making regarding ultimate fate of the urine and management issues.

Urine Fate. There are a variety of options for dealing with the urine collected from urine diverting toilets. One option would be the decentralized option – treatment and/or use of the urine at individual homes or cluster areas. A second option would be to collect all of the urine and use it as a commercial fertilizer. The third option would be to collect the urine and treat it at a centralized treatment facility.

Homeowners could collect the urine and use it as a fertilizer for their own yard. However, it is likely that more urine would be collected than would be required for residential fertilization. There would likely be the need for significant homeowner education to get them comfortable with handling human urine. If homeowners prefer not to use the urine for fertilization, it could be collected and transplanted to a urine treatment facility.

Research in Europe and anecdotal evidence has identified the effectiveness of urine-derived fertilizers for agricultural crops. For broad acceptance of this type of fertilizer, it would need to be 1) available at price equal to or lower than existing fertilizers, 2) free of any urine odor, and 3) hazard free (i.e. no micro-pollutants such as personal care products or pharmaceuticals). To develop this scenario on a broad scale would require 1) treatment via electrodialysis or ozonation at a centralized site, 2) significant transportation effort to collect the urine from individual properties and bring it to a treatment facility, and 3) a large, steady market for the fertilizer.

Collection and treatment at a centralized facility would have the same requirements as a treatment facility for fertilizer production, except that a market would not be required. However, disposal options would need to be determined. The treatment process would produce clean water, which would need to be recharged to the groundwater. Process residuals would also need to be disposed of. An alternative to trucking the urine to a treatment facility would be installation of a urine-only collection sewer.

Management Issues. Prior to considering broad use of urine diverting toilets to meet mandated nitrogen limits, a considerable number of questions need to be considered. First of all, how would property owners be required to install new toilets – local regulations, state penalties? How does the Town ensure that the toilets are installed and then kept in place (i.e. homeowners reinstall traditional toilets after inspection)? Will the Town be requiring rights-of-entry into each and every building to perform inspections? Will the increased management procedures require a new Town department or position? How will the Town pay for the increased management needs when most towns are facing considerable financial cutbacks? How does a Town track the data? If a local regulation is enacted, will the Town purchase the units in mass quantities and provide them to homeowners or does the homeowner bear the purchase them individually? How would TMDL compliance be measured or monitored?

One of the emerging concerns with regard to wastewater generation and treatment is the presence of endocrine-disrupting chemicals (or micro-pollutants), primarily residuals from personal care products and pharmaceuticals. Nitrogen and phosphorous in urine are found at significantly greater concentrations in urine than in feces. However, micro-pollutants have been observed to present a roughly equivalent ecotoxicological hazard potential in both urine and feces. As a result, removing only the urine from the waste stream would not reduce this potential hazard by more than half.

Diagrams of how a urine source separation toilet operates as well as urine collection tank examples are included as Figure 3-7. Due to lack of municipal precedence and study, specifically in the United States, the following advantages and disadvantages are derived from a pilot study conducted in Switzerland.

Urine source separation toilets have the following advantages.

- Water consumption is reduced.
- Minimal environmental concerns occur when properly sited and designed.
- The nutrients in the urine could be positively recirculated in the environment by use as fertilizers.
- The technology could decrease the nutrient removal costs associated with wastewater (less the urine component) at the WPCF.

Urine source separation toilets have the following disadvantages.

- Existing biological and chemical technologies at WWTFs are not sufficient to treat concentrated urine. Additional facilities would need to be designed and constructed.
- Homeowner renovation costs would include new toilets, plumbing, and urine storage facilities. Urine separating toilets are likely to be costly and lack decorative design options which may decrease homeowner acceptance.
- Increased homeowner disposal hauling costs associated with two separate collection systems.
- Septage hauling trucks may need retrofitted equipment to properly handle concentrated urine.
- Technology works correctly with proper use. Proper use is limited to sitting on the toilet, meaning behavior modification for males.
- Technology works correctly with proper maintenance, which includes removing urine scale that can block pipes over time and using certain cleaning agents which would not contaminate the collection tank.
- Human urine use as an agricultural fertilizer may not be socially acceptable.
- Not well suited to high seasonal community and tourist population.
- No municipal precedence; the feasibility needs to be better demonstrated from regulatory; implementation, and cost aspects.

While the advantages of separating urine for fertilizer production are undeniable, it should be noted that the majority of the research is from European countries that already have sanitary sewer service provided to as much as 80 percent of the population, so significant infrastructure is already in place. The conclusions from the research included the following:

- The technology is particularly valuable where nutrient emissions are subject to stringent regulations.
- It is recommended in regions where it makes economic sense to recycle nutrients to agriculture.
- Combined with conventional end-of-pipe (sewer and treatment plant) technology for the remaining wastewater, it could become economically cost competitive.
- Urine transport proved to be the most problematic point. Installing new pipes or transporting by tanker for centralized treatment would be a complex and costly undertaking.
- For large scale systems, urine would need to be stored prior to use, which would require specialized storage facilities.

D. **On-Site Systems Approved for General Use in Nitrogen-Sensitive Areas.** The various MassDEP approved categories for I/A systems were discussed at the beginning of this chapter section. The following text describes the ones with General Use Approval.

1. **Recirculating Sand Filters (Non-Proprietary Filters).** Sand, rock, or mixed media recirculating filters are non-proprietary systems with a recirculation tank and filter. Septic tank effluent flows from the septic tank to the recirculation tank, where it is pumped to the top of the filter and over the media. A portion of the flow is recirculated back to the recirculation tank and the remaining flow is discharged to the leaching area. A diagram of a typical recirculating sand filter is shown in Figure 3-8.

Anaerobic decomposition occurs in the septic tank, changing organic matter to ammonia. The ammonia is then converted to nitrate in the aerobic filter media. The recirculated effluent then undergoes denitrification in the recirculation tank, and nitrates are converted to nitrogen gas. The nitrogen gas is then lost to the atmosphere, yielding a net loss of nitrogen from the wastewater. (The MassDEP certification for General Use indicates that the technology consistently produces an effluent with total nitrogen less than 25 mg/L). Many variations on the basic system are available to handle the specific needs of a project or site.

Maintenance includes periodic removal and replacement of the upper layers of media or backwashing and routine pump maintenance. In emergencies, such as power loss, the system can be designed to function as a flow-through system, with treatment equivalent to a standard Title 5 system.

Recirculating sand, rock, or mixed media filters have the following advantages:

- Approved for General Use by MassDEP in nitrogen-sensitive areas.
- Septage pumping requirements are similar to those of a conventional Title 5 septic system.
- Well proven technology with operating history since the 1970s.
- Systems do not require a high level of technical skill to operate when designed and installed correctly.
- Better treatment than a conventional Title 5 septic system can be attained and the leaching size can be reduced.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.
- Nitrogen removal rates are approximately 50 percent, depending on the system.

They have the following disadvantages:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Generally requires a larger land area than a standard septic system. Land surface may be occupied by the filter unit and not available for other use.
- Systems are sensitive to temperature and must be protected from freezing.
- Costs are higher than those of a standard septic system.

2. **RUCK® System.** The RUCK® system is designed to divide the black (toilet wastes) and gray (non-toilet wastes) wastewater and treat each in separate septic tanks. The two flows are typically piped separately from a home (or group of homes) and divided to either a black water or gray water septic tank. Black water flows through the RUCK® filter, which is constructed of sand or other media. The filter is where nitrification occurs. The effluent is then returned to an anaerobic tank and mixed with the gray water to promote denitrification, using the gray water as a carbon source. The gray wastewater septic tank effluent is discharged through a distribution

box to a standard leaching area. (The MassDEP certification for General Use indicates that the technology consistently produces an effluent with total nitrogen less than 19 mg/L). Figure 3-9 presents a diagram of the RUCK® system.
The RUCK® system has the following advantages:

- Approved for General Use in nitrogen-sensitive areas for flows less than 2,000 gpd.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Low operational and maintenance costs.
- Nitrogen removal rates are approximately 50 percent, depending on the system and site.
- Routine maintenance requires no special training.

The RUCK® system has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires more space than a standard septic system.
- Requires more maintenance than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans, are used which must be maintained and periodically replaced.
- Retrofitting the plumbing to separate black and gray wastewater flows can be difficult and expensive.

3. **Bio-Microbics FAST® (Micro-, High Strength-, and Nitri-FAST®).** These units consist of a tank with a primary settling zone and an aerobic biological zone in which the modular unit is installed. Solids settle out of the liquid in the quiescent primary settling zone. Sewage is continually agitated and aerated in the aerobic zone. Bacteria attach to the surface of the modular unit (submerged plastic media) and reproduce by consuming the organic material in the sewage. A diagram of a Bio-Microbics FAST® system is shown in Figure 3-10. The General Use approval is for facilities with a maximum design flow less than 2,000 gpd and an expected effluent concentration of less than 25 mg/L total nitrogen.

The FAST® system has the following advantages:

- Proven technology in Massachusetts.
- Septage pumping requirements are similar to those of a standard septic system.
- The basic system uses a small mechanical aerator, which is accessible for service or replacement.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Generally requires same land area as a standard septic system.

The FAST® system has the following disadvantages:

- Costs are typically higher than those of a standard Title 5 system.
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced; a backup power source is required.
- The blower can be relatively noisy in a quiet residential area and therefore must be enclosed.

E. **On-Site Systems Approved for Provisional Use in Nitrogen-Sensitive Areas.** The various MassDEP approval categories for I/A systems was discussed at the beginning of this chapter section. The following text describes the technologies with Provisional Use Approval. The Provisional nitrogen removal systems are generally considered recirculating treatment technologies. Recirculating treatment technologies are a category of alternative treatment systems which are used in combination with standard septic systems. These systems typically include a recirculation chamber and a media to support microbial growth, which biologically treats the wastewater prior to discharge through a leaching system. A percentage of the wastewater is recirculated through the system, depending on influent quality, required effluent quality, and system design.

Recirculating treatment technologies vary in the type of media used, the wastewater pumping arrangement, and the overall system configuration. Some of these systems are produced by a specific manufacturer and are commonly referred to by their trade names. This section identifies and describes many of the recirculating treatment technologies and respective manufacturers which are currently approved for use in Massachusetts. The main disadvantage of these systems is the six- to eight-week startup period for biomass development. Summer residences are typically used over a three-month period; therefore, these systems do not provide the maximum performance during the first half of the period in which the residence is in use.

1. **Bioclere®.** Bioclere® is a trickling filter and pump unit in one manufactured unit, designed to treat the anaerobic effluent from a septic tank, which is high in ammonia. The filter media is PVC or polypropylene. Effluent from the septic tank is pumped to a distributor, which spreads the wastewater over the top of the media, where aerobic conditions allow nitrification to occur (conversion of ammonia to nitrate). In the media, anaerobic micro-sites form where some limited denitrification (NO_3-N to N_2 [gas]) can take place. However, the majority of denitrification occurs when the effluent is collected at the base of the filter, and about 70 percent of the flow is recirculated back to the septic tank. The rest of the effluent is discharged to a leaching area. A diagram of a Bioclere® treatment unit is shown in Figure 3-11.

Installation of the Bioclere® tank is relatively simple. One treatment unit contains a pump, a distributor, and the filter media. The treatment unit can either be retrofitted into existing septic systems by reusing the septic tank, piping, and leaching area, or it can be installed into new systems. The sealed double wall of the treatment unit provides insulation to minimize cold weather impacts. Nitrogen reductions of 50 percent are typical. The system can handle flow variations by varying the recirculation rates, and the units can handle increased flow by inserting additional media into the unit; however, the approval is limited to systems with flows less than 2,000 gpd.

The Bioclere® system has the following advantages:

- Well proven technology in Massachusetts.
- Approved for General Use in Massachusetts in non-nitrogen sensitive areas.
- No significant environmental or public acceptance concerns when properly sited and designed.
- The process operation is flexible, with ability to adjust cycle times and add additional media.

- The basic system has relatively low operation and maintenance costs. The pump contained in the unit is easily accessible for replacement, when required.
- Septage pumping requirements are similar to those of a standard septic system.
- Better treatment can be attained and the leaching size can be reduced.
- Nitrogen removal rates are approximately 50 percent.

They have the following disadvantages:

- Costs are typically higher than those of a standard Title 5 system.
- Maintenance agreements are required and have an associated cost.
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components.
- Generally require a larger area than a standard Title 5 system.
- Tops of Bioclere® tanks extend above ground.

2. **Smith & Loveless FAST® (Modular-FAST®).** The modular fixed activated sludge treatment (FAST®) systems are constructed using a submerged filter unit installed below ground in a configuration similar to that of a standard septic tank. Wastewater enters the primary settling zone of the tank, where primary solids removal is achieved. Flow is then recirculated by means of a centrally located draft tube through the submerged FAST® filter, which is located at the effluent end of the tank. A small portion of the recirculated wastewater flow is periodically discharged to a leaching area. An enclosed blower supplies air to the system in order to support bacterial growth on the filter media. Nitrification and denitrification are achieved as part of the FAST® system design and result in an approximate total nitrogen removal rate of 50 percent. A diagram of the FAST® system is included as Figure 3-12.

The FAST® system has the following advantages:

- Proven technology in Massachusetts.
- Septage pumping requirements are similar to those of a standard septic system.
- The basic system uses a small mechanical aerator, which is accessible for service or replacement.
- No significant environmental or public acceptance concerns when they are properly sited and designed.

- Generally requires same land area as a standard septic system.

The FAST® system has the following disadvantages:

- Costs are typically higher than those of a standard Title 5 system.
- More maintenance is required than a standard Title 5 system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced; a backup power source is required.
- The blower can be relatively noisy in a quiet residential area and therefore must be enclosed.

3. **Amphidrome®.** The Amphidrome® process combines filter technology with a biofilter, an equalization tank, a clearwell, and the common components of a septic system. Wastewater flows by gravity from an equalization/septic (anoxic) tank through the biofilter into a clearwell. Wastewater is then pumped in reverse through the biofilter to the anoxic tank. The biofilter alternates between aerobic and anoxic conditions, providing nitrification and denitrification as the cycle is repeated. Wastewater is allowed to cycle through the system several times before it is discharged. A diagram of the Amphidrome® system is included as Figure 3-13.

The Amphidrome® process has the following advantages:

- Utilizes deep bed filter technology, which has a reliable performance record.
- Septage pumping requirements are similar to those of a standard septic system.
- It has demonstrated very good nitrogen removal in several cluster and commercial installations on Cape Cod (greater than 50 percent nitrogen removals).

The Amphidrome® process has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Pumping requirements are high due to internal treatment configuration. Nitrogen removal ability is sensitive to sludge accumulation.

- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.
- Startup time can be as long as 12 weeks, depending on ambient temperature, so it may not be suitable for seasonal homes.

4. **Waterloo Biofilter®.** The Waterloo Biofilter® consists of a 6-foot by 6-foot by 4-foot enclosure which includes filter media, an air ventilation system, and a wastewater distribution system. The distribution system pumps effluent from the septic tank and sprays it over the surface of the media. Wastewater trickles through the media while air is blown through the system. The system uses a small ventilation fan and an effluent pump timed via a control panel to dose effluent at frequent intervals over a 24-hour period. The effluent is collected at the base of the biofilter and a portion is recirculated back through the media, while the rest is discharged to a leaching area. The mechanism for nitrogen removal is similar to the recirculating filters described earlier. A diagram of the Waterloo Biofilter is included as Figure 3-14.

The Waterloo Biofilter® has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.
- The basic system uses a small pump, which has low O&M costs. The pump is easily accessible for service or replacement.
- Although the design hydraulic loading rate is 10 gal/ft2/day, it can handle surges of up to 49 gal/ft2/day for several days with little effect on effluent quality.
- Better treatment than a standard septic system can be attained and the leaching size can be reduced.
- Removal rates for nitrogen are approximately 50 percent. Effluent BOD and TSS are expected to be <30 mg/L. Fecal coliform removal is typically 99 percent.

They have the following disadvantages:

- Costs are typically higher than those of a standard septic system.

- Systems are sensitive to the temperature of the septic tank effluent entering the system. Insulation of the septic tank is recommended.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used which must be maintained and periodically replaced.
- Denitrification unit periodically requires recharging with material like sawdust or leaves to serve as a carbon source for denitrification.
- Unit may need to be installed above ground depending on depth to groundwater.

5. **AdvanTex®.** The AdvanTex® system is a textile filter technology. The main components are a control panel, a filter pod, a recirculating splitter valve, a pumping package, and a processing tank. The filter material consists of an engineered textile that has greater surface area than sand or gravel, allowing greater volumes of wastewater treatment in less space. After initial settling in the first compartment of the processing tank, effluent is pumped to the filter pod. As effluent percolates through the filter media, a biological film develops, providing additional BOD, TSS, and nitrogen removal.

The splitter valve directs a portion of the flow to the effluent discharge and a portion back to the processing tank. The splitter valve also maintains a minimum water level in the processing tank; therefore, all of the treated effluent is recycled back to the processing tank when there is no influent. Effluent discharge is controlled by a timer, which discharges in "microdoses." The microdoses occur for relatively short intervals, typically 72 times per day. A process diagram is shown in Figure 3-15.

AdvanTex® systems have the following advantages:

- The system can be installed within a small footprint.
- High quality effluent (5 mg/L BOD and TSS) can be used for drip irrigation.
- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process operation is flexible, with the ability to adjust cycle times.
- The basic system uses a small pump, which has low operational and maintenance costs.

AdvanTex® systems have the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.
- May require media replacement at a higher cost than a system with sand or gravel media.

6. **NITREX® System.** This system is a denitrification filter unit that can be added to the end of an I/A system. The system requires a nitrified effluent for the unit to work; therefore a treatment process beyond a normal septic system is required prior to this system. The filter media is contained in a tank and is a gravity flow-through system. The media is comprised of wood chips and cellulose. See Figure 3-16.

The NITREX® system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment can be attained and the leaching size can be reduced.
- Does not require pumping.
- Excellent nitrogen removal is possible (greater than 50 percent) when the upstream treatment process has converted all the organic and ammonia nitrogen to nitrate nitrogen.

The NITREX® system the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires a very effective nitrification process as an earlier treatment step to provide a nitrified effluent to the system.
- Media life is unknown and is expected to need replacement in 10 to 20 years.

7. **SeptiTech® System.** This system is a fixed-film-type system. The first two tanks or chambers of the system provide solids settling and the anoxic zone for denitrification. The second chamber contains trickling filter media and wastewater is recirculated within this chamber for treatment. Flow is also recirculated back to the anoxic zone to promote denitrification. A diagram of the SeptiTech® system is included as Figure 3-17.

The SeptiTech® system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment than a standard septic system can be attained and the leaching size can be reduced.

It has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

8. **Singulair®.** This system (illustrated in Figure 3-18) is a type of extended aeration system. The treatment process is contained within a three-chambered tank. The first chamber provides solids settling; the second chamber is the aerobic zone where the wastewater is aerated to promote BOD removal and nitrification; and the third chamber is the final settling chamber. This chamber is equipped with a filtration unit to aid in clarification prior to effluent disposal. The system is followed by a recirculation chamber to pump 10 to 20 percent of the flow back to the first chamber for nitrogen recycle. The approval for the Singulair® system is limited to facilities with less than 2,000 gpd wastewater flow.

The Singulair® system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.

- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment than a standard septic system can be attained and the leaching size can be reduced.

The Singulair® system has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

9. **Bio-Microbics FAST® (Micro-, High Strength-, and Nitri-FAST®).** These systems were discussed under the General Approvals section. The General Use was provided for systems with flows less than 2,000 gpd and based on consistent effluent concentrations of less than 25 mg/L. Bio-Microbics has received two Provisional Use approvals. One approval is to determine the system's ability to achieve less than 19 mg/L total nitrogen in the effluent at flows less than 2,000 gpd; the other is to determine the ability of larger systems (2,000 to 10,000 gpd) to achieve less than 25 mg/L total nitrogen. A system figure as well as advantages and disadvantages of the Bio-Microbics FAST® system were presented in the General Use section.

F. **On-Site Systems Approved for Piloting in Nitrogen-Sensitive Areas.** The various MassDEP approval categories for I/A systems were discussed at the beginning of this chapter section. The following text describes the technologies with Piloting Use Approval. The Piloting nitrogen removal systems are generally considered recirculating treatment technologies. Recirculating treatment technologies are a category of alternative treatment systems which are used in combination with standard septic systems. These systems typically include a recirculation chamber and a media to support microbial growth, which biologically treats the wastewater prior to discharge through a leaching system. A percentage of the wastewater is recirculated through the system, depending on influent quality, required effluent quality, and system design.

Recirculating treatment technologies vary in the type of media used, the wastewater pumping arrangement, and the overall system configuration. Some of these systems are produced by a specific manufacturer and are commonly referred to by their trade names. This section identifies and describes many of the recirculating treatment technologies and respective manufacturers which are currently approved for use in Massachusetts. The main disadvantage of these systems is the six- to eight-week startup period for biomass development. Summer residences are typically used over a three-month period; therefore, these systems do not provide the maximum performance during the first half of the period in which the residence is in use.

1. **RUCK® CFT.** The CFT model is similar to the traditional RUCK® system. However, all of the wastewater flows through the filter. A supplemental carbon source (soapy water) is added to the effluent in the mixing chamber. Denitrification takes place in the mixing chamber. A schematic of the RUCK® CFT is shown in Figure 3-19.

The RUCK® CFT system has the following advantages:

- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Low operational and maintenance costs.
- Nitrogen removal rates up to 90 percent, depending upon the system and site.
- Routine maintenance requires no special training.

The RUCK® CFT system has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- Requires more space than a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps and/or fans are used, which must be maintained and periodically replaced.

2. **Cromaglass® System.** The Cromaglass® system (illustrated in Figure 3-20) is a type of SBR treatment process. The system operates in five stages: fill, aeration, denitrification, settling, and discharge. Flow enters the first stage, where solids settle out and the remainder of the flow passes through a non-corrosive screen. After passing through the screen, the wastewater is aerated and mixed using submersible pumps. The pumps are then shut down to provide an anoxic condition to promote denitrification. Flow is then pumped to the clarifiers for final

settling. Finally, flow is pumped from the clarifiers for effluent discharge to the leaching facilities.

The Cromaglass® system has the following advantages:

- Septage pumping requirements are similar to those of a standard septic system.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Better treatment than a standard septic system can be attained and the leaching size can be reduced.

It has the following disadvantages:

- Costs are typically higher than those of a standard septic system.
- More maintenance is required than a standard septic system due to mechanical and electrical components.
- Pumps are used which must be maintained and periodically replaced.

3. **OMNI® Recirculating Sand Filter (RSF).** The OMNI® RSF is a proprietary recirculating sand filter. The functioning and setup of the system is very similar to the process discussed for RSF in general (see Figure 3-8).

The OMNI® RSF has the following advantages:

- Modular design allows for easy installation.
- Septage pumping requirements are similar to those of a standard septic system.
- Does not require a high level of technical skill to operate when designed and installed correctly.
- Better treatment can be attained and the leaching size can be reduced.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.

The following are some disadvantages of the OMNI® RSF:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Land surface may be occupied by the filter unit and not available for other use.
- Systems are sensitive to temperature and must be protected from freezing.
- Costs are typically higher than those of a standard septic system.

4. **OMNI® Cycle System.** The OMNI Cycle System is a modified OMNI RSF – an anoxic tank is added to the RSF to provide additional nutrient removal. The anoxic tank, which is installed as either a separate tank in series with the recirculation tank or as a second compartment of the recirculation tank, is filled with a soy based newspaper to provide additional carbon to the system. The approval is limited to systems with a design flow of less than 2,000 gpd. A system diagram is included as Figure 3-21.

The OMNI® Cycle System has the same general advantages and disadvantages as the OMNI® RSF. One difference is the potential for additional septage pumping due to the decomposition of the newspaper media.

5. **Bio-Microbics BioBarrier® MBR System**. This system is a membrane bioreactor (MBR) process. The septic tank contains settling, anoxic, and aeration zones. The membrane, contained in the aeration zone, consists of several flat sheets of a filter with micro pores. Large solids are removed in the settling zone, after which the effluent flows through the anoxic zone and into the aeration zone. Air is introduced into the aeration zone via a pump. A portion of the effluent is recirculated back to the anoxic zone where denitrification occurs. The permeate pump uses vacuum pressure to pull treated water through the membranes, leaving behind large organic and inorganic particles (see Figure 3-22).

The BioBarrier® MBR has the following advantages:

- Modular design allows for easy installation.
- Septage pumping requirements are similar to those of a standard septic system.
- Better treatment can be attained and the leaching size can be reduced.

- No significant environmental or public acceptance concerns when they are properly sited and designed.
- The process has operational flexibility, with capability to adjust cycle times.

The following are some disadvantages of the BioBarrier® MBR:

- More maintenance is required than for a standard septic system due to mechanical and electrical components.
- Systems are sensitive to temperature and must be protected from freezing.
- Costs are typically higher than those of a standard septic system.
- Pumps and blowers are used which must be maintained and periodically replaced.
- The MBR units require periodic cleaning. The cleaning solution has to be contained and removed from the site.
- Above ground components include the blower and control panel.

6. **NITREX® Plus.** This system is a variation on the NITREX® filter discussed previously. The NITREX® Plus (shown in Figure 3-23) consists of a layer of sand above the NITREX® media. Effluent flows from the septic tank by gravity into perforated PVC distribution pipes at the top of the sand layer. Effluent flows down through the sand layer and into the NITREX® media layer. At the bottom of the NITREX® media layer are perforated PVC collection pipes. Effluent is collected in these pipes and flows to the soil absorption system.

The NITREX® Plus has the following advantages:

- Modular design allows for easy installation.
- Does not require a high level of technical skill to operate when designed and installed correctly.
- No significant environmental or public acceptance concerns when they are properly sited and designed.
- Does not require pumping for process (although some installations may require pumps to convey effluent to the various components).

The NITREX® Plus has the following disadvantages:

- Occupies a larger area than a standard septic system since the unit is installed in addition to the septic tank.
- Costs are typically higher than those of a standard septic system.
- Media life is unknown and is expected to need replacement in 10 to 20 years.

G. **Nitrogen Removal Performance for On-Site I/A Nitrogen Removal Systems.** The manufacturers of these systems typically provide operational data that characterizes the nitrogen removal performance of their systems. The testing procedures for the data provided by the manufacturer are typically not known or clearly articulated.

Barnstable County (with several partner agencies) has created the Massachusetts Alternative Septic System Test Center at the Massachusetts Military Reservation to test these systems with standardized testing procedures. Data from these tests is available on the web at www.barnstablecountyhealth.org/AlternativeWebpage/index.htm. It is recognized that these systems are tested with a constant flow of wastewater, which may not be representative of systems used at individual houses, especially those with seasonal use, which is common on Cape Cod.

In July 2007, the Barnstable County Department of Health and Environment published findings of their analysis of several years of operating data of nitrogen removal septic systems. The data was from 487 single-family installations and 70 multi-family installations. The main finding is that "when systems having four or more samples are considered, 69% of the 297 single family systems and 60% of the 50 multi-family I/A systems have medians that meet a regulatory threshold discharge standard of 19 mg/L or less of total nitrogen." Data analysis was presented for several system types and brands. In general, the analysis indicates that these systems do not meet their expected regulatory discharge standard 30 to 40 percent of the time based on median statistics. A further generalization indicates these systems remove approximately 50 percent of the nitrogen if the influent nitrogen is approximately 40 mg/L total nitrogen and the effluent is approximately 20 mg/L total nitrogen.

Several newer technologies, such as the NITREX® system, did not have sufficient long-term operational data to participate in this analysis. Long-term performance of the newer technologies at individual homes and multi-family installations will be evident and better understood in the next few years.

H. On-Site System Considerations and Technologies for Phosphorus Management.

1. **Introduction.** As discussed in the Needs Assessment Report, phosphorus is typically the limiting nutrient for freshwater ponds, lakes, and streams. If too much phosphorus enters these freshwater bodies, increased algal growth and eutrophication can occur, impacting water quality.

Municipal wastewater has total phosphorus concentrations in the range of 4 to 12 mg/L with a typical concentration of 7 mg/L as reported in Water Reuse by Metcalf & Eddy, 2007. The concentration can vary significantly depending on the activities in the house that produce the wastewater.

Work by the Cape Cod Commission for the Indian Pond Association (CCC, 2006) indicates that septic systems are among the largest watershed sources to the ponds. The true phosphorus loads from septic systems to ponds is difficult to quantify due to the complex interaction of phosphorus and soils. Phosphorus in septic system discharges will adsorb to soil particles until the soil adsorption sites are filled. Different soils have different adsorptive capacity, and groundwater chemistry will affect the adsorptive capacity. Once the sites have been filled, the phosphorus will move downgradient with groundwater flow and can emerge into a pond, lake, or stream. The adsorptive capacity of a watershed to a freshwater body is a complex function of soil characteristics and chemistry, groundwater chemistry, and distance to the waterbody. This geochemistry was discussed in the Ponds Action Plan in the Needs Assessment Report and it is noted that the ability of soils to remove phosphorus by adsorption is finite.

2. **Recent Research by the Barnstable County Department of Health and Environment on Controlling Phosphorus Discharges from On-Site Systems.** The Barnstable County Department of Health and Environment has recently completed evaluations of methods to control phosphorus in areas served by septic systems (Heufelder, et al., June 2006). Their main findings are briefly listed below:

a. Conventional 1,500 gallon septic tanks remove approximately 7% of the phosphorus in the wastewater that flows through it. This was based on operation of three septic systems at the Massachusetts Alternative Septic System Test Center form 1999 to 2002. The average influent total phosphorus concentration from this time period was 5.3 mg/L.

b. Three on-site technologies designed for increased phosphorus removal were tested at the Massachusetts Alternative Septic System Test Center and demonstrated 29 to 99 percent phosphorus removal.

   A Waterloo Biofilter® modified with a small module of hematite-coated wood chips achieved 29% total phosphorus removal.

   A Phosphex™ patented up-flow filter following a recirculating sand filter) containing basic oxygen furnace slag achieved 99% total phosphorus removal. Unfortunately the pH of the treated water was very basic with a pH greater that 11 standard units which precludes its discharge to the groundwater system under MassDEP regulations. Attempts to buffer this effluent were unsuccessful.

   A PhosRID™ patented up-flow reactor with iron additive and valence manipulation achieved total phosphorus removal of 99%. This system continues to undergo research and development at the Test Center. This technology has obtained Piloting Approval from MassDEP in accordance with MassDEP's Alternative System regulations discussed earlier in this chapter.

c. Literature review and data analysis of several advanced on-site system technologies for nitrogen removal do not exhibit a long-term history of success for phosphorus removal.

d. Several design enhancements of a standard Title 5 septic system can be made to promote additional phosphorus removals that could be required by Boards of Health for system replacements and approvals. These enhancements include:

   1) Maximizing vertical separation between the bottom of the leaching system and the top of the water table.

   2) Providing even distribution across the leaching area to prevent water logging or saturating one portion of the system.

   3) Periodically dosing the infiltration system to allow it to dry out between doses.

   4) Introducing the treated water into the upper layers of the soil (B layer) where there tends to be more phosphorus adsorption sites and where plant materials may be able to utilize the phosphorus as a nutrient.

e. This document also encourages diversion techniques to separate toilet wastes from the leaching system for separate disposal. It recognizes that additional research and education is needed on this item.

3. **Summary.** Septic systems can produce significant phosphorus loads in a pond watershed. Phosphorus in septic tank effluent does adsorb to soil particles as it moves through the soil, but the soil absorption sites fill up over time which allows a phosphorus plume to grow from each system discharge. These plumes can reach freshwater ponds, lakes, and streams depending on soil chemistry, and distance to the water body. Once the plume reaches the water body, it can cause eutrophication depending on several characteristics of the water bodies such as depth, outlet type, hydraulic retention time, etc.

The Ponds Action Plan in the Needs Assessment Report characterized many of Barnstable's ponds and prioritized the ones with the most water quality impairment.

Three on-site phosphorus removal technologies have been developed and tested at the Massachusetts Alternative Septic System Test Center and one of them shows promising phosphorus removals. The technology is PhosRID™ marketed by Lombardo Associates and it has received Piloting Approval by MassDEP, but it will need to receive general approval before Boards of Health and homeowners can be assured of long-term performance.

There are several design enhancements of a standard Title 5 septic system that can be made to promote additional phosphorus removals including:

- Maximizing vertical separation between the bottom of the leaching system and the top of the water table.
- Providing even distribution across the leaching area to prevent waterlogging or saturating one portion of the system.
- Periodically dosing the infiltration system to allow it to dry out between doses.
- Introducing the treated water into the upper layers of the soil (B layer) where there tends to be more phosphorus adsorption sites and where plant materials may be able to utilize the phosphorus as a nutrient.

Phosphorus is often removed in centralized and satellite wastewater treatment systems as discussed in Section 4.6 of this report.

3.3 CLUSTER TREATMENT SYSTEMS

Cluster treatment systems are systems which fall between individual on-site systems and larger municipal (satellite or centralized) facilities designed to serve large areas of a town. These systems are typically designed to treat and recharge wastewater generated (and collected by sewer systems) within individual neighborhoods. The main difference between cluster systems and centralized wastewater treatment facilities is the location of the treatment and treated water recharge.

Cluster systems can range in size from serving small groups of homes up to a group of 30 homes. Cluster treatment systems may utilize any one of the on-site technologies described previously in this chapter, or could be served by small applications of wastewater treatment systems (as described in Chapter 4) used for flows over 10,000 gpd. Because cluster systems are designed to handle “clusters” of properties, they require a collection system to transport the wastewater from the properties to the treatment facility. The collection system may be any one of the collection systems described in detail in Chapter 6.

These systems are regulated by the Title 5 regulations and do not require a groundwater discharge permit. They can be designed with I/A components for nitrogen removal, or they can be designed as conventional Title 5 septic systems. When designed for nitrogen removal, they would be expected to provide 50 percent nitrogen removal, or produce an effluent with approximately 19 to 25 mg/L total nitrogen. Research in Barnstable County for systems installed on Cape Cod (described earlier) indicates that they meet this performance level at less than 50 percent of the currently installed systems.

As discussed in the Needs Assessment Report, the Town owns and operates one conventional Title 5 septic system cluster system. The Red Lily Pond cluster septic system is located west of Red Lily Pond and Elizabeth Lake in Centerville. Figure 3-24 illustrates the site plan of this cluster system.

The system is comprised of a low-pressure collection system and grinder pumps. The wastewater flow is conveyed to two septic tanks, and the septic tank effluent flows to two sets of infiltration chambers. The Town Department of Public Works, Water Pollution Control Division operates the system.

The system was constructed in 1993 to reduce phosphorus impacts to Red Lily Pond and Elizabeth Lake from the individual septic tank discharges that were occurring before 1993. The system was not designed for nitrogen and phosphorus removal, but was designed to relocate the septic tank effluent to a new location that is outside of the watersheds to the ponds. No performance sampling of the system occurs and it is assumed to produce comparable effluent to any conventional individual on-site septic system.

Treatment and recharge sites would need to be located for these systems. Potential sites are discussed in the following chapter for Satellite Systems and would be applicable for Cluster Systems as well.

3.4 SCREENING OF ALTERNATIVE DECENTRALIZED TECHNOLOGIES

A. **Summary of Screening.** Table 3-1 summarizes key information for each technology alternative with respect to the screening criteria discussed in Chapter 2. All of the wastewater treatment technologies require review and approval by MassDEP and/or the local Board of Health. Table 3-1 includes information on technologies currently approved by MassDEP. Additional technologies may be approved in the future.

B. **Technology Review.** Conventional Title 5 septic systems are a reliable, simple, feasible technology with relatively low capital costs and minimal operation and maintenance requirements. Land requirements for septic systems are relatively low and can be further reduced according to local variance guidelines established in the Title 5 regulations. A typical full individual unit septic system for a three-bedroom home requires approximately 2,000 square feet of land area. A typical septic system for a three-bedroom home with a reduction in setback requirements and a 25 percent reduction in leaching field area requires approximately 1,000 square feet of land area. Septic systems typically provide moderate treatment of wastewater and are primarily designed for TSS and BOD removal. Nitrogen removal rates in septic systems are quite low. The Massachusetts Estuaries Project has identified that the existing septic systems are the largest source of nitrogen to the coastal estuaries.

Although I/A technologies (as defined by MassDEP) do not provide a significant advantage in land area requirements when compared to septic systems, the potential to design I/A systems with reduced groundwater separation is significant considering the high groundwater elevations in certain areas of Barnstable. I/A treatment technologies can provide high levels of treatment for BOD, TSS, and nitrogen. Expected nitrogen removal rates are approximately 50 percent.

C. **Findings.** Key information on the wastewater technologies has been summarized on Table 3-1 to allow a side-by-side comparison with respect to a set of standard criteria. Because I/A technologies are regulated by MassDEP, selection of any I/A technology to be used should be made by the individual property owner. The selection process will depend on the particular application (i.e. for repair, nitrogen removal, variance, etc.) and the current MassDEP status of the technology.

A primary difficulty with individual I/A systems is the maintenance requirement and cost. Currently, the Town of Barnstable, like most towns, is relying on the Barnstable County Department of Health and Environment for technical assistance. Improper maintenance, significant down times due to seasonal use, and owner inexperience all contribute to questionable and/or poor nitrogen-removal performance. If properly operated and maintained, those systems approved by MassDEP can achieve approximately 50 percent wastewater nitrogen removal. These systems are not considered as a feasible alternative for addressing the needs of an entire watershed with wastewater nitrogen removal requirements greater than 50 percent in the buildout condition. Broad application of these technologies to address the needs of the planning area would severely tax Town resources, requiring increased accounting of systems, inspections, O&M, and monitoring to ensure that the systems are performing properly and achieving the goals associated with large-scale implementation.

A second major difficulty with I/A systems is that they are designed for BOD, TSS, and nitrogen (albeit limited removal performance) removals. They do not remove phosphorus and they are not easily upgraded for additional treatment requirements that may occur in the future. Foreseeable future requirements may include:

1. More stringent nitrogen TMDLs.

2. Phosphorus TMDLs for the watersheds to ponds, lakes, and rivers.

3. Virus removal.

4. Total organic carbon removal.

5. Removal of pharmaceutical products (endocrine disruptors) that persist after traditional treatment in septic systems and in many WWTFs.

Based on Board of Health and Planning Department recommendations, I/A systems may be required to address specific site conditions and issues (i.e., high groundwater, setback requirements, repair or replacement of existing systems, or nitrogen removal in sensitive watersheds) on a limited basis. However, each application should be evaluated on a site-by-site basis for those areas not considered for cluster systems or sewering.

Tight tanks are considered a short-term, or "band-aid" solution to overcome an immediate problem and are recommended for use only on a temporary basis until a long-term solution is found. This was recognized by the MassDEP some time ago and has resulted in restrictions of their use. Allowable uses include keeping a primary residence open to habitation while a permanent system is installed. Another use applies to specialized situations, such as boat pumpout facilities, that typically are seasonal in nature and may have site conditions that make construction of a standard septic system impossible. There is also a significant concern that widespread approval of tight tanks would allow development in areas that should not be developed.

Composting, incinerating, and urine separation toilets are non-traditional wastewater disposal systems, and public acceptance is expected to be limited. Composting systems are not well suited to handle seasonal flows and loadings. The physical handling of composted or incinerated wastes may be objectionable to the public. Public acceptance due to odors is also an issue with these systems. These systems would be best suited for use at comfort stations or other public facilities where the general public would not be responsible for routine system maintenance.

It is recommended that individual and cluster nitrogen removal systems not be considered further as a realistic strategy to meet the nitrogen TMDLs in any subwatersheds that require greater than 25% wastewater nitrogen in the future condition. If they are considered for areas that require less than 25% removals, they would need reliable operations, maintenance, and monitoring to ensure compliance with the TMDLs.