FEASIBILITY REPORT

Putnam Lake Regional Wastewater Collection and Treatment

Town of Patterson, New York

June 29, 2018

OBG

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EXECUTIVE SUMMARY

This Feasibility Report identifies and evaluates alternatives for reducing the amount of phosphorus entering Putnam Lake. The objective of this report is to provide solutions for wastewater collection and treatment that are economically and technically feasible, safe, robust, energy efficient, resilient, low maintenance, and politically acceptable. The report seeks to:

- Evaluate the most cost-effective methods to reduce phosphorus loading and protect the groundwater from wastewater impacts;
- Develop a feasibility study/conceptual wastewater management plan, which examines the feasibility of providing public sewers; and
- Using the Plan, solicit political and financial support for upgrading and expanding sewage treatment around Putnam Lake.

Putnam Lake is a 226-acre man-made lake located in the Town of Patterson in Putnam County, approximately 60 miles north of New York City, and bordering the New York/Connecticut state line. Putnam Lake is located inside the NYS East of Hudson Middle Branch watershed. A total phosphorus TMDL for the Middle Branch was approved in 2000 and identified Putnam Lake as a major source of the phosphorus in the watershed. The Putnam Lake watershed has a direct drainage of 1,717 acres, which is predominantly residential lands and forest with some open water and wetland areas.

Numerous studies of Putnam Lake have been completed, and in 2001, a feasibility report was prepared for sewering the area and providing wastewater treatment for the watershed. It was determined to be cost prohibitive at that time.

OBG has been retained to examine the feasibility of extending public sewers to all residences within the watershed with a focus on concentrating on those within 250 feet of Putnam Lake. Potential alternatives for sewering included:

- Residential onsite septic systems
- Advanced treatment units
- Gravity collection system
- Grinder pump/ pressure sewer collection system
- Vacuum sewer collection system
- Effluent sewer collection system
  - Septic tank effluent pump (STEP) system
  - Septic tank effluent gravity (STEG) system
- Cluster collection/treatment system

Potential alternatives for treatment include:

- Construction of a new WWTP

It was determined through analysis and discussions with the NYSDEC and Town of Patterson that a gravity collection system and construction of a new WWTP will be the recommended proposed alternative for Putnam Lake with a focus of addressing removal of septic systems within a 250-foot offset from the lakeshore and adjacent properties within a reasonable limit (Service Area 1). Implementation of this sewage collection and treatment program for the area surrounding Putnam Lake is recommended as a strategy to address the requirements of the TMDL and provide for less nutrient flow into Putnam Lake, thus reducing the potential for nuisance algal blooms. Preliminary cost estimates for the construction of gravity sewers and a new WWTP to serve the customer base in Area 1 (287 customers) is approximately $25,100,000. To make this project economically feasible for the rate payers, substantial subsides in the form of grants will be required It is further recommended to:

- Complete a preliminary design to further the process of defining the scope of the project. The preliminary design should include field and desktop investigations necessary to gain a better understanding of the project scope.
- Begin planning process for development of a sewer district to manage and fund the sewage facilities.
- Implement stormwater improvements along lake shoreline concurrently with collection sewer system.

1. BACKGROUND

1.1 INTRODUCTION

Putnam Lake (the Lake) is a 226-acre man-made lake located in the Town of Patterson in Putnam County, approximately 60 miles north of New York City, and bordering the New York / Connecticut state line. Putnam Lake was created through the damming of Morlock Brook, a small tributary to the Croton River, with a 295-foot-long by 24-foot-high earthen dam in 1931. In the early 1930s, Putnam Lake had approximately 2,000 summer cottages along the shores. The land was divided into small lots and the Putnam Lake subdivision field in the late 1920's. As the area transitioned from a farming community to a bedroom community, these summer cottages were converted to year-round residences or demolished and replaced by larger homes.

Putnam Lake is a Class B waterbody under the New York Codes, Rules, and Regulations (6NYCRR Part 864.6), meaning it is best intended for contact recreation (i.e., swimming and bathing), non-contact recreation (i.e., boating and fishing), aesthetics, and aquatic life. The primary uses at the lake include a variety of recreational uses, including boating, swimming, and fishing. The entire lake shoreline is designated as parkland for use by all Putnam Lake residents, and includes beaches, park areas, boat launches, and boat storage.

Putnam Lake is located inside the NYS East of Hudson East Branch watershed. A total phosphorus TMDL for the East Branch was approved in 2000 and identified Putnam Lake as a major source of the phosphorus in the watershed. The Putnam Lake watershed has a direct drainage of 1,717 acres, which is predominantly residential lands and forest with some open water and wetland areas. The location of the lake may be seen in Figure 1.

Numerous studies of the Lake have been completed and in 2001, a feasibility report was prepared for sewering the area and providing wastewater treatment for the watershed and was determined to be cost prohibitive at the time.

1.2 EXISTING FACILITIES

Approximately 1,350 residences are located within the Putnam Lake watershed with approximately 230 residences close to the lake (i.e. within 250 feet). Based on the zoning data provided by Putnam County there are 2 commercial establishments or apartments within the watershed and all residences obtain water from wells and utilize residential on-site sewage systems for treatment of wastewater. Given the smaller lot size, it is likely that there are instances where wells and leachate fields may be in close proximity, resulting in septic systems imparting an influence on drinking water wells.

There are three existing wastewater treatment plants within proximity to Putnam Lake. The Mount Ebo Sewer Treatment Plant is located five miles southeast of Putnam Lake, Watchtower WWTP is located approximately four miles northwest of the lake and Clock Tower Commons lies four miles southeast of the lake. Further discussion of these facilities is included in subsequent sections.

1.3 OBJECTIVE

The objective of this study is to identify technically feasible and cost-effective approaches to provide public sanitary sewers and treatment to reduce the amount of phosphorus associated with wastewater entering Putnam Lake and protect the quality of the groundwater resource close to the Lake. These approaches will also consider energy efficiency, environmental impact, and political acceptability.

The following elements are included:

- Evaluate the most cost-effective methods to reduce phosphorus loading and protect the groundwater from wastewater impacts
- Develop a feasibility study/conceptual wastewater management plan, which examines the feasibility of providing public sewers

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FIGURE NO. 1

NYSOGS
PUTNAM LAKE
PUTNAM COUNTY

LOCATION MAP

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Feet

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- Using a long-term plan, solicit political and financial support for upgrading and expanding sewage treatment around Putnam Lake

2. METHODOLOGY

2.1 REGULATORY REQUIREMENTS AND STANDARDS

The NYSDEC is in the process of developing a Total Maximum Daily Loading (TMDL) for Putnam Lake that will help drive initiatives to remove biodegradable phosphorus attributed to poorly operating residential on-site treatment systems.

Regulatory standards and guidance documents reviewed and referenced include:

- Individual facility SPDES permits and General Permits GP 0-05-001.
- Recommended Standards for Wastewater Facilities (Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (GLUMRB), 2004) - referred to as Ten States Standards. This guidance document is applicable to all WWTPs and includes standards for: sewers, pumping stations and force mains, as well as wastewater treatment facilities.
- Technical Report-16 (New England Interstate Water Pollution Control Commission, 2011) – referred to as TR-16. This guidance document is applicable to all WWTPs and PCI wastewater treatment systems and includes standards for: sewers, pumping stations and force mains as well as wastewater treatment facilities.
- New York State Design Standards for Intermediate Sized Wastewater Treatment Systems (NYSDEC, 2014) – referred to as Intermediate Design Standards. This guidance document is applicable to all PCI wastewater treatment systems that discharge to surface water and to groundwater dischargers of more than 1,000 GPD and less than 10,000 GPD. Portions of Ten State Standards are incorporated by reference.
- New York City Department of Environmental Protection (NYCDEP), Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources.
- Unofficial Compilation of Codes, Rules, and Regulations of the State of New York Title 10 Department of Health, Chapter 11, Part 75. Standards for Individual Water Supply and Individual Sewage Treatment Systems Appendix 75-A – referred to as Appendix 75-A. This guidance document is applicable to individual septic systems that discharge 1,000 GPD or less to groundwater.
- Residential On-site Wastewater Treatment Systems Design Handbook (NYSDOH, 2012).

2.2 BASIC ASSUMPTIONS

The following assumptions were used to develop and evaluate potential alternatives:

- The average individual septic system influent total phosphorus concentration is 8 mg/L. This value is within the 6 mg/L to 12 mg/L typical range specified for Intermediate Sized Facilities (NYSDEC, 2014).
- The average hydraulic load per individual septic system is approximately 260 GPD. This number appears reasonable using two calculation methods:
  - The per capita hydraulic load is 100 GPD, in accordance with Ten State Standards, and the average household size is 2.61 people per dwelling unit, in accordance with the TMDL. Therefore, the hydraulic load is 100 GPD per person times 2.61 people = 261 GPD per individual septic system.
  - In accordance with the NYSDOH hydraulic flow rates for new construction (post 1994) is 110 gallons per day per bedroom (GPDPB). It is a reasonable assumption that most homes have approximately 2.4 bedrooms. Therefore, 110 GPDPB times 2.4 bedrooms is 264 GPD per individual septic system.
- The design peak hourly flow is four times average flow (Ten States Standards).

2.3 EVALUATION CRITERIA

Criteria used to evaluate alternatives include:

Methodology for Establishing Benefit to the Lake

The benefit to the Lake was measured by the pounds of phosphorus removed per year when compared to estimated Lake loadings (current load).

Methodology for Identifying Areas Required to be Sewered

Subsurface discharge of individual septic systems or private, commercial or industrial(PCI) wastewater treatment system effluent is prohibited in some areas by regulations or where operation and maintenance (O&M) of absorption beds may be difficult due to geological features. For the initial identification of areas that must be sewered, the following criteria were used: (These criteria were developed using limited soils data and, therefore, may require re-evaluation as additional information becomes available.)

Initial Criteria for Areas Required to be Sewered

- Areas where the ground elevation is less than 5 feet above high Lake water level: This criterion identifies areas where groundwater depth is too shallow in comparison with regulatory requirements for the installation of conventional absorption beds or trenches. Although there are allowable mounding methods for achieving minimum vertical separation distances, these methods would require the homeowner or PCI wastewater treatment system operator to maintain the structural integrity of the mounds, as well as direct surface water drainage pathways away from the mound. Since this requires a long-term commitment from the homeowner or PCI wastewater treatment system operator and there is no regulatory driver (i.e. a permit), installation of shallow absorption beds or trenches as a method to control residential phosphorus discharges to the Lake appears unfeasible.
- Areas within 100 feet of a surface water (lake, creek, etc.): per Intermediate Design Standards absorption fields, must have a 100 feet horizontal separation distance from surface waters.
- Areas in the 10-year flood plain are to be avoided: This criterion identifies areas where flooding may occur. In addition to not installing septic systems in the 10-year flood plain areas, it is not recommended to locate systems in the 100-yr flood plain if possible.

Ancillary Benefits

In this Plan, ancillary benefits such as improvements to public health, economic stability, and environmental quality are presented in qualitative, not quantitative, terms. Although a dollar value is not assigned to these benefits, they will be cited in the Plan.

Public health risks can arise from poorly functioning or non-maintained failing individual septic systems and PCI wastewater treatment systems. The risk of failing individual septic systems and surface breakouts of wastewater are higher during wet weather events which could cause flooding or standing water over the individual septic system.

Perhaps the greatest improvement in water quality could be realized by conveying all sewage that is currently treated by a septic system or PCI to a WWTP for treatment instead. Septic systems and PCIs are not designed to treat contaminants such as household cleaners, heavy metals or toxic pollutants which may be inadvertently disposed of through a sink or toilet. These contaminants, even when discharged in small quantities, over time can pose a serious health and environmental risk. WWTPs are, however, capable of removing these contaminants to some degree prior to discharge to the Lake. Further, WWTPs routinely monitor influent and effluent for these contaminants and if levels increase, can adjust operations to improve reductions.

3. DESCRIPTION OF EXISTING SERVICE AREAS AND PHOSPHORUS SOURCES

The current loading to the Lake from individual septic systems, are shown in Table 1.

Table 1: Summary of Phosphorus Loads for Individual Septic Systems and Design Flows for Area 1

Individual septic systems within Area 1	
Quantity of residences	285
Quantity of Commercial Establishments	2
Total Current Number of Individual Septic Systems	287
Total Average Flow (GPD)	78,880
Total Peak Hourly Flow (GPH)[1]	13,146
Total phosphorus load to the Lake	245.2

Notes:

1. Based on a peak hourly flow peaking factor of 4.
2. Conservative estimate based on individual septic system locations presented in this plan.

To determine the total number of homes to be included in this analysis, OBG performed its own evaluation by using tax parcel data provided by Putnam County to locate the center of the tax parcel.

Loading is based on individual septic systems located within 50 feet of the Lake with an annual phosphorus load of 6.1 lbs./ yr. Septic systems located between 50 and 250 feet of the Lake were assigned an average combined phosphorus load of 1.5 lbs./yr. This calculation assumes that 60% of the individual septic systems are performing normal (0 lbs. P/yr./system), 25% of the individual septic systems are short-circuiting (3.1 lbs. P/yr./system) and 10% are ponding (3.1 lbs. P/yr./system).

Table 2: Summary of Phosphorus Loads for Individual Septic Systems and Design Flows for Area 2

Individual septic systems within Area 2	
Quantity of residences	1,065
Quantity of Commercial Establishments	0
Total Current Number of Individual Septic Systems	1,065
Total Average Flow (GPD)	276,900
Total Peak Hourly Flow (GPH)[1]	46,150
Total phosphorus load to the Lake	0

Notes:

1. As all residences within Area 2 are located more than 250 feet from the lakeshore there is no phosphorus contribution provided that the septic systems are constructed and operated correctly.

Additional information pertaining to the development of the phosphorus loadings and residence count are included in Appendix A.

4. DESCRIPTION OF COLLECTION SYSTEM TECHNOLOGIES

Implementation alternatives are described below and may include one or more of the systems combined. Information has been obtained from the United States Environmental Protection Agency and the Water Environmental Research Foundation. Factsheets with additional information are included in Appendix B.

4.1 C1 - RESIDENTIAL ON-SITE SEPTIC TANK SYSTEM

Residential on-site treatment systems (generally known as septic tanks) utilize an anaerobic process followed by adsorption to treat wastewater. Septic tanks are the most common residential on-site treatment system and commonly used in rural areas where centralized collection and treatment systems are not available.

The system consists of two components: an enclosed below grade tank and an adsorption field located at grade or, in some cases, elevated to provide adequate separation above groundwater and to provide for use of imported granular fill when native material is unsuitable. In most cases, wastewater flows by gravity from the residence to the septic tank and then through the leach field. If the system includes a raised leach field, a small dosing pump is required.

A majority of the treatment takes place in the septic tank where solids are trapped and bacteria is reduced through the anaerobic process. Liquid leaving the septic tank (effluent) flows through the leach field where the remaining contaminants are adsorbed into the soils. Septic systems provide adequate removal for most residential pollutants but do not remove of readily available phosphorus.

While the longevity of properly installed residential on-site systems varies, typical lifespan for a septic tank and/or leach field is, at minimum, 15-20 years.

Elements of a properly installed and functioning septic tank and absorption area include:

- Septic tanks should be of concrete or plastic construction and sized for a minimum detention time of 36 hours;
- Absorption areas should be located a minimum of 2 feet above the seasonal high groundwater level;
- Absorption areas should be a minimum of 100 feet from any water body and 100 feet from any drinking water well;
- Allowable percolation rate of soil at the site (varies per site);
- Septic tanks within the NYCDEP watershed must be pumped out and inspected every 3 years.

4.2 C1A – ENHANCED TREATMENT UNITS

Removal of readily available phosphorus in a residential on-site system can be enhanced through the addition of an aeration step after the anaerobic septic tank. Typical installations consist of a three-compartment tank (anaerobic, aerobic and final settling) and the center compartment is outfitted with a small air pump and diffuser assembly. The air requirement is low and can be provided by a 120v air pump that can easily be installed in a new or existing system. While adding a second tank adjacent to an existing septic tank is possible, installation of an entirely new watertight system provides the most benefit.

The estimated installed cost for the aeration system in an existing tank is approximately $2,000 for a residential system.

Proper operation of the advanced treatment unit is dependent on the homeowner maintaining the aeration system and pumping out the septic tank on a regular basis. When coupled with properly constructed leach fields for subsurface disposal of effluent this alternative may be a good strategy for treatment in areas not directly adjacent to a waterbody. Quantitative results will vary with soil type, loading and condition of existing system.

4.3 C2 – GRAVITY COLLECTION SYSTEM

A gravity sewer system is used to collect wastewater from multiple sources and convey it by gravity to a central location where it can be treated. Wastewater from each source is conveyed through a lateral sewer to a collection line. Collection (sewer) lines are typically eight-inch or larger diameter pipe. Pipe diameters increase with increasing volume of water being transported. Pipes of sufficient size and slope are installed to keep the suspended solids moving through the system and to maintain an adequate flow, so as not to surcharge the system. If gravity flow is not possible throughout the system, lift (pumping) stations are employed. Lift stations are installed at low points of the network to pump the sewage via a force main up to another gravity line, to convey wastewater over hills, and/or up to a treatment facility. Manholes are installed at regular intervals to provide maintenance access to collection lines.

Sanitary sewers are sized based on design flows, with a minimum pipe diameter (typically 8-inches) to reduce the chance of clogging. They are also designed to maintain a minimum velocity under low flow conditions to ensure self-cleaning of the pipes, while staying below a maximum velocity to avoid damage to sewers and manholes. Slopes of gravity sewers are designed to ensure velocities remain within the allowable range. Pipe depth is another important design parameter; which depends on the lowest connection point, the depth of the water table, topography, and the frost line; that could greatly affect costs, depending on the amount of necessary excavation.

In its purest form (i.e., uniform slope from service connections to treatment components) gravity is an inexpensive means to convey water. However, the topography is rarely conducive to purely gravity flow, and lift stations must often be included. The cost of gravity sewers may be prohibitive unless there is sufficient population density to justify the installation.

There are several advantages of gravity collection systems, including:

- Being the most common and established types of sewer systems.
- Large enough pipes to handle grit and solids.
- Maintaining velocities, which reduces hydrogen sulfide production and odor problems.

There are also disadvantages of gravity systems, including:

- Allowable slopes for maintaining acceptable flow, which could require deep excavations in less than desirable terrain, increasing capital construction costs.
- Excavations are deeper and wider than for pressure sewers resulting in substantial additional costs in difficult or rocky soils or with high groundwater conditions.
- The need for lift stations to pump wastewater from low points ultimately to a treatment plant, increasing costs considerably.
- Inflow and infiltration, resulting from manholes and deteriorated piping, increasing the volume of sewage, resulting in larger pipes and lift stations, which will increase costs.

4.4 C3 – GRINDER PUMP / PRESSURE SEWER COLLECTION SYSTEM

Pressure sewers are a means of collecting wastewater from multiple sources and conveying it to a central location for treatment by using pressure instead of gravity. Pressurized sewers eliminate the slope requirements of gravity sewer systems and are instead able to follow the contour of the terrain and maintain a relatively constant depth below the soil surface. A typical arrangement is for each connection (or small cluster of connections) to flow to a centralized basin. When the basin fills to a set point, a grinder pump within the basin pumps the wastewater into the pressurized sewer. Grinder pumps utilize a unique rotating assembly that reduces the size of solids and stringy matter that could otherwise plug a pipe and allow for small diameter pipes to be used for conveyance. As various grinder pumps along the length of the sewer inject sewage into the line, the wastewater is progressively moved toward the treatment facility.

Pressurized sewer systems have higher energy demands than traditional gravity sewer systems, since each grinder pump must be connected to a power source. The pumps do not work when there are power outages and the size of the pump basin provides some detention time to allow for connection to a backup power system. One method for addressing backup power during a power outage is to install a common electric drop for a series of several grinder pumps. With this approach, a single portable generator can be employed to operate grinder pumps serving a group of homes. The generator(s) can be rotated between the groups of homes such that each group of pumps is operated every few hours to coincide with available detention time within the grinder pump basin.

As an alternate to this approach, grinder pumps could be powered from the residence and the homeowner responsible for temporary electric as needed.

Grinder pumps are somewhat maintenance free but require annual inspections. While pumps reportedly will last 8-10 years, replacement can be planned or take place when the equipment fails. Maintenance could be the responsibility of the residence or set up to be the responsibility of the sewer district. If the responsibility of the district, an agreement would have to be in place to allow the sewer district staff to enter private property for maintenance of the equipment.

There are several advantages of pressure sewers, including:

- The ability to sewer areas with undulating terrain, rocky soil conditions, and high bedrock or groundwater tables.
- Reduced material and installation costs, resulting from shallower placement, lack of manholes and lift stations, and longer sections of smaller diameter piping.
- The pump basin can be located such that the existing house lateral can remain in place and interior plumbing modifications won't be required.
- The ability to handle low flow situations.

Pressure sewer systems also have disadvantages, including:

- Require temporary power during power outages.
- Systems are often located on private property requiring access agreements for sewer district staff to maintain the systems as needed.
- The lifespan of a grinder pump system is typically 8-10 years requiring replacement when they fail.

4.5 C4 – VACUUM SEWER COLLECTION SYSTEM

A vacuum sewer system is used to collect wastewater from multiple sources and convey it to a central location for treatment. As the name suggests, a vacuum (negative pressure) is drawn on the collection system. When a service line is opened to atmospheric pressure, wastewater and air are pulled into the system. The wastewater that enters with the air forms a "plug" in the line, and air pressure pushes the wastes toward the vacuum station. This differential pressure comes from a central vacuum station. Vacuum sewers can take advantage of available slope in the terrain, but are most economical in flat terrain. Vacuum sewers have a limited capacity to pull water uphill with a maximum expected lift is between 30 and 40 feet. Vacuum sewers are designed to be watertight since any air leakage into the system reduces the available vacuum.

Vacuum sewers do not require a septic tank however, a valve pit with a pneumatic pressure valve is used to separate gravity flow from a residence or commercial establishment. Often, a common valve pit will serve multiple locations. Each valve pit is fitted with a pneumatic pressure-controlled vacuum valve which automatically opens after a predetermined volume of sewage has entered the sump. The difference in pressure between the valve pit (at atmospheric pressure) and the main vacuum line (under negative pressure) pulls wastewater and air through the service line. When the vacuum valves close, atmospheric pressure is restored inside the valve pit. The sewage travels in the vacuum main as far as its initial energy allows, eventually coming to rest. As other valve pits in the network open, more sewage and air enters the system. Each input of energy moves the sewage toward the central vacuum station. The violent action in the pipe tends to break up the larger suspended solids during transport.

Vacuum systems typically consist of one (or few) vacuum pumping stations resulting in a centralized location for the bulk of the maintenance activities. Many successful vacuum sewer systems are located in warmer areas with flat topography and less impact from freezing temperatures however, there are a few systems located in the northern part of the United States. Other than the vacuum pumps, the only other item that requires regular maintenance is the valve pit located at each residence or commercial establishment. Typically, the sewer district will have responsibility of all components in the system up to the customer connection to the valve pit. As the valve pits are often located on private property, agreements will need to be in place for the sewer district staff to access the valve pit.

Vacuum pump stations include two or more vacuum pumps and a large vacuum tank. The vacuum pumps run on short cycles that are sufficient for creating an adequate vacuum in the system. The large vacuum tank at the station maintains the vacuum on the collection system and keeps the vacuum pumps from having to operate at all times. There is a loss in negative pressure as the valve pits are actuated. The vacuum pumps turn back on when this negative pressure reaches a certain set point. Sewage flows into a collection tank when it gets to the vacuum station and traditional sewage pumps then convey the collected wastewater via a force main to the treatment facility.

Advantages of vacuum sewer systems include:

- Being conducive to flat and hilly terrain, rocky soils, dense communities in rural areas, and high groundwater tables and bedrock.
- Less disruptive installation, resulting from the small diameter pipes (typically 4-inches) and shallow excavations.
- The ability to locate vacuum sewer mains outside of and adjacent to the edge of pavement.
- Less disturbance than gravity sewers, including no need for manholes.
- Typically, the need for only one vacuum station, instead of multiple lift stations, reducing energy costs.
- Reduced odors and hydrogen sulfide production in the collection system because of a sealed system with short detention times.

Disadvantages of vacuum sewers include:

- The maximum expected capacity to draw wastewater uphill is between 30 and 40 feet.
- Low population densities with few connections result in poor performance because the movement of wastewater depends on the differential pressure created when valves open.
- Large and expensive vacuum stations.
- Noise and odor created by the vacuum station.
- The need to regularly inspect system components by staff or remote monitoring via telemetry.
- Regular maintenance, including changing oil and oil filters on vacuum pumps, removing and cleaning inlet filters on vacuum pumps, testing alarm systems, checking motor couplings, and checking operation of the vacuum station shutoff and isolation valves.
- Rebuilding controllers every 3 to 6 years and rebuilding valves every 8 to 12 years.
- Wastewater backup when valves fail to open.
- Several mechanical components in the system at risk for failure.

4.6 C5 – EFFLUENT SEWER COLLECTION

An effluent sewer is used to collect wastewater from multiple sources that has undergone liquid/solid separation or primary treatment and convey it to a central location for final treatment. Septic Tank Effluent Pump and Septic Tank Effluent Gravity sewers (commonly referred to as STEP or STEG) use on-lot septic tanks to provide liquid/solid separation. Clarified effluent then moves into the watertight collection system using either a pump (STEP) or gravity (STEG). STEP and STEG configurations can also be combined within a gravity or pressure collection system.

Septic Tank Effluent Pump (STEP)

In a STEP system each wastewater source or group of sources flows into a conventional, watertight septic tank to capture solids and provide primary treatment. However, in this case, an effluent pump (typically capable of pumping 3 or more gallons per minute) is installed either in the outlet end of the septic tank or in a separate holding tank or vault. The pump injects the clarified effluent into a pressure or gravity sewer system. As each STEP pump in the collection systems operates, effluent is progressively moved toward the wastewater treatment facility.

Retrofitting existing septic tanks can sometimes be a means of cost savings, however, if many must be replaced because of insufficient capacity, deterioration of concrete, or leaking, costs for a STEP system will increase significantly.

Advantages of STEP systems include:

- The ability to handle low flow conditions.
- Opportunities for cost savings by potentially reusing some existing septic tanks.
- The ability to sewer areas with undulating terrain, rocky soil conditions, and high bedrock or groundwater tables.
- Reduced material and installation costs, resulting from shallower placement, lack of manholes and lift stations, and longer sections of smaller diameter piping.
- Modifications to existing plumbing within homes and businesses are not necessary.

Disadvantages of STEP systems include:

- Not having a large excess capacity typical of conventional gravity systems.
- There are several mechanical components located within the service area.
- O&M costs are typically higher than they are for gravity systems, due to the number of pumps.

Power outages can result in overflows, but generators can prevent this.

Septic Tank Effluent Gravity (STEG)

In a STEG system, each source or group of sources has a watertight septic tank with an effluent screen and an access riser. Effluent flows out of the tank and into a collection sewer by gravity. The collection sewer is typically plastic pipe 4 to 8 inches in diameter. The piping from the tank to the collection line includes an accessible cleanout. STEG systems operate via gravity to a low point in the system where a lift station can be utilized to transfer the liquid downstream to a gravity or larger pumped system.

There are several advantages of STEG systems, including:

- The septic tank provides primary treatment of wastewater and captures debris, grease and grit that could impact downstream treatment processes.
- Septic tanks that are watertight and in good condition can remain in place and be converted to effluent transfer by pumping or gravity.
- Suitable for cluster systems.
- The ability to handle low flow conditions.

- Opportunities for cost savings by potentially reusing some existing septic tanks.
- Reduced material and installation costs, resulting from shallower placement, lack of manholes and lift stations, and longer sections of smaller diameter piping.
- Modifications to existing plumbing within homes and businesses are not necessary.

STEG systems also have disadvantages, including:

- STEP systems require temporary power during extended power outages (more than 1 day)
- Most existing septic tanks aren't considered watertight enough to work for a STEP/STEG system and will require replacement.
- Existing house laterals or septic tanks may not be optimally located to support a STEG system or easy access for sewer district employees.
- Requires that septic tanks be pumped out on a routine basis, usually every 3-5 years.
- Pumps and discharge piping are often located on private property requiring access agreements for sewer district staff to maintain the systems as needed.
- The lifespan of a pumps is 8-10 years requiring replacement when they fail.
- Allowable slopes for maintaining acceptable flow, which could require deep excavations in less than desirable terrain, increasing capital construction costs.
- The need for lift stations to pump wastewater from low points ultimately to a treatment plant, increasing costs considerably.
- Not having a large excess capacity typical of conventional gravity systems.

4.7 C6 – CLUSTER COLLECTION / TREATMENT SYSTEM

Cluster / Decentralized collection systems treat wastewater from several homes (aka. cluster) and are typically designed to treat 1,000 to as much as 20,000 gallons per day. Most systems consist of one or more larger septic tanks followed by an appropriately sized adsorption field.

Under this alternative, flow currently treated by individual septic systems would be diverted to a common septic system sized to treat the quantity of homes connected. Discharge from each new septic tank would be conveyed by gravity or pumped to a to a subsurface discharge point located at a distance of 250 feet or more from the Lake or other watercourse. It is assumed that the wastewater treatment system would be designed so that nutrient loading to the Lake from each system would be minimized due to the distance from the adsorption field to the Lake. Key features of this alternative include:

- Construction of gravity collection sewers to convey sewage to a common location for treatment;
- Installation of a residential sewer lateral from each residence to a collection sewer. Installation, as well as maintenance of the sewer lateral, would be the responsibility of the home owner;
- Installation of a wastewater treatment system to serve each cluster of homes. Operation and maintenance of the wastewater treatment system would be the responsibility of the group of homes that it serves. Identification of a responsible entity for O&M, as well as reporting to the NYSDEC would be necessary;
- It is expected that design flows for each wastewater treatment system is estimated to be between 1,000 GPD and 10,000 GPD, with subsurface discharge, therefore, the systems would be designed to comply with Intermediate Design Standards (NYSDEC, 2014). A General Permit GP 0-05-001 may be required. Projected phosphorus load from these systems to the Lake is estimated at essentially 0 lb./d; and
- Location of the absorption field would require at least two feet of appropriate soil type between the bottom of the absorption bed and the highest groundwater level, bedrock or permeable strata, as well as meeting

minimum distances from water wells, in accordance with the Residential On-site Wastewater Treatment Systems Design Handbook.

5. DESCRIPTION OF ALTERNATIVES

OBG reviewed the existing conditions surrounding the Lake and prescreened those collection technologies that are most suitable for Putnam Lake. Due to the density of residences and the history of septic tank issues adjacent to the Lake technologies that involve continued use of on-site treatment systems and/or cluster systems that require substantial area were dropped from further consideration. Vacuum sewers were also dropped from additional consideration due to inherent problems with the systems in difficult soils and northern climates.

The area surrounding the Lake is separated into project areas: Area 1 – within the proposed district boundary and Area 2 – remaining property within the lake watershed. The limits of Areas 1 and 2 are shown in Figure 2. As described under Basic Assumptions, residences located more than 250 feet from the Lake are assumed to discharge zero phosphorus load to the Lake; however, there is some evidence to suggest that this assumption is questionable as these discharges likely exert some phosphorus load particularly when there is a malfunction in the leach field. Inclusion of these areas in the long-term plan may have ancillary economic and health related benefits to the community. Alternatives considered for analysis are presented in Figures 3A, 3B and 3C

5.1 BASELINE CONDITION

Baseline conditions represent conditions at the time the TMDL was developed. As the baseline condition, they serve as the basis of comparison for the evaluation of alternatives.

5.2 ALTERNATIVE 1 – CONNECT UNSEWERED AREAS TO EXISTING PUBLICLY OWNED TREATMENT WORKS

This alternative includes decommissioning/abandoning existing individual septic systems in unsewered areas and diverting flows to a collection system. Each homeowner would be responsible for installation, operation and maintenance of the residential sewer connection from the residence to the collection system (gravity sewer, grinder station, forcemain, etc.). For planning purposes, connection costs are estimated at $2,500. A new sewer district will be formed to support the installation, upgrade, operation and maintenance of the collection system.

While decommissioning individual septic systems within 250 feet of the Lake will address phosphorus loadings, it is recommended that all homes as well as PCI wastewater treatment systems within the potential service area be considered for inclusion in a collection system project to maximize the benefit to the community provided that the project is economically feasible.

The following paragraphs describe each alternative considered for evaluation. Potential facilities for each alternative are estimated for Areas 1 and 2. However, Figures of proposed infrastructure were developed for Area 1 improvements only as these will provide the most benefit to the lake relative to removal of readily available phosphorus.

The following collection system alternatives were short listed and evaluated and are based on discharge to a WWTP within one mile of Putnam Lake:

Alternative 1A: Gravity Collection

Alternative 1A generally consists of installing gravity sewers within existing streets and directing flows to low points to small pump stations. These pump stations would transfer flow to a larger pump station for discharge to a regional WWTP. To install new house laterals, each property owner would abandon their existing septic system and install a new gravity 4-inch diameter lateral from each residence to the right of way at the street. This may require some internal plumbing modifications, depending on the locations of the existing septic tank and new gravity sewer. Additionally, the property owner could expect to perform infrequent maintenance

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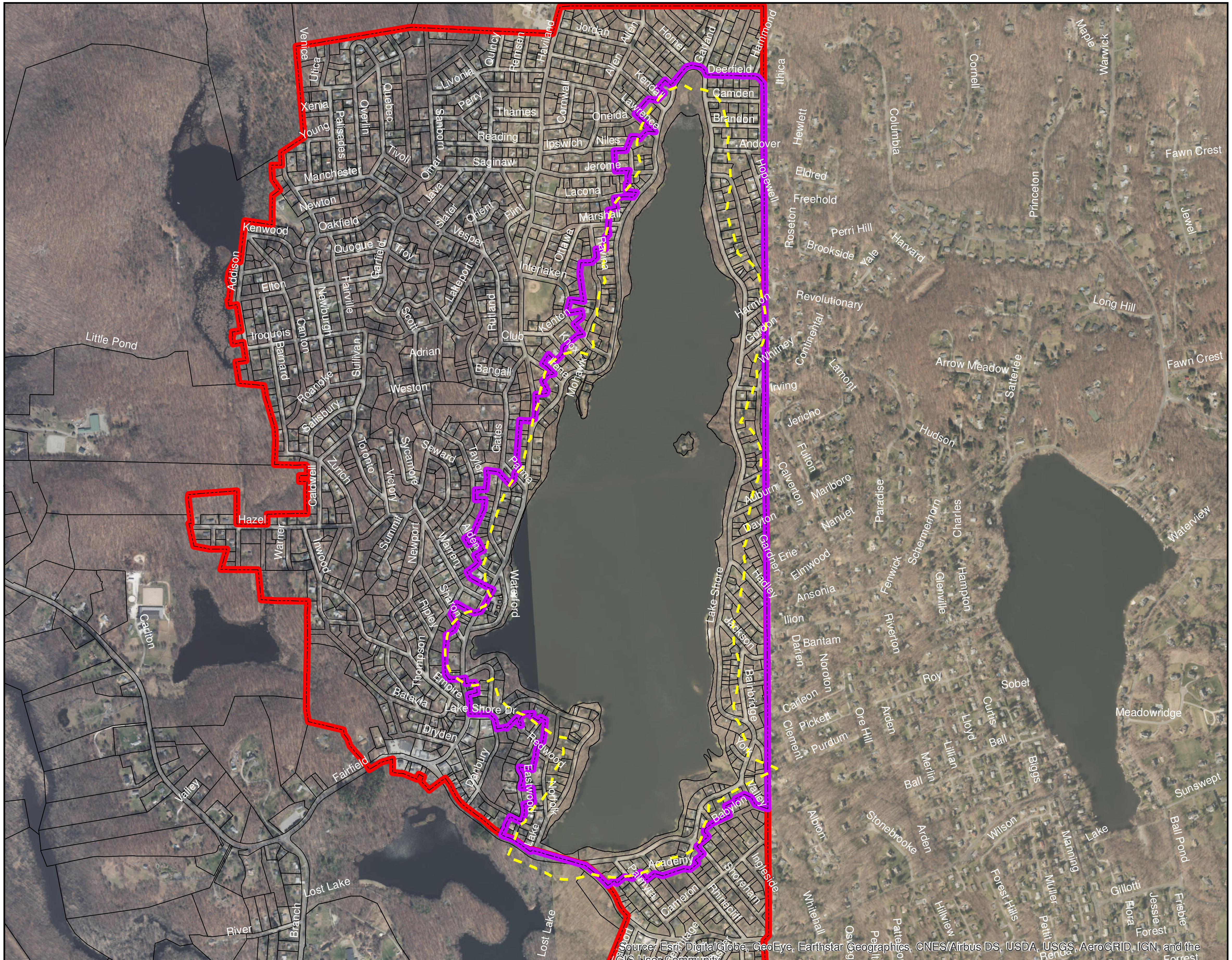

N

LEGEND

- Parcels
- Proposed Service Area 1
- Proposed Service Area 2
- 250-ft Offset

NEW YORK STATE OFFICE OF GENERAL SERVICES

PUTNAM LAKE PROPOSED DISTRICT EXTENSION

0 500 1,000 2,000
Feet

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MAY 2018

O'BRIEN & GERE ENGINEERS, INC.

I:\Nys-Ogs.2069\69637.C11-Engineering\Docs\DWG\MXD\Boundary Map.mxd consisting of sewer cleaning, tree root removal, and repairing damaged lines. The proposed facilities are shown on Figure 3A and further described below:

Area 1:

- Approximately 26,000 LF of 8-inch diameter gravity sewer (5 to 8 ft. deep)
- Approximately 104 manholes
- Seven (7) lift stations
- Approximately 16,000 LF of 4-inch diameter force main
- Laterals to each residence
- Disconnect and decommission each residential on-site treatment system

Area 2:

- Approximately 93,000 LF of 8-inch diameter gravity sewer (5 to 8 ft. deep)
- Approximately 372 manholes
- Four (4) lift stations
- Approximately 8,000 LF of 4-inch diameter force main
- Laterals to each residence
- Disconnect and decommission each residential on-site treatment system

Alternative 1B: Pressure Sewers

Alternative 1B generally consists of installing grinder pumps and pressure sewers throughout the service area. The pressure sewers would transfer flow to a POTW within one mile of the Lake. The property owner would be responsible for the installation of the sewer lateral from the house to the grinder pump station as well as decommissioning the existing septic tank. Routine maintenance would likely consist of replacing the grinder pump approximately every 5 to 10 years. The proposed facilities are shown on Figure 3B and further described below:

Area 1:

- Approximately 40,000 LF of 2-inch diameter low pressure sewer
- Approximately 287 grinder pumping stations
- Disconnect and decommission each residential on-site treatment system

Area 2:

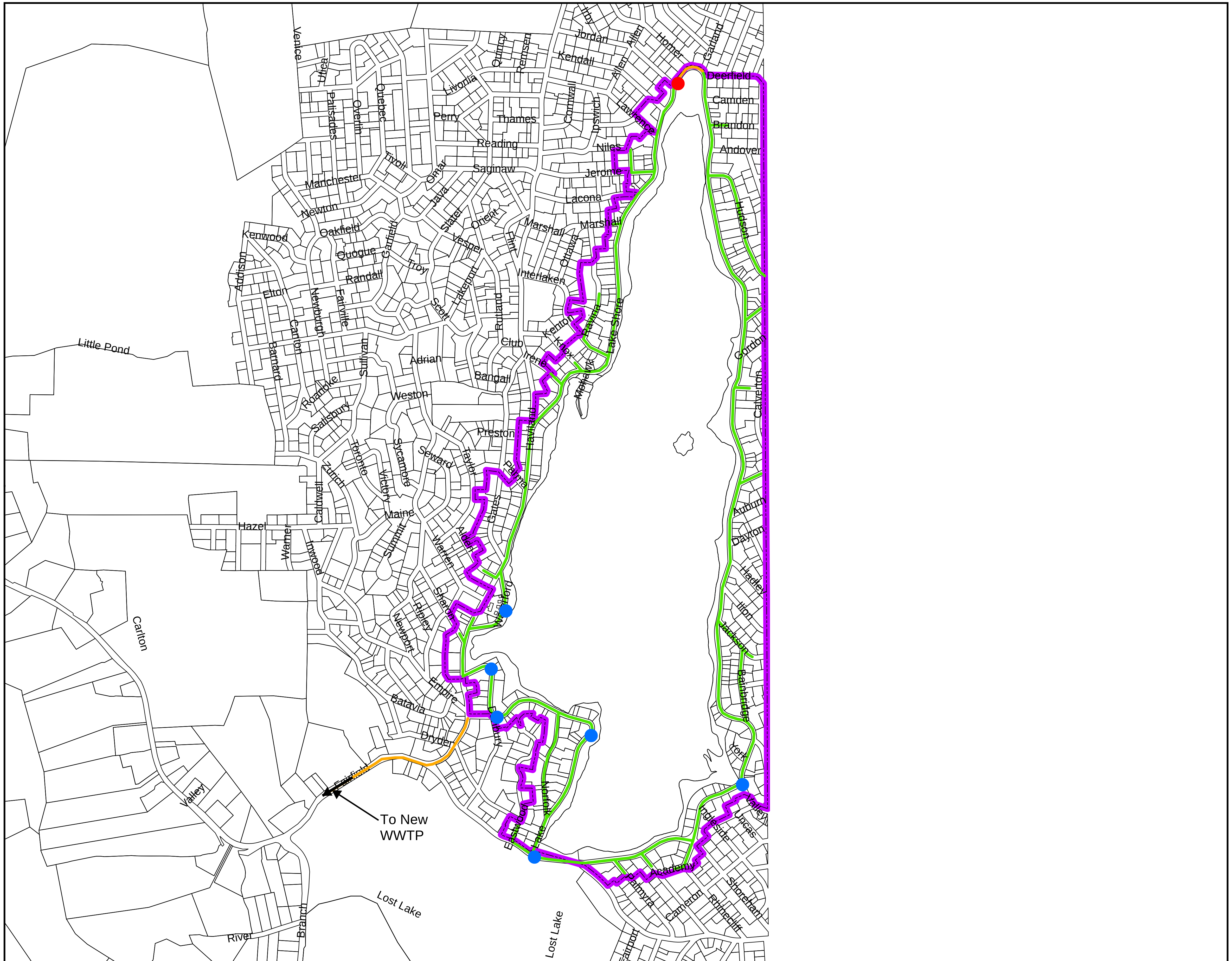
- Approximately 146,000 LF of 2-inch diameter low pressure sewer
- Approximately 1,065 grinder pumping stations
- Disconnect and decommission each residential on-site treatment system

5.3 ALTERNATIVE 2 – SEPTIC TANK EFFLUENT COLLECTION AND TREATMENT

This alternative includes utilizing residential on-site treatment and collection of effluent for treatment offsite at a POTW. For this alternative to be most effective, all existing septic tanks will be replaced with new equipment properly designed to support effluent collection and transfer. In this case, responsibility of the interior plumbing and lateral to the new septic tank would be the responsibility of the homeowner and septic tank, effluent collection and district-wide collection and transfer systems would be the responsibility of the district

Alternative 2A: STEG – Septic Tank Effluent Gravity Collection

Based on the presumed location of septic tanks behind most homes and the additional work required to route gravity piping around the residence to the appropriate location for connection this alternative as deemed not feasible.



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LEGEND

- Parcels
- 8" - 10" Gravity Sewer
- 4" Force Main
- Proposed Service Area 1
- Pumping Station (50-100 gpm)
- Pumping Station (100-200 gpm)

NEW YORK STATE
OFFICE OF GENERAL
SERVICES

PUTNAM LAKE
GRAVITY COLLECTION SYSTEM

0 500 1,000 2,000
Feet

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MAY 2018

O'BRIEN & GERE ENGINEERS, INC.

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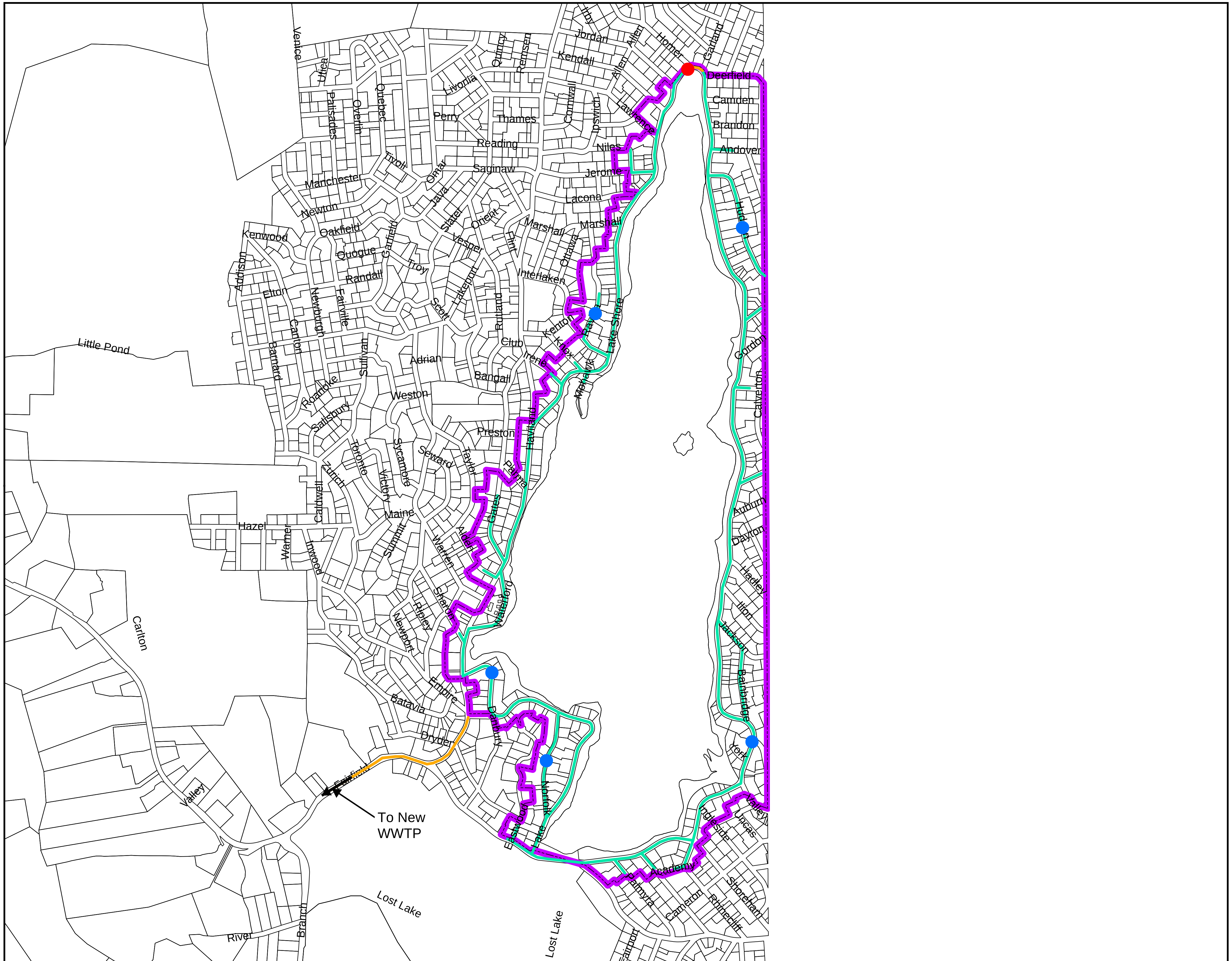

N

LEGEND

- Parcels
- 4" Force Main
- 1.5" Force Main
- Proposed Service Area 1
- Pump Station
- Air Release Valve

NEW YORK STATE
OFFICE OF GENERAL
SERVICES

PUTNAM LAKE
GRINDER PUMP / PRESSURE
SEWER COLLECTION SYSTEM

0 500 1,000 2,000
Feet

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MAY 2018

O'BRIEN & GERE ENGINEERS, INC.

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Alternative 2B: Septic Tank Effluent Pumped Collection

Alternative 4B generally consists of replacing existing septic tanks and installing new tanks with effluent pumps to convey flow to a common lift station. This lift station would then transfer flow to a new WWTP constructed to serve Putnam Lake. The proposed facilities are shown on Figure 3C and further described below:

Area 1:

- Approximately 287 new septic tanks with effluent pumping system
- Approximately 40,000 LF of 2-inch diameter low pressure sewer
- One (1) lift station
- Approximately 2,000 LF of 2-inch diameter force main

Area 2:

- Approximately 1,065 new septic tanks with effluent pumping system
- Approximately 146,000 LF of 2-inch diameter low pressure sewer

6. WASTEWATER TREATMENT ALTERNATIVES

NYCDEP regulations generally prohibit the construction of new surface discharge facilities unless a septic emergency is determined and require substantial permitting and studies to advance the project. Construction of subsurface discharge facilities are more feasible and the permitting process can be more straightforward.

Given the difficulty in development of a new surface discharge WWTP in the NYCDEP watershed directing flows to an existing facility is most favorable.

6.1 EXISTING PUBLICLY OWNED TREATMENT WORKS

The Mount Ebo Sewer Treatment Plant (SPDES NY0148946) is located five miles southeast of Putnam Lake and is permitted for a flow of 160,000 GPD and currently is processing approximately 103,000 GPD. Based on this brief analysis it appears that the facility has excess capacity to treat flows from the Putnam Lake service area. Watchtower WWTP (SPDES NY0165778) is located approximately three miles northeast of the lake. Currently, the facility processes a maximum flow of 130,000 GPD and is permitted for up to 165,000 GPD resulting in minimal available capacity. A third treatment option, Clocktower Commons lies four miles southeast of the lake. However, flow data have not yet been collected for this plant.

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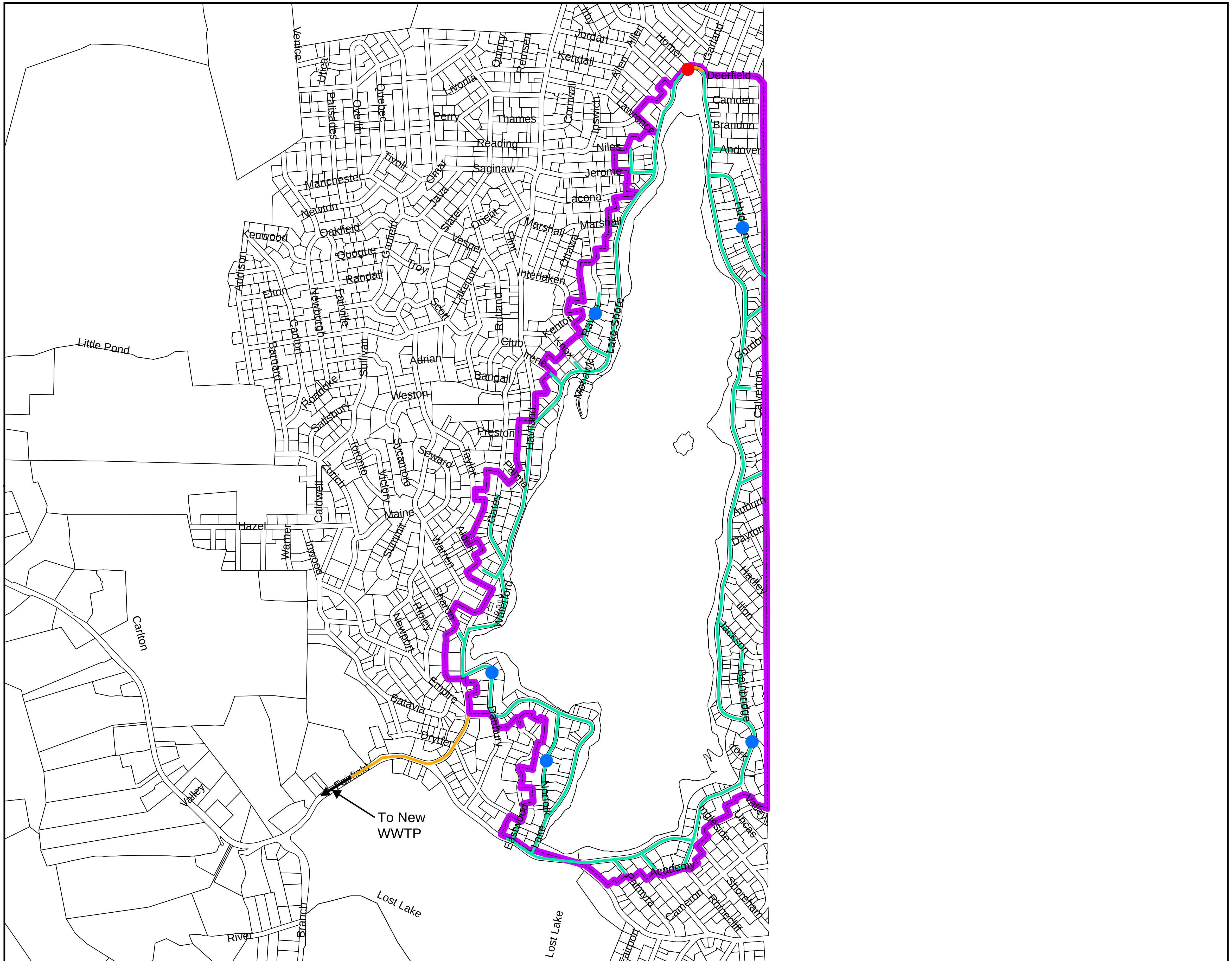
FIGURE 3C



N

LEGEND

- Parcels
- 4" Force Main
- 1.5" Force Main
- Proposed Service Area 1
- Pump Station
- Air Release Valve

NEW YORK STATE OFFICE OF GENERAL SERVICES

PUTNAM LAKE PROPOSED SEPTIC TANK EFFLUENT PUMP SYSTEM

0 500 1,000 2,000
Feet

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MAY 2018

O'BRIEN & GERE ENGINEERS, INC.

Table 3: Putnam Lake Wastewater Treatment Alternatives

	Watchtower WWTP (SPDES NY0165778)	Mt. Ebo (SPDES NY0148946)
Permitted Capacity (GPD)	165,000	160,000
Historical Flow (GPD)	130,000	103,000
Available Capacity (GPD)[1]	35,000	57,000
Projected Area 1 Flows (GPD)[2]	78,880	78,880
Projected Area 2 Flows (GPD)[3]	276,900	276,900
Available Capacity for Putnam Lake Flows[4]	Area 1 – NO Area 2 – NO	Area 1 – NO Area 2 – NO
Distance from Putnam Lake	3 miles	1 miles

Notes:
1. Unconfirmed with POTW. Data is based on the NYSDEC database
2. Estimated flows generated within 250 feet of the lakeshore
3. Estimated flows generated within service area minus Area 1
4. Full build out of all 1,350 residences will likely be a long-term project.
5. SPDES permit number and flow data to be collected

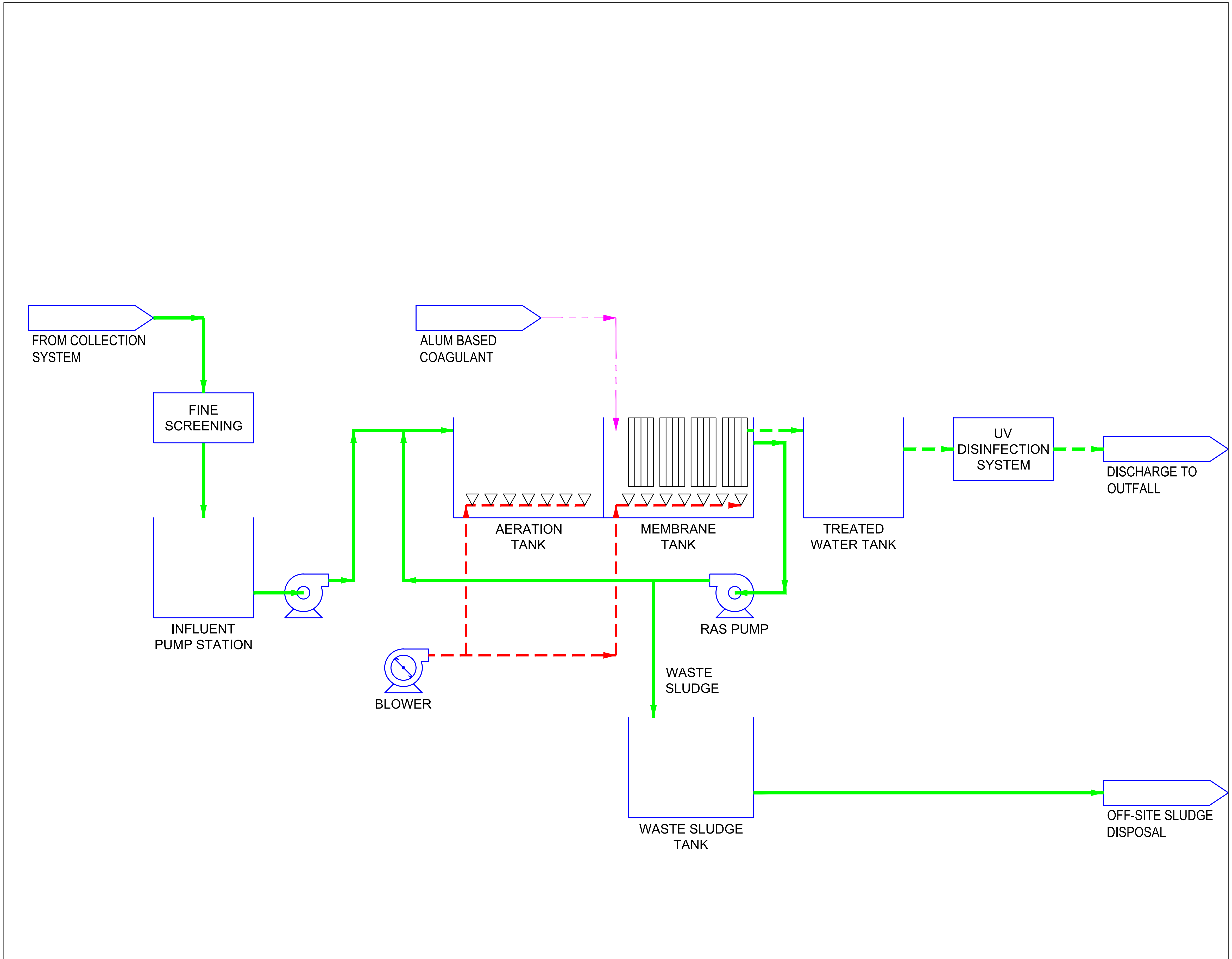
6.2 POTENTIAL ADDITIONAL TREATMENT REQUIREMENTS

As noted above, based on available records neither the Watchtower or Mt. Ebo WWTPs have excess flow capacity in the levels required for the proposed service area and it is anticipated that a new wastewater treatment plant will be needed to process the flows from this area. The NYCDEP does not allow for construction of new wastewater treatment facilities within the watershed unless there is a proven need due to failing septic tanks influencing the watershed. Under this condition, NYCDEP may issue a variance to correct the discharge of sewage by constructing a treatment facility when no other feasible alternative is available.

New wastewater treatment facilities within the NYCDEP watershed are required to meet high effluent standards and recently, the NYCDEP has allowed the used of membrane treatment systems in lieu of conventional tertiary treatment facilities. For this study, it is assumed that a new membrane treatment facility would be suitable for installation and is evaluated further as described below. In support of the NYCDEP Filtration Avoidance Program, the NYCDEP will subsidize capital and operational costs for treatment processes above those typically required for a conventional WWTP. For this effort, cost calculations present the NYCDEP subsidy for the membrane treatment process and ancillary systems.

Sewage would be conveyed to the proposed membrane treatment system with a rated capacity of 0.158 MGD, approximately twice the projected annual flow rate. Membrane technology was selected because it is capable of meeting the strict discharge limits, although at the levels proposed, it will require overdesign and significant operator skill. Compared to other technologies, MBRs have a small footprint which will reduce the cost of procuring property to site the facility.

Influent flow would be conveyed to a headworks consisting of an influent flow meter (Parshall flume), fine screening and an influent pump station (Figure 4). From the pump station, flow would be conveyed to a microfilter membrane treatment system consisting of two aeration tanks with partitioned membrane tanks containing microfilter membrane cassettes. To achieve ultra-low phosphorus levels in the discharge an



LEGEND

SEWAGE
MBR TREATMENT WATER
AIR
CHEMICAL

NEW YORK STATE OFFICE OF GENERAL SERVICES

PROCESS FLOW DIAGRAM MEMBRANE TREATMENT

FILE NO. 2069.69637
JUNE 2018

O'BRIEN & GERE ENGINEERS, INC.

aluminum-based coagulant would be dosed to the membrane tanks. Solids would be recycled to the aeration tank and waste solids would be disposed of. Membrane permeate would be conveyed to a treated water tank and disinfected using ultraviolet radiation before discharging through a new surface discharge outfall. Although a subsurface discharge is preferred, the facility location has not yet been established. If a location with adequate area and proper soil conditions can be identified, then a subsurface discharge will be implemented instead.

The flow rates for Area 1 are projected to remain relatively stable. The design influent flows and water quality, developed using Ten State Standards (2014) and New York State Design Standards for Intermediate-Sized Wastewater Treatment Systems (2014), are contained on Table 4.

Table 4: Design Influent Hydraulic and Water Quality Loads – Area 1

Influent Parameter	Units	Area 1
Annual average flow rate	gpd	78,900
Peak hourly flow rate	gpd	316
Average BOD load	lb/d	134
Peak hour BOD load	lb/d	268
Average TSS load	lb/d	158
Average TKN load	lb/d	28
Peak hour TKN load	lb/d	578
Average phosphorus load	lb/d	5

The projected discharge permit requirements (Table 5) were assumed to be equivalent to the surface water discharge permit requirements listed in the Kent Manor Condominium SPDES Permit (NY0207322), with the exception of the phosphorus limit, which is expected to be 0.1 mg/L, per the NYSDEC. The proposed rated capacity (maximum monthly average) is twice the average annual flow rate. Additional parameters that will likely be included in the SPDES permit include an annual phosphorus load as well as 3-log removal of Giardia Lamblia cysts and Enteric viruses.

Table 5: Projected SPDES Permit Criteria – Area 1

Parameter	Type	Limit	Units
Flow	Monthly average	158,000	gpd
BOD	Daily maximum	5	mg/L
TSS	Daily maximum	10	mg/L
Settleable solids	Daily maximum	0.1	mL/L
pH	Range	6.5 – 8.5	SU
Ammonia – summer	Daily maximum	1.5	mg/L
Ammonia – winter	Daily maximum	2.2	mg/L
Phosphorus	30-day arithmetic mean	0.1	mg/L
Dissolved oxygen	Daily minimum	7.0	mg/L

To achieve a high discharge quality, the following summarizes design criteria with a more detailed description contained in Appendix C.

- Standard Oxygen Required (SOR) for BOD and ammonia removal is 337 lb/d at average annual and 1,325 lb/d at peak hour. This value accounts for return stream as well as maintaining an effluent dissolved oxygen concentration of 8.0 mg/L.
- Waste activated sludge (WAS) wasting rate of 189 lb/d
- Aluminum -based coagulant dosed at a rate of 5.5 gpd of 50% Alum
- Approximately 0.6 alum totes per month

Due to the larger service area, the rated capacity of the membrane treatment system for Area 2 would be increased to 1.86 mgd, approximately twice the projected average annual flow. Likewise, the design hydraulic and water quality loads increase as shown on Table 6. The concentration-based SPDES limits listed on the above Table 5 for Area 1 are expected to be the same for Combined Areas 1 and 2. The limit of annual phosphorus load discharged to the Lake would likely be adjusted to accommodate the higher flow rate.

Table 6: Design Influent Hydraulic and Water Quality Loads – Combined Areas 1 and 2

Influent Parameter	Units	Combined Areas 1 and 2
Annual average flow rate	gpd	356,000
Peak hourly flow rate	mgd	1,423,000
Average BOD load	lb/d	605
Peak hour BOD load	lb/d	1,210
Average TSS load	lb/d	712
Average TKN load	lb/d	128
Peak hour TKN load	lb/d	256
Average phosphorus load	lb/d	24

To achieve a high discharge quality, the following summarizes design criteria with a more detailed description contained in Appendix C.

- Standard Oxygen Required (SOR) for BOD and ammonia removal is 1,521 lb/d at average annual and 5,975 lb/d at peak hour. This value accounts for return stream as well as maintaining an effluent dissolved oxygen concentration of 8.0 mg/L.
- Waste activated sludge (WAS) wasting rate of 854 lb/d
- Aluminum -based coagulant dosed at a rate of 24.6 gpd of 50% Alum
- Approximately 2.7 alum totes per month

One of the most significant factors of any potential wastewater treatment system alternative is the regulatory requirements detailed in *Rules and Regulations for the Protections from Contamination and Degradation and Pollution of the New York City Water Supply* (2010). Maintaining a high-quality water supply for New York City residents governs the uses and discharges to the Lake, including discharges from wastewater treatment systems. Per the regulation, design, construction and operation of wastewater treatment plants is generally prohibited when a sewage discharge is reasonably likely to cause degradation of the surface water quality or water supply. Regulations further restrict treated effluent discharges to surface water in phosphorus or fecal coliform-restricted basins or if the treatment system is located within a 60-day travel time to the potable water intake. The proposed system is located within a restricted zone and therefore, a variance must be issued by the New York City Department of Environmental Protection (Department) along with the standard review and approval process. While the proposed system will be designed to meet regulatory criteria, it is unknown if a variance will be issued. Discussions with the Department have been initiated to clarify the potential for receiving a variance and subsequent project approvals.

A second significant factor to be considered is benefit to the lake, the primary objective of this project. While sewering and treating sewage within 250 ft of the Lake (Area 1) significantly reduces phosphorus loading to the Lake, implementation beyond the 250-foot boundary results in a net increase in phosphorus load to the Lake (or watershed) since these systems currently do not deposit a phosphorus load to the Lake and the WWTP effluent will include trace amounts of phosphorus. Further, collecting sewage from these septic tanks, treating at a decentralized treatment facility and disposing of the treated waste to the Lake would introduce other pollutants that are currently removed during migration through the soil. Because of these influences, treating sewage from beyond the 250-ft boundary may be feasible but require careful consideration of all factors prior to implementation.

7. ALTERNATIVES COST EVALUATION

The basis of cost estimates is a combination of costs presented in previous consultants' reports and updated based on current bid tabs and standards. They have been utilized to develop conceptual screening level costs for various infrastructure improvements. A summary of unit prices is included as Appendix D and a breakdown of the overall costs in Appendix E.

An opinion of probable costs was developed for each alternative and presented below:

Table 7: Probable Project Cost for Putnam Lake Collection Sewers

	Area 1	Area 2	Treatment	Areas 1 and 2
Alternative 1A - Gravity Collection	$15,693,375	$43,047,675	---	$58,741,050
Alternative 1B - Grinder/Pressure Collection	$10,008,675	$38,819,475	---	$48,828,150
Alternative 2B - Effluent Collection	$9,738,675	$36,794,475	---	$46,533,150
Alternative 3A – Gravity Collection and Treatment Plant	$15,693,375	---	$9,356,389	$25,049,764
Alternative 3A – Gravity Collection and Treatment Plant	$15,693,375	$43,047,675	$18,984,000	$77,725,050
Alternative 3B – Pressure Collection and Treatment Plant	$10,008,675	---	$9,356,389	$19,365,064
Alternative 3B – Pressure Collection and Treatment Plant	$10,008,675	$38,819,475	$18,984,000	$67,812,150

Table 8 summarizes collection and treatment operation and maintenance (O&M) costs.

Table 8: Estimated Annual O&M Costs

Alternatives	Staffing	Electrical	Collection System Miscellaneous	Sub Total	Wastewater Treatment Primary Treatment O&M	MBR O&M	Total
1A - Gravity Sewers - Area 1	$45,000.00	$2,500.00	$10,000.00	$57,500.00	$51,824.16	$50,960.42	$160,284.58
1A - Gravity Sewers - Area 2	---	$1,200.00	$10,000.00	$11,200.00	$181,923.30	$178,891.25	$372,014.55
1A - Gravity Sewers - Total	$45,000.00	$3,700.00	$20,000.00	$68,700.00	$233,747.46	$229,851.67	$532,299.13
1B - Pressure Sewers - Area 1	$45,000.00	$20,664.00	$10,000.00	$75,664.00	$51,824.16	$50,960.42	$178,448.58
1B - Pressure Sewers - Area 2	---	$76,680.00	$10,000.00	$86,680.00	$181,923.30	$178,891.25	$447,494.55
1B - Pressure Sewers - Total	$45,000.00	$97,344.00	$20,000.00	$162,344.00	$233,747.46	$229,851.67	$625,943.13
2B - STEP - Area 1	$45,000.00	---	$10,000.00	$55,000.00	$35,989.00	$50,960.42	$141,949.42
2B - STEP - Area 2	---	---	$10,000.00	$10,000.00	$126,335.63	$178,891.25	$315,226.87
2B - STEP - Total	$45,000.00	---	$20,000.00	$65,000.00	$162,324.63	$229,851.67	$457,176.29

Notes:

1. Electrical cost for pumps under Alternate 2B will be borne by homeowner.
2. Collection system staffing estimated at 0.5 FT employee employed by District.
3. Primary wastewater treatment O&M based on $1.80/1,000 gallons treated for raw wastewater and $1.25/1,000 gallons treated for STEP.
4. MBR O&M based on $1.77/1,000 gallons treated.
5. Grinder pump electrical costs estimated at $6/month and will be borne by District.

Tables 9 through 14 present potential user cost scenarios for Area 1 alternatives 1A, 1B and 2B. As noted in previous sections, detailed O&M and user costs scenarios were not developed for Area 2 dues to the high cost of the proposed improvements and limited benefit to lake water quality.

Table 9: Alternative 2B Funding Analysis

	Area 1
Capital Cost Sewer	$9,738,675.00
Capital Cost Treatment	$0.00
NYCDEP Capital Cost Subsidy[1]	$0.00
Total Local Capital Cost	$9,738,675.00
NYSEFC Financing[2] (Annual)	$426,304.98
O&M (Annual)	$141,949.42
NYCDEP O&M Subsidy[3]	$50,960.42
Total Local O&M Cost	$90,989.00
Annual Cost Subtotal	$517,293.98
No. of Users	287
Annual Cost/ User w/o Grants	$1,802.42
Annual O&M Per User[4]	$317.03
Capital Cost Repayment	$1,485.38

Notes:

1. NYCDEP subsidy for tertiary treatment capital cost.
2. Based on 30-year loan at an annual interest rate of 2%.
3. NYCDEP subsidy for tertiary treatment O&M.
4. O&M Costs for primary and secondary treatment are not grant eligible.

Table 10: Alternative 2B Estimated Grant Requirements

Annual User Fee	Required Grant Funding
$400.00	$12,074,819
$500.00	$11,213,819
$600.00	$10,352,819
$700.00	$9,491,819
$800.00	$8,630,819
$900.00	$7,769,819
$1,000.00	$6,908,819

Table 11: Alternative 3A Funding Analysis

	Area 1
Capital Cost Sewer	$15,693,375.00
Capital Cost Treatment	$9,356,389.00
NYCDEP Capital Cost Subsidy[1]	$5,111,394.50
Total Local Capital Cost	$19,938,369.50
NYSEFC Financing[2] (Annual)	$872,790.83
O&M (Annual)	$160,284.58
NYCDEP O&M Subsidy[3]	$50,960.42
Total Local O&M Cost	$109,324.16
Annual Cost Subtotal	$982,114.99
No. of Users	287
Annual Cost/ User w/o Grants	$3,422.00
Annual O&M Per User[4]	$380.92
Capital Cost Repayment	$3,041.08

Notes:

1. NYCDEP subsidy for tertiary treatment capital cost.
2. Based on 30-year loan at an annual interest rate of 2%.
3. NYCDEP subsidy for tertiary treatment O&M.
4. O&M Costs for primary and secondary treatment are not grant eligible.

Table 12: Alternative 3A Estimated Grant Requirements

Annual User Fee	Required Grant Funding
$400.00	$26,019,450
$500.00	$25,158,450
$600.00	$24,297,450
$700.00	$23,436,450
$800.00	$22,575,450
$900.00	$21,714,450
$1,000.00	$20,853,450

Table 13: Alternative 3B Funding Analysis

	Area 1
Capital Cost Sewer	$10,008,675.00
Capital Cost Treatment	$9,356,389.00
NYCDEP Capital Cost Subsidy[1]	$5,111,394.50
Total Local Capital Cost	$14,253,669.50
NYSEFC Financing[2] (Annual)	$623,946.31
O&M (Annual)	$178,448.58
NYCDEP O&M Subsidy[3]	$50,960.42
Total Local O&M Cost	$127,488.16
Annual Cost Subtotal	$751,434.47
No. of Users	287
Annual Cost/ User w/o Grants	$2,618.24
Annual O&M Per User[4]	$444.21
Capital Cost Repayment	$2,174.03

Notes:

1. NYCDEP subsidy for tertiary treatment capital cost.
2. Based on 30-year loan at an annual interest rate of 2%.
3. NYCDEP subsidy for tertiary treatment O&M.
4. O&M Costs for primary and secondary treatment are not grant eligible.

Table 14: Alternative 3B Estimated Grant Requirements

Annual User Fee	Required Grant Funding
$500.00	$18,238,034
$600.00	$17,377,034
$700.00	$16,516,034
$800.00	$15,655,034
$900.00	$14,794,034
$1,000.00	$13,933,034

8. PERMITTING

Table 15 identifies potential permits and approvals which may be necessary to construct the proposed improvements. The applicability of these programs will be reviewed and confirmed as the design progresses.

Table 15: Potential Required Permits and Approvals

	Permit	Activity	Agency
	Federal		
1	Section 404 of the Clean Water Act	Discharge of dredged or fill material into waters of the United States (including non-isolated wetlands; delineation required for application). Nationwide Permits vs. Project-Specific Permit.	United States Army Corps of Engineers (USACE)
2	ESA (Section 7 of ESA)	Consultation process to identify Federally- or State-listed, proposed or candidate species and/or critical habitats that occur within the proposed project area. The presence of certain bat species requires time of year restrictions on tree-cutting.	United States Fish & Wildlife Services (USFWS), New York State Department of Environmental Conservation (NYSDEC)
	State		
3	Section 401 of the Clean Water Act (401 Water Quality Certification)	Certification is used to ensure that federal agencies issuing permits or carrying out direct actions, which may result in a discharge to waters of the United States do not violate New York State's water quality standards or impair designated uses.	NYSDEC
4	Protection of Waters (6 New York Codes, Rules and Regulations (NYCRR) Part 608; Article 15 of the Environmental Conservation Law (ECL))	Work within protected water bodies (bed and banks)	NYSDEC
5	Freshwater Wetlands (6 NYCRR Parts 663 – 664; Article 24 of the ECL)	Activities within State-regulated wetlands and buffer areas (mapped by NYSDEC).	NYSDEC
6	State Pollutant Discharge Elimination System (SPDES) General Permit for Storm Water Discharges from Construction Activity (GP-0-15-002)	Storm water discharges from construction phase activities disturbing one-acre or greater. Includes preparation and implementation of SWPPP and review of Stormwater Pollution Prevention Plan (SWPPP) by Municipal Separate Storm Sewer Systems (MS4s) local jurisdictional authorities.	NYSDEC MS4s
7	SPDES Permit for the Discharge of Wastewater (and Stormwater) (6 NYCRR Part 750)	Combined SPDES Permit (wastewater from treatment facility and site storm water discharges). See No. 32 below if wastewater from pre-treatment facility is discharged to local POTW.	NYSDEC
8	Wastewater Disposal System (Approval of Plans & Specifications)	Approval of wastewater facility designs.	NYSDEC (tie-in to public sewer may also require local approval)
9	Highway Work Permit	Work within highway rights-of-way (highway and utility improvements).	New York State Department of Transportation (NYSDOT) and/or local DOT
10	State Environmental Quality Review Act (Article 8 of the ECL; 6 NYCRR Part 617)	Environmental impact assessment. Preparation of Full Environmental Assessment Form (EAF). May also involve "Environmental Justice"-related public participation activities. Federal funding/permits may require National Environmental Policy Act (NEPA) review.	Lead & Involved Agencies
11	Federal & State Preservation Laws (36	Activities affecting historic, architectural, archaeological and cultural resources. Involved	NYS Parks, Recreation and Historic Preservation (NYSOPRHP) – Field

	Permit	Activity	Agency
	Code of Federal Regulations (CFR) 800; 9 NYCRR Part 428; Sections 3.09 and 14.09 of the NYS Parks, Recreation and Historic Preservation Law)	State agency determines need for consultation with SHPO. Consultation via SHPO's Cultural Resource Information System (CRIS). Initial consultation includes submission of project description and location, photographs, and documentation of prior disturbance and/or cultural resource investigation. Goal is to obtain "No Effect" letter from SHPO.	Services Bureau (State Historic Preservation Office (SHPO))
12	Floodplain Development Permit	Work within 100-year floodplain. Approval process is typically delegated to local floodplain administrator.	Municipality (typical)
	Regional		
13	New York City (NYC) Watershed Rules & Regulations	Consultation with NYCDEP regarding potential impacts on NYC watershed (NYC's water supply source); typically coordinated with SPDES storm water permitting processes.	New York City Department of Environmental Protection (NYCDEP)
	Local (Municipal)		
14	Water and Wastewater System Improvements Approval of Plans	Approval of water and wastewater infrastructure improvements and connections.	New York State Department of Health (NYSDOH), NYSDEC, Putnam County Health Department
15	Industrial Wastewater Discharge Permit (Local Sewer Use Ordinance & Federal Pretreatment Regulations)	Approval of additional sanitary and process waste discharges to POTW. Modification of existing permit. Also includes approval of pre-treatment program.	Municipality (only required for certain commercial businesses)
16	Building Permits	Building code compliance. It is assumed that the municipality will self-permit proposed public facilities (*i.e.,* code review and issuance of building permits).	Local Code Enforcement Office
17	Certificate of Occupancy	Approval to occupy building.	Local Code Enforcement Office

9. ENVIRONMENTAL REVIEW (SEQRA)

New York's State Environmental Quality Review Act (SEQRA) requires state and local government agencies to consider environmental impacts equally with social and economic factors during discretionary decision-making. This means these agencies must assess the environmental significance of all actions they have discretion to approve, fund or directly undertake. SEQRA requires the agencies to balance the environmental impacts with social and economic factors when deciding to approve or undertake an "Action".

As a first step in the environmental review process, the agency must classify the action as a Type I, Type II (Exempt) or Unlisted Action. The project exceeds regulatory thresholds, which would require the action to be classified as a Type I Action requiring a coordinated review with other local and State involved Agencies. Upon the completion of a 30-day (maximum) Lead Agency coordination process, a single entity will be designated as the SEQRA Lead Agency, which will be responsible for coordinating the SEQRA compliance for the project. The lead agency and the project sponsor should be identified early in the project.

Any action classified as Type I requires the project sponsor to complete Part 1 (Project & Setting) of a Full Environmental Assessment Form (EAF) (also known as the Long Form). The Lead Agency will subsequently complete Parts 2 (Identification of Potential Project Impacts) and 3 (Evaluation of the Magnitude & Importance of Project Impacts) of the EAF. The Lead Agency shall then decide on the significance of the impact on the environment, as a result of the project, based on the information provided in the EAF, as well as input from the Involved Agencies. The Lead Agency's issuance of a "Negative Declaration" indicates that the project will not result in a significant adverse impact on the environment; issuance of a "Positive Declaration" indicates that the project may result in one or more significant adverse impacts, which need to be evaluated in an Environmental

Impact Statement (EIS). The SEQRA process must be completed prior to local and state agency discretionary decision-making.

Included in the SEQRA process is determination of potential archeologically sensitive areas within the project boundary. State agencies making discretionary decisions must document compliance with the State Historic Preservation Act prior to making those decisions. Generally speaking, it is desirable to avoid any areas of archeological sensitivity, as completing field surveys to confirm presence of archeological features and addressing the same can be costly and result in substantial project delays. It is recommended that these areas be avoided to the extent practicable and that the proposed infrastructure be located in previously disturbed areas.

10. FUNDING STRATEGIES

A review of the prime alternatives presented in previous sections include the following types of projects:

- Construction of new collection and pumping facilities;
- Construction of new wastewater treatment facilities;
- Consolidation and management of individual septic systems and PCI wastewater treatment systems.

There are several funding sources/programs available for supporting the above listed wastewater improvement projects including:

- New York State Clean Water State Revolving Fund (CWSRF) administered by New York State Environmental Facilities Corporation (NYSEFC). Based on review of the NYSEFC program and recent census data, the project will be eligible for low interest financing but not hardship (0% interest) funding;
- NYS Department of Environmental Conservation (NYSDEC) /NYSEFC Wastewater Infrastructure Engineering Planning Grant Program (EPG);
- New York State Community Renewal Community Development Block Grant Program (CDBG);
- Local Government Efficiency (LGE);
- New York City Department of Environmental Protection (NYCDEP) Filtration Avoidance Program funding for tertiary treatment;
- New York State Water Infrastructure Improvement Act (WIIA) grant program administered by New York State Environmental Facilities Corporation (NYSEFC);
- New York State Water Quality Improvement Program (WQIP) grant opportunities administered by New York State Environmental Facilities Corporation (NYSEFC) and New York State Department of Environmental Conservation (NYSDEC); and
- New York State Energy Research and Development Authority (NYSERDA).

In addition, periodically federal dollars are made available for specific projects that have a significant impact on water quality. The above funds can be combined with local municipal dollars.

The Intended Use Plan (IUP) of the CWSRF includes scoring criteria that reflect a primary emphasis on water quality improvement and secondary emphasis on water quality protection. Projects addressing water quality problems in a NYSDEC approved watershed management plan receive additional points in the scoring system. The scoring system is based on:

- The existing conditions that cause or caused the problem;
- The value of the resource that will be improved or protected based on the classification of the receiving water;
- The severity of impairment to the desired usage of the affected water;

- The degree of improvement to the desired usage likely to result;
- Consistency with an approved management plan;
- An obligation or mandate for the project; and
- The financial impact on the applicant municipality.

Review of the above criteria indicates that the Putnam Lake related water quality improvement projects may score well.

11. FINDINGS & RECOMMENDATIONS

Implementation of a sewage collection and treatment program for the area surrounding Putnam Lake is recommended as a strategy to address the requirements of the TMDL and provide for reduction in nutrient loading into Putnam Lake thus reducing the potential for nuisance algal blooms. The following represents the primary findings and recommendations for consideration:

- Elimination of septic systems within Area 1 will reduce phosphorus loading to the lake by approximately 233.8 lbs/yr.
- Begin planning process for development of a sewer district to manage and fund the sewage facilities.
- Identify potential sites for a WWTP to serve Putnam Lake
- Expand public education programs on proper maintenance of septic systems.
- While implementation of sewage collection and treatment for Area 2 may not provide substantial benefits and be economically feasible, consideration should be given to protecting individual water wells and evaluating the potential of a regional drinking water system serving the Putnam Lake area.
- Begin dialogue with the NYCDEP regarding requirements for construction of a WWTP in the vicinity of Putnam Lake.
- Implementation of the recommended alternative (Gravity sewers and WWTP) is estimated to cost $25,100,000 and substantial grant funding will be required to bring the annual user fee down to a level that is considered acceptable to the public. Based on the evaluation presented herein, in addition to NYCDEP cost sharing, grants totaling $22,600,000 are required to result in a user fee of $800/yr, considered by many as a reasonable cost for service. Reducing the annual user fee to $500/yr will require approximately $25,158,000 in grants from sources outside of NYCDEP subsidies.
- Based on the selected collection system approach, complete a preliminary design to further the process of defining the scope of the project. The preliminary design should include field and desktop investigations necessary to gain a better understanding of the project scope.
- Implement stormwater improvements along lake shoreline concurrently with collection sewer system.

Appendix A – Flow and Loading Calculations

Flow Estimate - Putnam Lake Service Area

AREA 1

Within 50 feet of the lake

Property Code	Quantity	Flow Rate (GPD)	Total Flow (GPD)	Description
210	6	260	1560	One-family year round residence
311	2	0	0	Vacant
			1,560	***Gallons per Day***

Outside 50 feet and within 250 feet of the lake

Property Code	Quantity	Flow Rate (GPD)	Total Flow (GPD)	Description
210	205	260	53300	One-family year round residence
215	1	520	520	One-family year round residence with accessory apartment
220	7	520	3640	Two-family year round residence
230	1	780	780	Three-family year round residence
260	4	260	1040	Season Residences
280	3	520	1560	Residentail - Multi-Purpose/Multi-Structure
311	39	0	0	Vacant
312	3	0	0	Residential Land Including a Small Improvement (not used for living accommodations)
421	1	1400	1400	Restaurants
483	1	260	260	Converted Residence
			62,500	***Gallons per Day***

Outside 250 feet and within the service area

Property Code	Quantity	Flow Rate (GPD)	Total Flow (GPD)	Description
210	52	260	13520	One-family year round residence
215	1	520	520	One-family year round residence with accessory apartment
220	1	520	520	Two-family year round residence
260	1	260	260	Season Residences
311	11	0	0	Vacant
			14,820	***Gallons per Day***

TOTAL FLOW	**78,880**	***Gallons per Day***

AREA 2

Outide Area 1 limits and within Area 2 limits

Property Code	Quantity	Flow Rate (GPD)	Total Flow (GPD)	Description
210	1350	260	351000	One-family year round residence
215		520	0	One-family year round residence with accessory apartment
220		520	0	Two-family year round residence
260		260	0	Season Residences
281		520	0	Multiple Residences
311		0	0	Vacant
330		0	0	Vacant Land Located in Commercial Areas
432		2000	0	Service and Gas Stations
652		100	0	Office Building (Gov't)
			351,000	***Gallons per Day***

TOTAL AREA 2 FLOW	**351,000**	***Gallons per Day***

Appendix B – Collection System Technology Fact Sheets

Fact Sheet C1

Performance & Cost of
Decentralized Unit Processes

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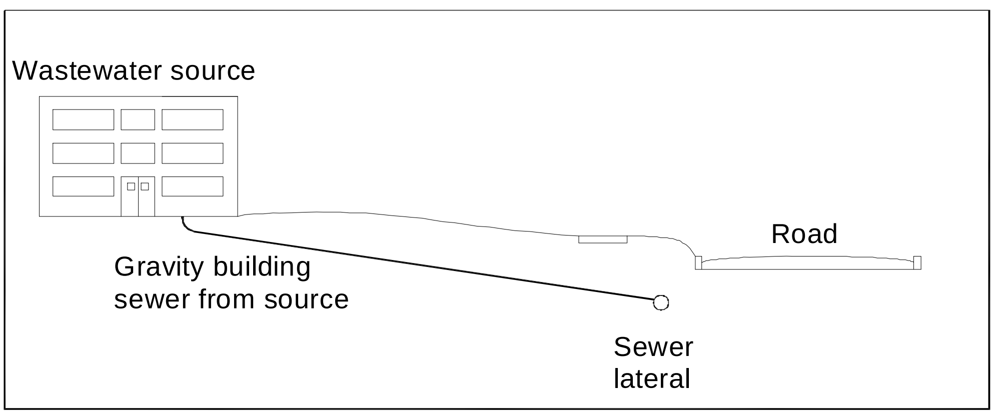
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

GRAVITY SEWER SYSTEMS

What is a Gravity Sewer System?

A gravity sewer system is used to collect wastewater from multiple sources and convey the wastewater by gravity to a central location. Wastewater from each source is conveyed through a building sewer to a collection line. Collection (sewer) lines are typically eight-inch or larger diameter pipe. Pipe diameters increase with increasing volume of water being transported. Pipes are installed with sufficient slope to keep the suspended solids moving through the system. If gravity flow is not possible throughout the system, lift stations (pumps) are employed. Lift stations are installed at lower elevations of the network in order to pump the sewage up to another gravity line, to convey wastewater over hills, and/or up to a treatment facility. Manholes are installed at regular intervals to provide maintenance access to collection lines.



Properly designed and constructed gravity sewers are a viable collection option for urban areas, but can be expensive for small communities. In its purest form (i.e., uniform slope from service connections to treatment components) gravity is an inexpensive means to convey water. However, the topography is rarely conducive to purely gravity flow, and lift stations must often be included. The cost of gravity sewers may be prohibitive unless there is sufficient population density to justify the installation.

Compatibility with the Community Vision

Selecting any wastewater collection option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Installation costs for gravity sewers are significant. The community must have a good vision of its future to ensure that the sewer is properly sized. If the capacity for long-term use is built into the design, the system can accommodate the anticipated growth for the next 50 or more years. Realistically, over-building the sewer means that the current users will bear the cost of that future use.

Once installed, the components of a gravity sewer are minimally visible. Manhole lids and lift stations will be evident at the surface but are not obtrusive. Odors may be associated with access points and odor control may be necessary. The potential loss of trees or other local charm during installation must be considered because of the need for broad and deep cuts during excavation. For this reason, it is a common practice to install sewers under paved roads resulting in severe and lengthy community disruption.

When considering options for a Management Program, the community must decide whether on-lot costs for installation, maintenance and repair will be borne directly by the landowner or spread across the community.

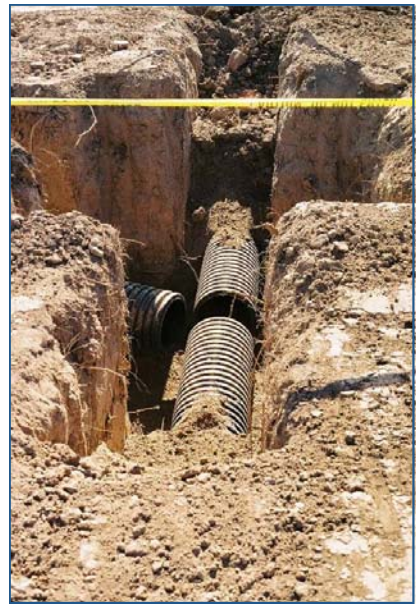
Land Area Requirements

The land area required for a gravity sewer system is a function of the area required for installation of piping. Horizontal Directional Drilling (HDD) boring can minimize the need for large, deep trenches that disrupt existing utilities, landscaping, roads and driveways. Additional land will be required for each lift station. Lift stations can be fairly compact, but sufficient space is needed to install a wet-well, pumps and controls, and the electric service. Manholes do not require additional land, but they must be accessible.

Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation of Gravity Sewer Systems

Gravity sewers must be installed so that the pipeline has a sufficient slope to prevent suspended solids from settling. If the community has relatively flat topography, the sewers will get progressively deeper (and more expensive) along their length. In rolling terrain, the sewer lines are installed to move wastewater from the



top of hills to the valley bottom. If the slope is sufficient to transport sewage, then the pipeline need not get deeper with length.

Installation of pipe, manholes, lift stations, building connections, junction chambers or boxes and terminal cleanouts requires large amounts of excavation. This results in disruption of utilities, temporary road closures and detours. Overall, there is a significant amount of disturbance over a long duration associated with the installation of traditional gravity sewer. However, once installed, most gravity components are either below ground or flush with finish grade.

Most jurisdictions set the minimum sewer pipe diameter at eight inches. As more wastewater is collected and carried by a given pipeline, the pipe diameter must increase. Although larger pipes require wider excavations, pipe depth is the primary driver for excavation costs. The pipes are sized to carry the peak flow rate that would be expected from a given service area. The peak flow rate is often calculated as four times the daily flow rate plus an estimation of the amount of groundwater infiltration that will occur.

Licensing requirements for personnel who install gravity sewer systems varies with jurisdictions, but typically they must be licensed as a public utility contractor by the state or region in which they work.

Operation and Maintenance

Effective operation of a conventional gravity sewer begins with proper design and construction. Regular inspection of system components is critical. Leaky pipe connections are a potential source of groundwater and stormwater infiltration. This extra water must be treated. Infiltration must be controlled, or the capacity of the treatment system will be exceeded during wet weather conditions. Modern construction materials have reduced the infiltration issue. However, tree roots, shifting soils, and poor pipe connections (especially to manholes) are still major problems and gravity sewers commonly are designed to carry up to 40% clear water.

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

Proper maintenance includes periodic line repairs and inspection, cleaning out blockages, and repairing areas where significant infiltration is occurring. On an approximate 10-year rotation, each sewer line should be inspected via a down-the-hole closed-circuit camera so that areas needing repair can be identified. Service providers must have the knowledge and skills related to sewer cleaning technologies and the associated safety precautions. Operators must have proper training and may be subject to certification requirements depending upon jurisdiction.

Costs for Gravity Sewer Systems

Installation costs include five major factors: Pipe diameter, excavation depth, total length, restoration, and labor. Larger flows require larger diameter pipe which is more expensive. Deeper, excavation may be required to provide sufficient slope or overcome soil and site issues. The extent of site disturbance and nature of the restoration required affect costs. Roads, sidewalks, and yards will be highly disturbed during installation. Existing utilities may have to be moved or worked around. Horizontal Directional Drilling (HDD) can be used in some cases to minimize time and money during actual installation because utility replacement, road closings, detours and expensive dewatering and restoration costs associated with trenching are substantially reduced. While each of these factors is system-specific, the purchase and installation of gravity sewer components could easily range from $100 to $200 and more per foot of main line service.

Larger flows require larger diameter pipe for gravity sewer systems. Deeper (and more expensive) excavation is also needed but the cost may be offset by the fact that pumps and lift stations are only required in areas with inadequate slope for gravity flow.

Gravity sewers in cluster or small community systems do not include septic tanks for primary treatment on each lot. Thus, the central treatment facility must provide primary treatment (liquid-solid separation).

If gravity flow can be maintained throughout the system, there is no electrical requirement. If lift stations are needed, energy costs vary according to the number, specifications and size of the pumps used. The required number of lift stations is dependent on the topography of the community. Engineers will evaluate the location and strive to use gravity flow to collect wastewater and direct it to points of lower elevation. At these low points in the system, lift

For other Collection system options, see:

Factsheet C2: Pressure sewers

Factsheet C3: Effluent sewers

Factsheet C4: Vacuum sewers

stations followed by short pressure mains can be installed to move the wastewater back to a higher elevation. The energy cost will depend on the daily wastewater volume and the distance (both horizontally and vertically) that wastewater has to be transferred.

Tables 1-3 are cost estimations for the materials, installation, and maintenance of conventional gravity sewer. These costs assume an estimated average distance between wastewater sources of 200 feet, relatively flat topography, 20% overhead and profit to the contractor, and no sales tax on materials. Engineering fees and other professional services are not included in the costs. Communities may choose to have lot owners pay for materials and installation of on-lot components. Tables 1 and 2 assume that the lot-owner will build and maintain the system components that are installed on-lot and that the utility will build and maintain the collection network. Table 3 assumes that a utility will build the collection network and the on-lot components; however, the lot-owner would still be responsible for the building sewer maintenance. For the purpose of estimating costs, Tables 2 and 3 provide three example gravity sewer systems developed and priced for flows ranging from 5,000 to 50,000 gpd. The costs given in this document are for comparison purposes only. The actual cost for a system will vary tremendously depending on site conditions and local economics. The costs for the systems below include piping, manholes, installation, and maintenance. These examples do not include a lift station.

Table 1. Estimated cost to the lot owner if utility does not cover the materials and installation of on-lot components.

On-Lot Cost	Cost Issues	Costs
Materials and Installation	Install building sewer and connect to sewer main	$1,800 - $2,700
Annual electricity	No energy unless source needs lift pump to sewer main	-0-
Annual O&M	Annualized cost to clean building sewer	$16 - $24 per yr

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 2. Estimated cost of materials and installation to build the collection network not including the on-lot components.

Network Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$210,000 - $315,000	$419,000 - $629,000	$2,182,000 - $3,273,000
Annual O&M	$6,400 - $9,600	$12,800 - $19,200	$65,000 - $97,000
Annual electricity	Lift stations are the primary energy demand for gravity collection systems		

Table 3. Estimated cost of materials and installation for utility to install both the collection network and on-lot components

	Wastewater Volume (gpd)		
Network and On-Lot Cost	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$234,000 - $352,000	$469,000 - $703,000	$2,429,000 - $3,644,000
Annual O&M	$6,400 - $9,600	$12,800 - $19,200	$65,000 - $97,000
Total Cost per lot	$11,700 - $17,600	$11,700 - $17,600	$12,000 - $18,000
60 year life cycle cost – present value (2009 dollars)	$435,000 - $653,000	$871,000 - $1,306,000	$4,472,000 - $6,708,000

References

1. Crites, R. and G. Tchobangolous. 1998. Small and Decentralized Wastewater Management Systems. WCB/McGraw Hill Company, Boston, MA.
2. Lenning, D., T. Banathy, D. Gustafson, B.J. Lesikar, S. Wecker, D. Wright. 2005. Technology Overview Text. *In* (D.L. Lindbo and N.E. Deal eds.) Model Decentralized Wastewater Practitioner Curriculum. National Decentralized Water Resources Capacity Development Project. North Carolina State University, Raleigh, NC.

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Fact Sheet C2

Performance & Cost of
Decentralized Unit Processes

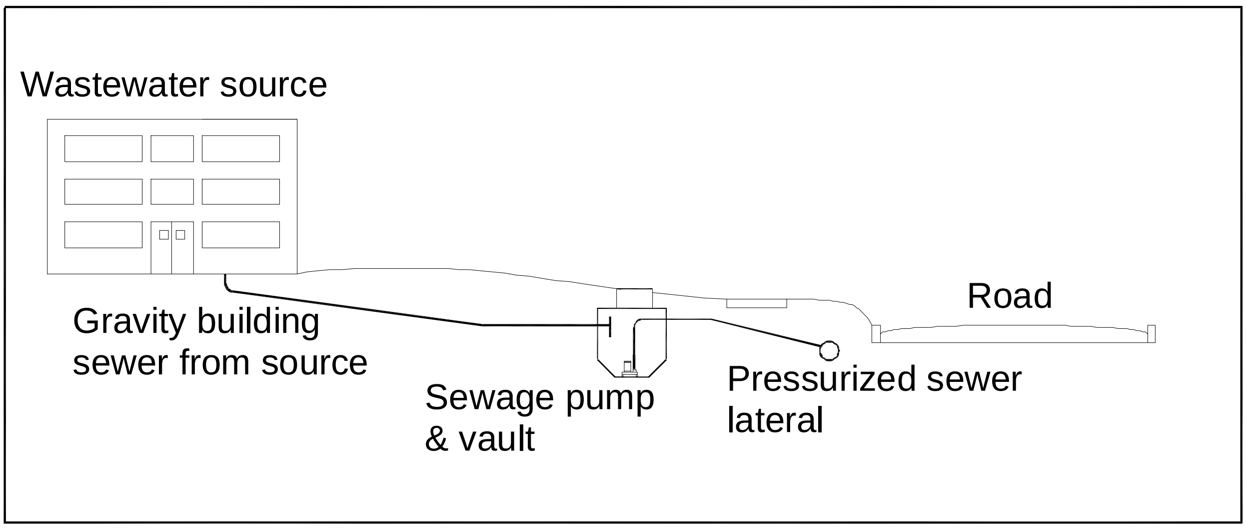
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

PRESSURE SEWER SYSTEMS

Pressure Sewers and Their Use

Pressure sewers are a means of collecting wastewater from multiple sources and delivering the wastewater to an existing collection sewer, and/or to a local or regional treatment facility. Pressurized sewers are not dependent on gravity to move wastewater; and thus there is less concern about the local topography. A typical arrangement is for each connection (or small cluster of connections) to have a basin that receives wastewater. When the basin fills to a set point, a pump within the basin injects wastewater into the sewer. This transfer of wastewater pressurizes the sewer. As various pumps along the length of the sewer inject sewage into the line, the wastewater is progressively moved to the treatment facility.

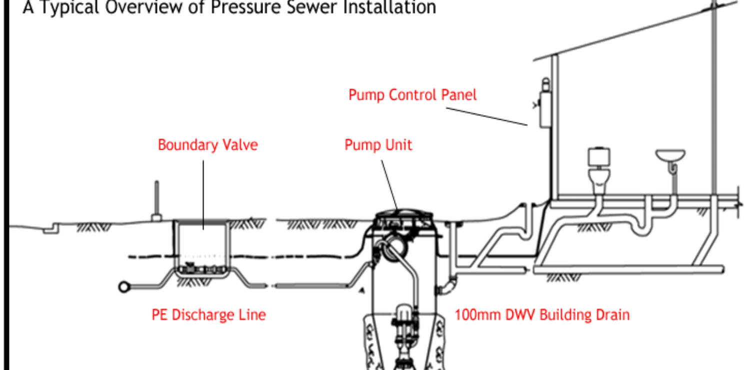


The principle advantage of pressure sewers is the ability to sewer areas with undulating terrain, rocky soil conditions and high groundwater tables. Because lines are pressurized, sewer pipe installation can follow the surface topography and remain at a relatively constant depth below the soil surface. As compared to gravity sewers, pressure sewers have smaller diameter pipes. Shallower placement, lack of manholes or lift stations and longer sections of smaller diameter piping equates to a less expensive and less obtrusive installation. This is especially true for road crossings. Horizontal directional drilling (HDD) allows small diameter systems to be installed without disrupting traffic, opening trenches across paved roadways, or moving existing utilities. The piping can also be located along the shoulder instead of the middle of the paved surface.

A community has four basic options when choosing a means of collecting wastewater. This factsheet will focus on solids-handling pumps as a means of taking all the wastewater from a source. The other options are gravity, effluent and vacuum sewers. These three options are discussed in other Fact Sheets in this series. Often, collection technologies can be combined within the same network to provide the best solution for a small community. The most common hybrid includes solids -handling pumps in combination with gravity sewers.

For more information, see:
Factsheet C1: Gravity sewers
Factsheet C3: Effluent sewers
Factsheet C4: Vacuum sewers

The typical installation includes a pump basin at each home or business. This basin provides some wastewater storage. When a designated volume of wastewater has been produced, the pump engages and transfers the sewage into the sewer line. A pump basin for an individual residence typically has a capacity to store about 30 to 70 gallons between pumping events. Each pump basin contains floats or pressure sensors that detect the water depth in the basin. When the predetermined depth is achieved, the pump activates and continues to remove wastewater until a low-water level is reached. Backflow into the pump basin is prevented by a check valve that is integral to the pump. Most pumps operate on 240VAC, which is easily available from the home or business that is being serviced by the pressure sewer system



A Typical Overview of Pressure Sewer Installation
Source: pressuresewerservices.com

As a comparison, conventional gravity sewers use a few (but large) lift stations to offset excessive excavations that are often required to achieve minimum slope or to move sewage over hills. Pressure sewers have small pump stations at each connection. There are advantages and disadvantages to each method. For a small community, the primary advantage of pressure sewers is the reduced cost of sewer pipe installation. Small communities have smaller population densities; and therefore, there are fewer people per square mile of service to bear the cost of the system.

Compatibility with Community Vision

Pressure sewer systems are expandable. A community may desire to only provide sewer to the existing population. As new neighborhoods are established, it might be reasonable to connect them to the collection system on an as-needed basis if there is sufficient available capacity. A better solution might be to create a new cluster or neighborhood system to service them. In contrast, conventional gravity sewage collection systems are generally built to accommodate maximum growth that may or may not occur and are difficult to finance through the current users.

Selecting any wastewater collection option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

A management issue that was addressed early in the history of pressure sewers was that of pump ownership. Some communities chose to put the burden of ownership on the property owners and homeowner associations with disastrous results. Today, pressure sewer systems are wholly maintained by a local utility (either private or public). In most cases, the connection fee includes the cost (including installation) of all the on-lot components. The operation and maintenance costs are amortized into the monthly sewer bill. This level of utility ownership helps to ensure consistent and sustainable performance.

Land Area Requirements for Pressure Sewers

The on-lot land area required for a pressure sewer system is a function of the area required for installation of the pump basin and the piping that connects it to the sewer main. A single-family home will typically have a basin with 30 to 70 gallon capacity installed below ground with a tank lid 18 to 30 inches in diameter that allows access to the pump and controls. Institutional, commercial or industrial facilities (schools, restaurants, supermarkets, apartment complexes factories, etc.) will have larger basins and may require multiple pumps.

Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation of Pressure Sewers

Pressure sewer systems can typically be installed with trenchers and small excavators. Trenches for small diameter pipes can often be dug and restored in the same day. The collection network is comprised of mostly two-inch to six-inch diameter plastic pipe. Occasional clean-outs, air release valves at high points, isolation valves, and other components must also be installed within the network. Large, deep trenches are rarely needed with pressure sewers. The shallower trench width and depth results in minimum surface disturbance, and quicker restoration. Directional boring can reduce highway closures and other urban disruptions and save both time and money. The small diameter piping is flexible and can be routed around obstacles. Pressure sewer mains can often be located on the shoulder of the road.

A licensed electrician must run a circuit from the owner's electrical breaker box out to a sub-breaker box on the exterior of the house or business located near the pump. Once the pump basin has been set, the electrician connects the pump and controls to the owner's electric service.

Licensing requirements for personnel who install pressure sewer systems vary, but they must typically be licensed as a public utility contractor by the state or region in which they work.

Operation and Maintenance for Pressure Sewers

Solids-handling pumps are used under harsh conditions. Corrosive gases and moisture in pump basins will eventually penetrate seals and bushings, resulting in pump failure. These small pumps are designed to be rebuilt, which is more economical than replacing the pump. They are rugged devices, but they are only intended to move the food wastes, fecal solids and the associated paper products, not plastic or metallic objects. When considering the nature of their management program, the community must decide who is financially responsible for pump repair and replacement costs.

Regular service is important for all system components to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of components used.

Pressurized sewer systems transmit the entire wastewater flow, thus providing the possibility of oils and fats congealing in the pipe network. System cleaning is not normally required for properly designed systems, but if cleanouts are installed in the network, cleaning procedures are facilitated. It is rare that mainline clearing is required. On-lot service line cleaning can be minimized by requiring all commercial food preparation businesses to install grease interceptors before the grinder pump to remove excessive fats, oils and grease (FOGs).

Because the system is pressurized, it is inherently watertight and groundwater infiltration should not be a problem. However, the pump basins must be periodically inspected to ensure that surface water and groundwater are not entering the system through the building sewer. Illegal connections from downspouts, foundation drains and similar sources must be identified and excluded. Avoiding excessive water inflow prevents overloading the pump and wastewater treatment facility.

Costs for Pressure Sewers

The cost of a pressure sewer system can be divided into two major components: The on-lot cost and the collection network cost. On-lot costs include the pump, basin, controls, building sewer, lateral piping, electrical service, and installation. The collection network includes all the piping in the utility easements that directs the sewage to the treatment facility. A small community may consider several means of funding a pressure sewer system. One means is to secure sufficient funding to install the collection network and install the on-lot components. Federal funding and low interest loans are sometimes available to fund these projects. A second means is for the utility to build the collection network and charge each connection for the on-lot cost. Depending on the style of pump and basin selected by the managing utility, on-lot costs are estimated to be $4,800 to $7,200 for an existing single-family home. Typical solids-handling pumps will use less than 1kW-hr of power per day and the electrical cost would be about 50 dollars per year depending upon local electrical rates.

Using many low power-consuming pumps reduces installation cost as compared to a conventional gravity system that may require one or more large-capacity lift stations. Further, it allows more flexibility in choosing locations for and routes to treatment facilities. Larger capacity pumps require three-phase electricity, and this may not be available in remote areas within small communities.

Tables 1-3 are cost estimations for the materials, installation, and maintenance of pressure sewers. These costs assume an estimated average distance between wastewater sources of 200 feet, relatively flat topography, 20% overhead and profit to the contractor, and no sales tax on materials. Engineering fees and other professional services are not included in the costs. Communities may choose to have the lot owners pay for the materials and installation of the on-lot components. Tables 1 and 2 assume that the lot-owner will pay for the system components that are installed on-lot and that the utility will build and maintain the collection network. Table 3 assumes that a utility will build and maintain the collection network and the on-lot components. Tables 2-3 also provide cost estimates for the collection network for three different sizes of communities.

Table 1. Estimated cost to the lot owner if utility does not cover the materials and installation of on-lot components.

On-Lot Cost	Cost Issues	Costs
Materials and Installation	Pump, pump basin, pump controls, excavation, and connection to network	$4,800 - $7,200
Annual electrical	Estimated at 1 kW-hr per day (paid by the lot owner)	$44 - $66 per yr
Annual O&M	Annualized major pump overhaul every 10 years	$120 - $240 per yr

Table 2. Estimated cost of materials and installation to build the collection network not including the on-lot components.

Network Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$33,000 – $49,000	$65,000 - $98,000	$344,000 - $516,000
Annual O&M	$6,400 - $9,600	$13,000 - $19,000	$56,000 - $84,000
Annual electricity	No network energy cost unless lift stations are needed		

Table 3. Estimated cost of materials and installation for utility to install both the collection network and on-lot components

Network and On-Lot Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$132,000 - $199,000	$265,000 – $397,000	$1,341,000 - $2,012,000
Annual O&M	$11,000 - $16,000	$21,000 - $32,000	$106,000 - $159,000
60 year life cycle cost present value (2009 dollars)	$243,000 - $365,000	$811,000 - $1,216,000	$4,707,000 - $6,106,000

References

1. Crites, R. and G. Tchobangolous. 1998. Small and Decentralized Wastewater Management Systems. WCB/McGraw Hill Company, Boston, MA.

2. Lenning, D., T. Banathy, D. Gustafson, B.J. Lesikar, S. Wecker, D. Wright. 2005. Technology Overview Text. In (D.L. Lindbo and N.E. Deal eds.) Model Decentralized Wastewater Practitioner Curriculum. National Decentralized Water Resources Capacity Development Project. North Carolina State University, Raleigh, NC.

3. U.S. EPA. 1991. Alternative Wastewater Collection Systems. Office of Water, Technology Transfer Manual, EPA/625/1-91/024, Washington, DC.

4. Water Environment Federation. 2008. Alternative Sewer Systems, Manual of Practice FD-12, Second Edition. WEFPress, Alexandria, Virginia.

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Fact Sheet C4

Performance & Cost of
Decentralized Unit Processes

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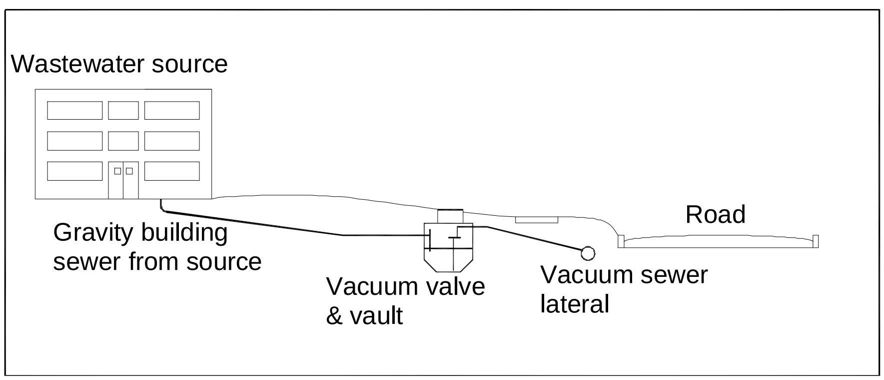
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

VACUUM SEWER SYSTEMS

What is a Vacuum Sewer System?

A vacuum sewer system is used to collect wastewater from multiple sources and convey it to a central location where it can be treated. As the name suggests, a vacuum (negative pressure) is drawn on the collection system. When a service line is opened to atmospheric pressure, wastewater and air are pulled into the system. The wastewater that enters with the air forms a “plug” in the line, and air pressure pushes the wastes toward the vacuum station. This differential pressure comes from a central vacuum station. Vacuum sewers can take advantage of available slope in the terrain, but are most economical in flat terrain. Vacuum sewers have a limited capacity to pull water uphill. The maximum expected lift is between 30 and 40 feet. Vacuum sewers are designed to be watertight since any air leakage into the system reduces the available vacuum.



Vacuum sewers do not require a septic tank at each wastewater source. All of the domestic wastewater and waste constituents are collected and transported by this collection method. Sewage from one or more homes or businesses flows by gravity into a small valve pit. A service line connects the valve pit to the main vacuum line. Each valve pit is fitted with a pneumatic pressure-controlled vacuum valve. This valve automatically opens after a predetermined volume of sewage has entered the sump. The difference in pressure between the valve pit (at atmospheric pressure) and the main vacuum line (under negative pressure) pulls wastewater and air through the service line. The amount of air that enters with the sewage is controlled by the length of time that the valve remains open. When the vacuum valves closes, atmospheric pressure is restored inside the valve pit. The sewage travels in the vacuum main as far as its initial energy allows, eventually coming to rest. As other valve pits in the network open, more sewage and air enters the system. Each input of energy moves the sewage toward the central vacuum station. The violent action in the pipe tends to break up the larger suspended solids during transport.

Like gravity sewers, vacuum sewers are installed on a slope toward the vacuum station. Periodic upturns or 'lifts' are installed in the vacuum line to return it to a shallower elevation. Overall, the lines are installed in a saw-tooth or vertical zigzag configuration so that the vacuum created at the central station is maintained throughout the network.

Pipes for vacuum sewers are installed in a saw-tooth or zigzag configuration to maintain a vacuum throughout the system.

Vacuum stations may include two or more vacuum pumps and a large vacuum tank. The pumps run on 3 to 5 minute cycles or long enough to create adequate vacuum in the system. The tank at the vacuum station holds the vacuum on the collection network and prevents the vacuum pumps from having to operate continuously. As valve pits are activated, there is a loss in the vacuum (negative pressure) in the system. When the negative pressure reaches a threshold level, the vacuum pumps re-engage to pull more vacuum. When sewage reaches the vacuum station, it flows into a collection tank. Sewage pumps are then used to convey the collected sewage through a force main to the treatment component. As with vacuum pumps, multiple sewage pumps are used to provide a backup in case of pump failure.

How is a vacuum sewer system used?

Because of the cost of a vacuum station, vacuum sewers are most appropriate for communities with 200 or more connections. However, in some circumstances, as few as 75 to 100 connections can be feasible. A typical vacuum station can pull from a 15,000-foot radius and serve about 1,200 connections. The general conditions conducive to the use of vacuum sewers include: unstable soil; flat terrain; rolling land with many small elevation changes; high water table; rocky conditions; new and denser urban development in rural areas; and sensitive ecosystems. Established communities that have historical neighborhoods with narrow streets and limited access can also effectively utilize vacuum sewers because the small diameter pipe and shallow excavation takes less area to install.

It is generally not advisable to use this technology in areas with low population and low population densities. Because the movement of wastewater depends upon the differential pressure created when valves open, long pipe runs with few connections can result in poor performance. The same problem is seen when connections are installed but are not yet in use. As a solution for this, temporary valve pits installed at strategic locations can be fitted with timer-controlled valves that allow air to enter even though wastewater is not being generated by the source.

Compatibility with Community Vision

Vacuum sewers are scalable. The system can be zoned (divided into sections) to accommodate the rate of build-out as well as to facilitate maintenance. Access locations to valve boxes and cleanouts (if required) will be evident at the soil surface but are not obtrusive. Higher population densities are well-accommodated with this option. If maintaining local charm while improving infrastructure is a priority, communities can preserve assets such as historical areas or heritage trees.

Selecting any wastewater collection system option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Vacuum stations are centrally located within their service area. Usually only a single vacuum pump station is required rather than multiple lift stations found in conventional gravity and pressure networks. This frees up land, reduces energy costs and reduces some operational costs. No manholes are necessary and odors and risks associated with hydrogen sulfide gas are significantly reduced because the system is sealed and detention times are short. Vacuum stations are quite large and expensive compared to effluent or pressure sewer system components, but can be designed to blend into the landscape.

A particular problem with vacuum sewers is the noise and odor created by the central vacuum station. As air is drawn through the system, sewer gases are extracted. A good solution to this problem is to pass the exhaust air through a bio-filter, which can absorb much of the gas and reduce odors.

Land Area Requirements for Vacuum Sewers

The land area required for a vacuum sewer system is a function of the area required for installation of the valve pit, the vacuum network and the central vacuum station. Valve pits for single-family residences typically have a 10-gallon capacity and occupy a relatively small area. Tanks for multiple connections or commercial facilities may require larger area (depending upon daily wastewater volume) and thus occupy more space. The area disturbed during excavation of the valve pit will be larger than the dimensions of the valve pit and piping. Horizontal directional drilling (HDD) helps to eliminate the need for large, deep trenches that disrupt existing utilities, landscaping, roads and driveways with installation of conventional sewers. Vacuum collector system pipes are typically only four inches in diameter and thus a trencher or small excavator is often used for excavation.

Note that additional land area will be required for the treatment and dispersal components selected by the community.

Construction and Installation

A valve pit is located at each wastewater source or cluster of sources. Valve pits are typically prefabricated and ready to install. They must be properly oriented and set at the correct elevation to allow for gravity flow from the source. Anti-flotation measures are required in areas with high water tables. An air intake must be installed on the building sewer downstream of the plumbing house trap to ensure adequate venting for the valves. On-lot excavation is typically accomplished using a backhoe. The service line from the valve pit to the vacuum main can also be installed with a backhoe, but this often results in over-excavation. Using a chain trencher instead will result in less property disruption and require less site restoration. Proper bedding and backfilling techniques must be used to avoid settling over time. Service lines that connect valve pits to vacuum mains must be separated from potable water lines to avoid cross-contamination. Vacuum mains must also be separated from other utilities.

A valve pit is installed at each wastewater source.

Piping for most vacuum sewer mains is O-ring gasketed PVC pipe, so solvent welding is not required. It is normally buried about 36 inches deep, but depths of 4 to 5 feet are not uncommon in colder climates. The small diameter piping used for vacuum sewers is flexible and can be routed horizontally around obstacles. Vacuum sewer mains can often be located outside of and adjacent to the edge of pavement. Division valves must be installed at branch/main intersections, both sides of a bridge and road crossings, both sides of areas of unstable soils, and at periodic intervals on long routs. Some local codes still require cleanouts at specified intervals.

Vacuum testing of both valve pits and mains is performed over the course of the installation and upon completion of the entire system. Overall, there is a significant amount of disturbance associated with the installation, but not nearly as much as with deeper conventional gravity sewers. Once installed, most components are either below ground or flush with finish grade. Licensing requirements for personnel who install vacuum sewer systems vary, but they must typically be licensed as a public utility contractor by the state or region in which they work.

Maintenance Requirements

Regular service is important for all systems to ensure best long term performance to protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

Effective operation of a vacuum sewer system begins with proper design and construction, but regular inspection of system components by staff or remote monitoring is critical. Vacuum stations can be remotely monitored via telemetry or visited daily to record pump running hours and lubricant levels. A variety of tasks must be performed on a regular weekly, monthly or semi-annual basis. These tasks include changing oil and oil filters on vacuum pumps; removing and cleaning inlet filters on vacuum pumps; testing all alarm systems; checking/adjusting motor couplings, and; checking operation of vacuum station shut-off and isolation valves. The operator must conduct external leak tests on all vacuum valves and check/adjust valve timing. Preventive maintenance includes annual visual inspections of valve pits and valves, as well as rebuilding controllers every 3 to 6 years and rebuilding valves every 8 to 12 years.

As with all mechanical devices, vacuum valves will fail with some frequency. When a valve sticks open the whole system has reduced vacuum. Locating the stuck valve may be time consuming and require two persons. When a valve fails to open, wastewater will backup in the valve pit (and potentially into the source). These failures are easier to locate but can result in an on-lot backup or the discharge of sewage.

Good recordkeeping of system performance and costs is critical. The advent of web-based telemetry has greatly improved the operator's ability to monitor system status. Vacuum sewer system operators must be capable, dependable and knowledgeable. About 2.5 to 3 hours per year per service connection is a good estimate for time commitment. Training and certification is advisable and will typically be required by the local jurisdiction.

Costs for Vacuum Sewers

Long term costs include vacuum station utilities, clerical costs, transportation, supplies/spare parts as well as miscellaneous expenses such as insurance and accounting. Additional costs will be incurred for equipment reconditioning and replacement by trained service providers. Vacuum station equipment has a life expectancy between 15 and 25 years, but there are annual costs associated with reconditioning that offset replacement. Vacuum valves must typically be rebuilt every 8 to 12 years and their controllers require rebuilding every 4 to 6 years.

The vacuum pumps and sewage pumps are the only elements of the vacuum sewer system that require electricity. It is reported that monthly power costs range from $1.66 to $3.34 per month per connection. Larger stations typically have lower power consumption per connection. Each vacuum station must have a standby electric generator to keep the system operating during electric power failures. Part of the energy cost must include the fuel needed to operate this backup power source.

To justify the cost of a vacuum system, 150 to 200 connections are needed.

Because 150 to 200 connections are needed before the cost of the vacuum station can be justified, this fact sheet will only investigate the cost of a 200-home community. The vacuum station given in this example is capable of handling more connections and so costs would come down if the full capacity of the station is used. Thus, at full capacity, the cost per connection would decrease. The costs given in this document are for comparison purposes only. The actual cost for a system will vary significantly depending on site conditions and local economics. The costs for the systems below include valve pits and controller valves at all connections, system piping, vacuum pumps, sewage pumps and all additional appurtenances. The extent of site disturbance and nature of the restoration required will also affect costs.

Table 1 provides cost estimation for the materials, installation, and maintenance of a vacuum sewer system. These costs assume that the wastewater sources average about 200 feet apart, the topography is relatively flat, the contractor would charge 20% for overhead and profit, and there are no sales tax on materials. Engineering fees and other professional services are not included in the costs. With a vacuum sewer system, it is assumed that one vacuum pit will serve at least two sources. Thus, for a 200-connection community, there are only 100 vacuum pits. This example assumes that the utility will install and maintain the vacuum pits. Each lot owner must still to pay for installation of a building sewer to the nearest vacuum pit.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost of materials and installation to build the vacuum collection network, including the on-lot components.

Cost Factor	Building Sewer to Vacuum Pit	Collection Network Cost including 100 Vacuum Pits
Materials and Installation	$1,800 - $2,700	$1,869,000 - $2,804,000
Annual electricity	-0-	$9,500 - $14,000
Annual O&M	$16 - $24 per yr	$82,000 - $123,000
60 year life cycle cost – present value (2009 dollars)		$4,775,000 - $7,162,000

References

1. Crites, R. and G. Tchobangolous. 1998. Small and Decentralized Wastewater Management Systems. WCB/McGraw Hill Company, Boston, MA.
2. Lenning, D., T. Banathy, D. Gustafson, B.J. Lesikar, S. Wecker, D. Wright. 2005. Technology Overview Text. In (D.L. Lindbo and N.E. Deal eds.) Model Decentralized Wastewater Practitioner Curriculum. National Decentralized Water Resources Capacity Development Project. North Carolina State University, Raleigh, NC.
3. Naret, R. 2009. Vacuum Sewers – Operation and Maintenance and System Management Guidelines. Course Number C-8029, PDHengineer.com, http://www.pdhengineer.com/courses/en/C-4029.pd , retrieved on line, Jan 20, 2010.
4. Naret, R. 2009. Vacuum Sewers – Design and Install Guidelines. Course Number C-8015, http://www.pdhengineer.com/courses/en/C-8015.pd , retrieved on line Jan 22, 2010.
5. U.S. EPA. 1991. Alternative Wastewater Collection Systems. Office of Water, Technology Transfer Manual, EPA/625/1-91/024, Washington, DC.

6. Water Environment Federation. 2008. Alternative Sewer Systems, Manual of Practice FD-12, Second Edition. WEFPress, Alexandria, Virginia.

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Fact Sheet C3

Performance & Cost of
Decentralized Unit Processes

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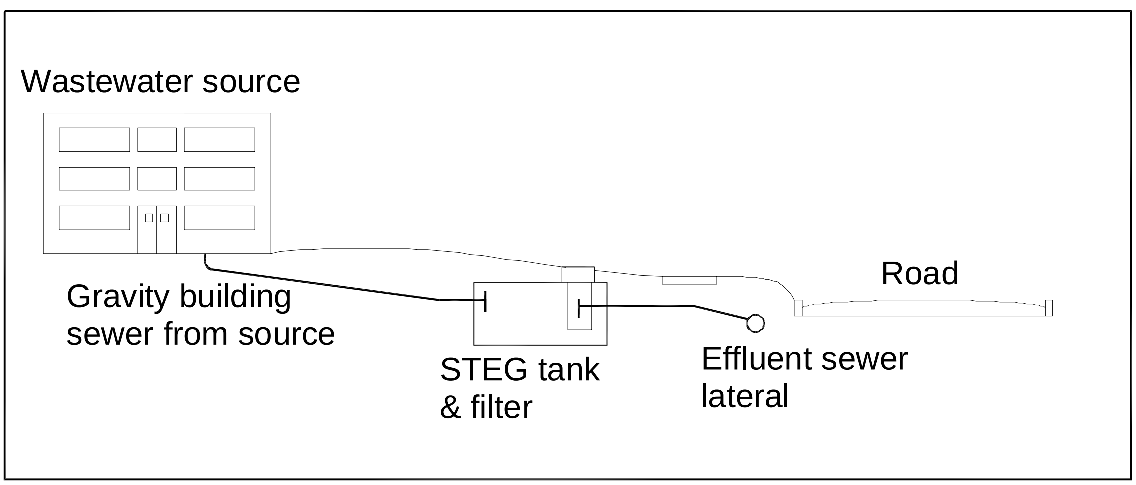
DECENTRALIZED WASTEWATER SYSTEMS

COLLECTION SERIES

EFFLUENT SEWER SYSTEMS

Effluent Sewer Systems and Their Use

The term effluent is commonly is defined as *liquid flowing out of a component or device after undergoing treatment.* An effluent sewer carries wastewater that has undergone liquid/solid separation or primary treatment. Septic Tank Effluent Pump and Septic Tank Effluent Gravity sewers (commonly referred to as STEP or STEG) use on-lot septic tanks to provide liquid/solid separation. Raw sewage flows from the house or business to a watertight underground tank (septic tank). The clarified effluent then moves into the collection system using either a pump (STEP) or gravity (STEG). As a collection system, effluent sewers are used to convey effluent from multiple sources to a central location where it can be treated. STEP and STEG configurations can be combined within a given system.



In a STEG system, each source or group of sources has a watertight septic tank with an effluent screen and an access riser. Effluent flows out of the tank and into a collection sewer by gravity. The collection sewer is typically plastic pipe about 4 to 8 inches in diameter. The piping from the tank to the collection line includes an accessible cleanout.

In a STEP system each wastewater source or group of sources is again fitted with a watertight septic tank. However, in this case, an effluent pump (typically capable of pumping 3 or more gallons per minute) is installed in the outlet end of the septic tank or in a separate pump tank or vault. The pump injects the clarified effluent into a pressure sewer system. As each STEP pump in the collection systems operates, effluent is progressively moved toward the wastewater treatment facility.

In a STEP system, an effluent pump is installed within a pump vault in the outlet end of a septic tank.

STEG systems operate totally via gravity owing to a higher elevation relative to the treatment facility. STEP systems operate via pressure owing to a lower elevation or complex topography relative to the treatment facility. Thus, a typical effluent sewer is a mixture of STEP and STEG depending upon the location of the service lines.

Properly designed and constructed STEP/STEG systems are a viable wastewater collection option for individual residences, cluster developments as well as small communities. All styles of collection systems require significant excavation since a pipe network must be installed to connect all the wastewater sources within the designated service area. With STEP/STEG systems, the width and depth of the required excavation for piping is greatly reduced relative to conventional gravity sewers. Because a STEP system is pressurized it does not depend on a slope to move effluent. If topography allows gravity flow, then pumps are not needed at each location. While STEG systems flow by gravity, because solids have been removed in the septic tank, the pipe slope requirements are reduced or eliminated. When compared to conventional gravity sewers, STEP/ STEG systems have lower installation expense and result in less community disruption.

Solids remain in the on-lot tank in STEP/STEG systems, resulting in the collection of a lower-strength effluent. Costs of downstream treatment components may thus be reduced. A STEP/STEG community must have a plan for the pumping and management of the residuals held in the tanks. See the Fact Sheet on Liquid-solid Separation for information on expected reduction of organic strength and solids that can be expected from septic tanks. Information on septage handling can be found in the Fact Sheet on Residuals Management.

For more information, see:

Factsheet T1: Liquid-Solid Separation

Factsheet T8: Residuals Management

Compatibility with the Community Vision

Selecting any wastewater collection option must be considered within the context of a community's broad, long-range plans for land use. Changes in development patterns, population density, livability, and delivery of services will occur as a result of the choices made and these must all be taken into account.

Once installed, the components of a STEP/STEG system are minimally visible. Cleanouts are installed within the collection network, but are not obtrusive. Odors may be associated with access points (primarily air-relief valves at high points in the system) and odor control may be necessary. Odor control is usually achieved by venting to soil beds which can be blended into local landscapes. The potential loss of trees or similar obstacles during installation is reduced because STEP/STEG systems can be built with flexible plastic pipe that can be routed around obstacles.

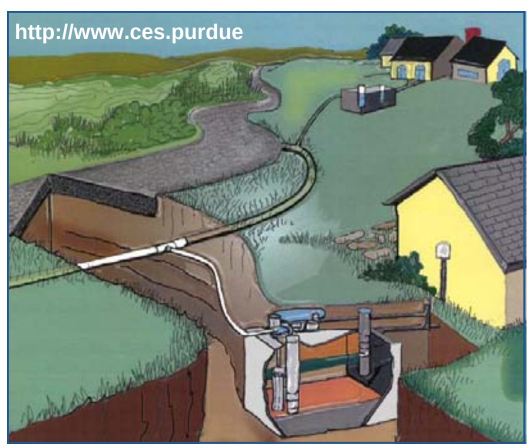
As with any collection system, the use of STEP/STEG can result in (or facilitate) increased population density, but these options have far less capacity to drive community growth than central sewers. Because effluent is collected and conveyed to a central location for treatment, the need for on-lot dispersal systems is eliminated. If a STEP/STEG system is being installed in community that already has septic tanks and drainfields, it is strongly recommended to abandon those components and install a new building sewer, a new tank and on-lot piping from the source to the collector in the street. STEP/STEG tanks and building sewers must be watertight so that stormwater and groundwater does not enter the system.

When considering options for a Management Program, the community must decide whether individual on-lot costs for installation, maintenance and repair will be borne directly by the landowner or amortized into the monthly sewer bill.

Land Area Requirements for STEP/STEG Systems

The land area required for a STEP/STEG system is a function of the area required for installation of the septic tank and piping. Tanks for single-family residences have a typical capacity of 1,000 to 1,500 gallons and occupy an area of about 4 feet by 8 feet. Tanks for multiple connections or commercial facilities may require larger capacity (depending upon daily wastewater volume) and thus occupy more space. The area disturbed during excavation will be larger than the dimensions of the tank.

Note that additional land area will be required for the treatment and dispersal components selected by the community.



Construction and Installation

STEP/STEG systems are built in two stages: (1) the collection network and (2) the on-lot components that provide the liquid/ solid separation. The major on-lot component is the watertight tank. When possible, tanks are placed such that wastewater can flow from the source by gravity. Tanks are bedded with crushed gravel to provide level and stable support. For STEP tanks, an effluent pump is placed in a screened pump vault installed in the discharge end of the tank. A control panel is installed on the side of a building that is in close proximity to the tank. If included, cleanouts and air release devices (and associated access enclosures) are installed in the outlet piping. STEG tanks also have an effluent screen that prevents excess solids from leaving the tank. Both types of tanks must have access risers that come to the soil surface. The risers should have tamper-resistance fasteners to prevent unauthorized entry into the tanks.

Like all other alternative collection systems STEP collection network require minimum excavation. The required depth of the pipeline is minimal and can generally follow the terrain. The collection network is installed either through trenching or Horizontal Directional Drilling (HDD). HDD reduces or eliminates the need for large, deep trenches that disrupt existing utilities, landscaping, roads and driveways. STEG systems must maintain an overall slope toward a lift station or treatment facility. However, since there are no heavy sewage solids to be transported, slope can be significantly reduced or eliminated. In all cases, slope and sewage velocity requirements are less than a conventional gravity sewer. Many small communities have both STEP and STEG within the same cluster of sources.

Licensing requirements for personnel who install STEP/STEG systems varies, but they must typically be licensed by the state or region in which they work.

Maintenance Requirements

Effective operation of a STEP/STEG system begins with proper design and construction, but regular inspection of system components is critical. Leaky tanks or pipe connections are a potential source of groundwater infiltration that can overload the system's capacity. Tank residuals must be pumped out on a requisite basis (ideally, when solids are 25 to 33% of the liquid depth of the tank) and effluent screens (in STEG tanks) must be inspected annually and cleaned as needed. Service providers must be properly trained and have knowledge and skills related to effluent screens, electrical connections and controls and other sewer appurtenance technologies. They must know and observe the associated safety precautions. Operators must have proper training and may be subject to certification requirements depending upon jurisdiction.

Regular service is important for all systems to ensure best long term performance protect public health and the environment. This also protects the investment. Frequency of operation and maintenance is dependent upon wastewater volume, relative risk to public health and the environment as well as the complexity of any pretreatment components used prior to dispersal.

If pumps in STEP configurations are installed with quick-disconnect fittings, maintenance is facilitated and replacement costs are reduced. System components should be standardized as much as possible to facilitate easy maintenance. Some wastewater sources may need more powerful pumps if they are located at lower elevations or at distant sites. When these special pumps fail, they must be replaced with pumps of similar capacity.

Typically, preventive maintenance visits are required for the on-lot components as well as the communal collection components. Historically, STEP unit service callouts are overwhelmingly related to electrical/control issues. With STEG systems, effluent screens should be checked annually and cleaned as needed.

Costs for STEP/STEG Systems

The cost of a STEP/STEG system can be divided into two major components: The on-lot cost and the collection network cost. On-lot installation costs include the pump, tank, controls, building sewer, and electrical service. A STEG system would not have the pump, controls and electric service costs. The initial on-lot costs are usually paid by the lot owner. The installer must follow the guidelines established by the utility for the selection and placement of components. Depending on the style of pump and tank selected by the utility, and the STEP pressure requirements needed to inject sewage into the network, the on-lot costs are estimated to be $3,500 to $5,000 for a single-family home. The electrical cost would be about 30 dollars per year.

The cost of the collection network is variable and will be driven by the primary nature of the system. For a STEP system, it will likely consist of mostly two to four-inch diameter plastic pipe. If the system is primarily a STEG, the pipe sizes are more likely to be four to six-inch plastic pipe. Included within the network are occasional clean-outs, air release valves at high points, isolation valves that allow the operator to shut down sections of the system, and other components. Installation costs must account for rocky soils, wet soils, utility easements, site restoration, and labor.

Tables 1-3 are cost estimations for the materials, installation, and maintenance of STEP/STEG effluent sewers. These costs assume an estimated average distance between wastewater sources of 200 feet, relatively flat topography, 20% overhead and profit to the contractor, and no sales tax on materials. Engineering fees and other professional services are not included in the costs. Communities may choose to have the lot owners pay for the materials and installation of the on-lot components. Tables 1 and 2 assume that the lot-owner will pay for the system components that are installed on-lot and that the utility will build and maintain the collection network. For this example, Table 1 assumes that all connections are STEP. A STEG would not include the cost of the pump. Table 3 assumes that a utility will build and maintain the collection network and the on-lot components.

The costs provided in this document are for comparison purposes only. The actual costs will vary significantly depending on site conditions and local economics. For localized cost investigations, consult the Cost Estimation Tool associated with these materials.

Table 1. Estimated cost to the lot owner for if utility does not cover the materials and installation of on-lot STEP components.

On-Lot Cost	Cost Issues	Costs
Materials and Installation	Pump, septic tank, controls, excavation, and connection to network	$3,000 - $5,000
Energy	Estimated at one-half kW-hr per day	$24 - $36 per yr
O&M	Annualized pump replacement and septage removal every 10 years	$56 - $84 per yr

Table 2. Estimated cost of materials and installation to build the STEP collection network, not including the on-lot components.

Network Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$32,000 - $48,000	$65,000 - $97,000	$340,000 - $510,000
O&M	$6,000 - $9,000	$12,000 - $18,000	$61,000 - $91,000
Energy	No network electric cost unless lift stations are needed		

Table 3. Estimated cost of materials and installation for utility to install both the STEP collection network and on-lot components

Network and On-Lot Cost	Wastewater Volume (gpd)		
	5,000 gpd or 20 homes	10,000 gpd or 40 homes	50,000 gpd or 200 homes
Materials and Installation	$88,000 - $133,000	$177,000 - $265,000	$901,000 - $1,352,000
O&M	$6,000 - $9,000	$12,000 - $18,000	$60,000 - $90,000
60 year life cycle cost – present value (2009 dollars)	$243,000 - $365,000	$487,000 - $730,000	$2,452,000 - $3,678,000

References

1. Crites, R. and G. Tchobangolous. 1998. Small and Decentralized Wastewater Management Systems. WCB/McGraw Hill Company, Boston, MA.
2. Lenning, D., T. Banathy, D. Gustafson, B.J. Lesikar, S. Wecker, D. Wright. 2005. Technology Overview Text. In (D.L. Lindbo and N.E. Deal eds.) Model Decentralized Wastewater Practitioner Curriculum. National Decentralized Water Resources Capacity Development Project. North Carolina State University, Raleigh, NC.

3. U.S. EPA. 1991. Alternative Wastewater Collection Systems. Office of Water, Technology Transfer Manual, EPA/625/1-91/024, Washington, DC.

4. Water Environment Federation. 2008. Alternative Sewer Systems, Manual of Practice FD-12, Second Edition. WEFPress, Alexandria, Virginia.

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Wastewater Management Fact Sheet

Membrane Bioreactors

INTRODUCTION

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

APPLICABILITY

For new installations, the use of MBR systems allows for higher wastewater flow or improved treatment performance in a smaller space than a conventional design, i.e., a facility using secondary clarifiers and sand filters. Historically, membranes have been used for smaller-flow systems due to the high capital cost of the equipment and high operation and maintenance (O&M) costs. Today however, they are receiving increased use in larger systems. MBR systems are also well suited for some industrial and commercial applications. The high-quality effluent produced by MBRs makes them particularly applicable to reuse applications and for surface water discharge applications requiring extensive nutrient (nitrogen and phosphorus) removal.

ADVANTAGES AND DISADVANTAGES

The advantages of MBR systems over conventional biological systems include better effluent quality, smaller space requirements, and ease of automation. Specifically, MBRs operate at higher volumetric loading rates which result in lower hydraulic retention times. The low retention times mean that less space is required compared to a conventional system. MBRs have often been operated with longer solids residence times (SRTs), which results in lower sludge production; but this is not a requirement, and more conventional SRTs have been used (Crawford et al. 2000). The effluent from MBRs contains low concentrations of bacteria, total suspended solids (TSS), biochemical oxygen demand (BOD), and phosphorus. This facilitates high-level disinfection. Effluents are readily discharged to surface streams or can be sold for reuse, such as irrigtion.

The primary disadvantage of MBR systems is the typically higher capital and operating costs than conventional systems for the same throughput. O&M costs include membrane cleaning and fouling control, and eventual membrane replacement. Energy costs are also higher because of the need for air scouring to control bacterial growth on the membranes. In addition, the waste sludge from such a system might have a low settling rate, resulting in the need for chemicals to produce biosolids acceptable for disposal (Hermanowicz et al. 2006). Fleischer et al. 2005 have demonstrated that waste sludges from MBRs can be processed using standard technologies used for activated sludge processes.

Membrane Filtration

Membrane filtration involves the flow of water-containing pollutants across a membrane. Water permeates through the membrane into a separate channel for recovery (Figure 1). Because of the cross-flow movement of water and the waste constituents, materials left behind do not accumulate at the membrane surface but are carried out of the system for later recovery or disposal. The water passing through the membrane is called the *permeate*, while the water with the more-concentrated materials is called the *concentrate* or *retentate*.

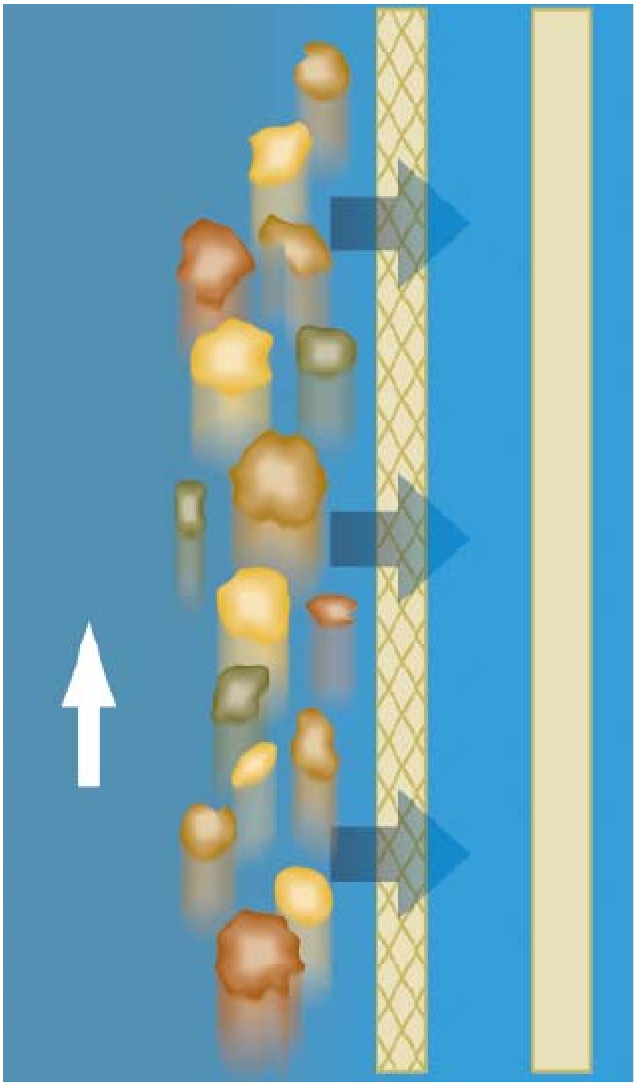

Figure 1. Membrane filtration process (Image from Siemens/U.S. Filter)

Membranes are constructed of cellulose or other polymer material, with a maximum pore size set during the manufacturing process. The requirement is that the membranes prevent passage of particles the size of microorganisms, or about 1 micron (0.001 millimeters), so that they remain in the system. This means that MBR systems are good for removing solid material, but the removal of dissolved wastewater components must be facilitated by using additional treatment steps.

Membranes can be configured in a number of ways. For MBR applications, the two configurations most often used are hollow fibers grouped in bundles, as shown in Figure 2, or as flat plates. The hollow fiber bundles are connected by manifolds in units that are designed for easy changing and servicing.

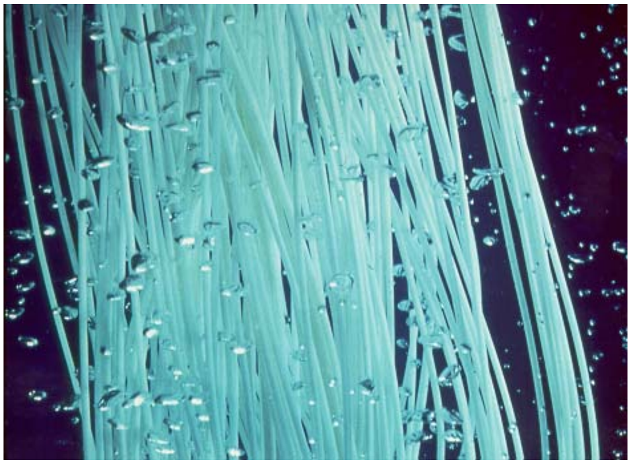

Figure 2. Hollow-fiber membranes (Image from GE/Zenon)

Design Considerations

Designers of MBR systems require only basic information about the wastewater characteristics, (e.g., influent characteristics, effluent requirements, flow data) to design an MBR system. Depending on effluent requirements, certain supplementary options can be included with the MBR system. For example, chemical addition (at various places in the treatment chain, including: before the primary settling tank; before the secondary settling tank [clarifier]; and before the MBR or final filters) for phosphorus removal can be included in an MBR system if needed to achieve low phosphorus concentrations in the effluent.

MBR systems historically have been used for small-scale treatment applications when portions of the treatment system were shut down and the wastewater routed around (or bypassed) during maintenance periods.

However, MBR systems are now often used in full-treatment applications. In these instances, it is recommended that the installation include one additional membrane tank/unit beyond what the design would nominally call for. This “N plus 1” concept is a blend between conventional activated sludge and membrane process design. It is especially important to consider both operations and maintenance requirements when selecting the number of units for MBRs. The inclusion of an extra unit gives operators flexibility and ensures that sufficient operating capacity will be available (Wallis-Lage et al. 2006). For example, bioreactor sizing is often limited by oxygen transfer, rather than the volume required to achieve the required SRT—a factor that significantly affects bioreactor numbers and sizing (Crawford et al. 2000).

Although MBR systems provide operational flexibility with respect to flow rates, as well as the ability to readily add or subtract units as conditions dictate, that flexibility has limits. Membranes typically require that the water surface be maintained above a minimum elevation so that the membranes remain wet during operation. Throughput limitations are dictated by the physical properties of the membrane, and the result is that peak design flows should be no more than 1.5 to 2 times the average design flow. If peak flows exceed that limit, either additional membranes are needed simply to process the peak flow, or equalization should be included in the overall design. The equalization is done by including a separate basin (external equalization) or by maintaining water in the aeration and membrane tanks at depths higher than those required and then removing that water to accommodate higher flows when necessary (internal equalization).

DESIGN FEATURES

Pretreatment

To reduce the chances of membrane damage, wastewater should undergo a high level of debris removal prior to the MBR. Primary treatment is often provided in larger installations, although not in most small to medium sized installations, and is not a requirement. In addition, all MBR systems require 1- to 3-mm-cutoff fine screens immediately before the membranes, depending on the MBR manufacturer. These screens require frequent cleaning. Alternatives for reducing the amount of material reaching the screens include using two stages of screening and locating the screens after primary settling.

Membrane Location

MBR systems are configured with the mem-

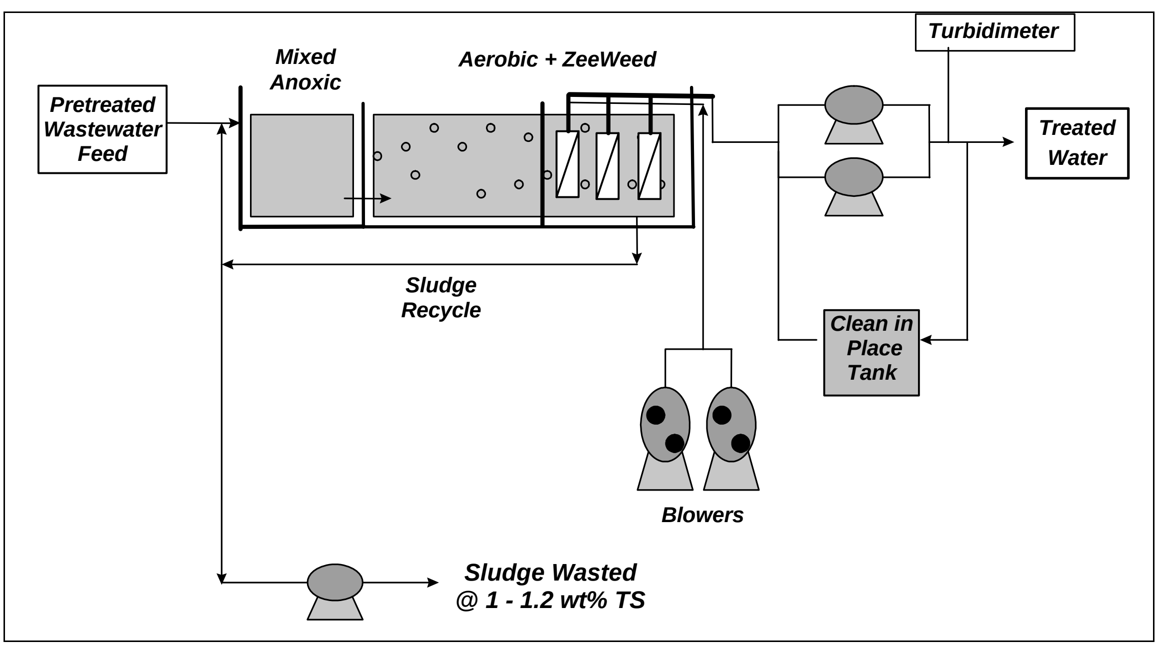

Figure 3. Immersed membrane system configuration (Image from GE/Zenon)

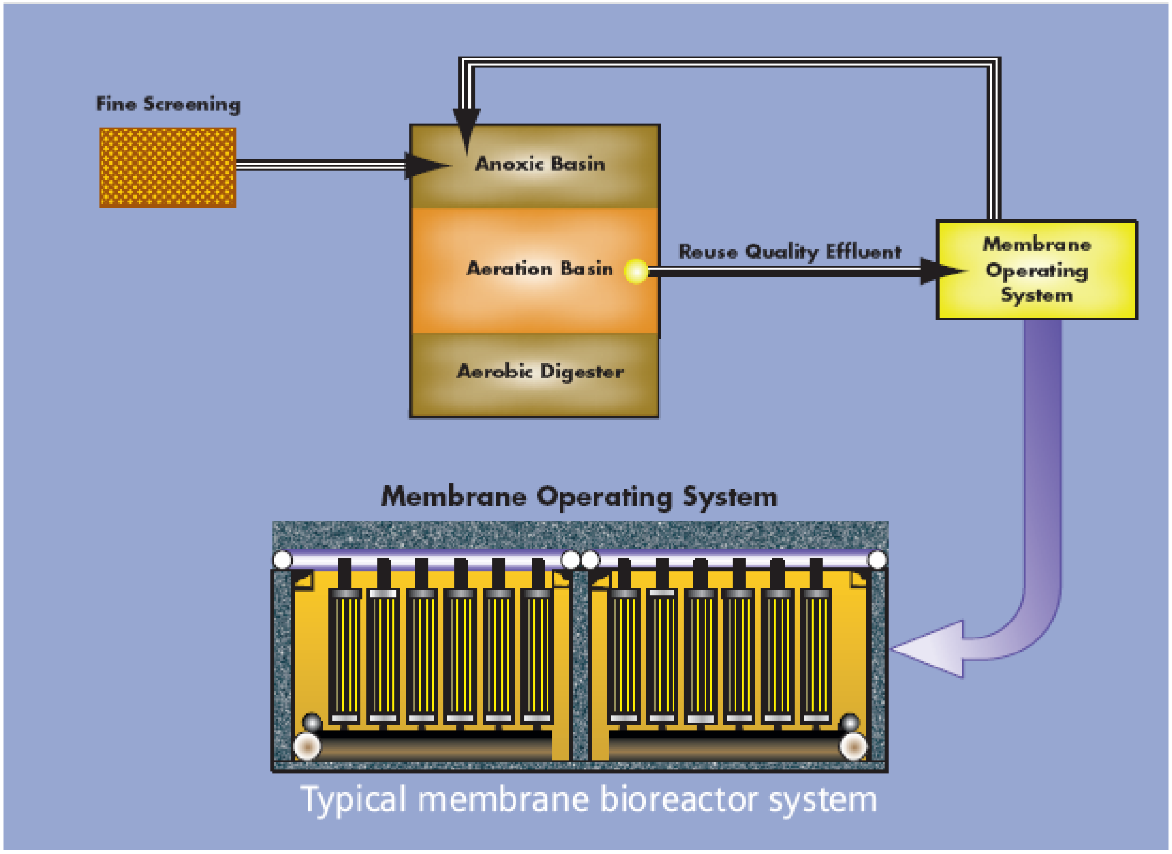

Figure 4. External membrane system configuration (Image from Siemens/U.S. Filter)

branes actually immersed in the biological reactor or, as an alternative, in a separate vessel through which mixed liquor from the biological reactor is circulated. The former configuration is shown in Figure 3; the latter, in Figure 4.

Membrane Configuration

MBR manufacturers employ membranes in two basic configurations: hollow fiber bundles and plate membranes. Siemens/U.S.Filter's Memjet and Memcor systems, GE/Zenon's ZeeWeed and ZenoGem systems, and GE/Ionics' system use hollow-fiber, tubular membranes configured in bundles. A number of bundles are connected by manifolds into units that can be readily changed for maintenance or replacement. The other configuration, such as those provided by Kubota/Enviroquip, employ membranes in a flat-plate configuration, again with manifolds to allow a number of membranes to be connected in readily changed units. Screening requirements for both systems differ: hollow-fiber membranes typically require 1- to 2-mm screening, while plate membranes require 2- to 3-mm screening (Wallis-Lage et al. 2006).

System Operation

All MBR systems require some degree of pumping to force the water flowing through the membrane. While other membrane systems use a pressurized system to push the water through the membranes, the major systems used in MBRs draw a vacuum through the membranes so that the water outside is at ambient pressure. The advantage of the vacuum is that it is gentler to the membranes; the advantage of the pressure is that throughput can be controlled. All systems also include techniques for continually cleaning the system to maintain membrane life and keep the system operational for as long as possible. All the principal membrane systems used in MBRs use an air scour technique to reduce buildup of material on the membranes. This is done by blowing air around the membranes out of the manifolds. The GE/Zenon systems use air scour, as well as a back-pulsing technique, in which permeate is occasionally pumped back into the membranes to keep the pores cleared out. Back-pulsing is typically done on a timer, with the time of pulsing accounting for 1 to 5 percent of the total operating time.

Downstream Treatment

The permeate from an MBR has low levels of suspended solids, meaning the levels of bacteria, BOD, nitrogen, and phosphorus are also low. Disinfection is easy and might not be required, depending on permit requirements..

The solids retained by the membrane are recycled to the biological reactor and build up in the system. As in conventional biological systems, periodic sludge wasting eliminates sludge buildup and controls the SRT within the MBR system. The waste sludge from MBRs goes through standard solids-handling technologies for thickening, dewatering, and ultimate disposal. Hermanowicz et al. (2006) reported a decreased ability to settle in waste MBR sludges due to increased amounts of colloidal-size particles and filamentous bacteria. Chemical addition increased the ability of the sludges to settle. As more MBR facilities are built and operated, a more definitive understanding of the characteristics of the resulting biosolids will be achieved. However, experience to date indicates that conventional biosolids processing unit operations are also applicable to the waste sludge from MBRs.

Membrane Care

The key to the cost-effectiveness of an MBR system is membrane life. If membrane life is curtailed such that frequent replacement is required, costs will significantly increase. Membrane life can be increased in the following ways:

- Good screening of larger solids before the membranes to protect the membranes from physical damage.

- Throughput rates that are not excessive, i.e., that do not push the system to the limits of the design. Such rates reduce the amount of material that is forced into the membrane and thereby reduce the amount that has to be removed by cleaners or that will cause eventual membrane deterioration.

- Regular use of mild cleaners. Cleaning solutions most often used with MBRs include regular bleach (sodium) and citric acid. The cleaning should be in accord with manufacturer-recommended maintenance protocols.

Membrane Guarantees

The length of the guarantee provided by the membrane system provider is also important in determining the cost-effectiveness of the system. For municipal wastewater treatment, longer guarantees might be more readily available compared to those available for industrial systems. Zenon offers a 10-year guarantee; others range from 3 to 5 years. Some guarantees include cost prorating if replacement is needed after a certain service time. Guarantees are typically negotiated during the purchasing process. Some manufacturers' guarantees are tied directly to screen size: longer membrane warranties are granted when smaller screens are used (Wallis-Lage et al. 2006). Appropriate membrane life guarantees can be secured using appropriate membrane procurement strategies (Crawford et al. 2002).

SYSTEM PERFORMANCE

Siemens/U.S. Filter Systems

Siemens/U.S.Filter offers MBR systems under the Memcor and Memjet brands. Data provided by U.S. Filter for its Calls Creek (Georgia) facility are summarized below. The system, as Calls Creek retrofitted it, is shown in Figure 5. In essence, the membrane filters were used to replace secondary clarifiers downstream of an Orbal oxidation ditch. The system includes a fine screen (2-mm cutoff) for inert solids removal just before the membranes.

The facility has an average flow of 0.35 million gallons per day (mgd) and a design flow of 0.67 mgd. The system has 2 modules, each containing 400 units, and each unit consists of a cassette with manifold-connected membranes. As shown in Table 1, removal of BOD, TSS, and ammonia-nitrogen is excellent; BOD and TSS in the effluent are around the detection limit. Phosphorus is also removed well in the system, and the effluent

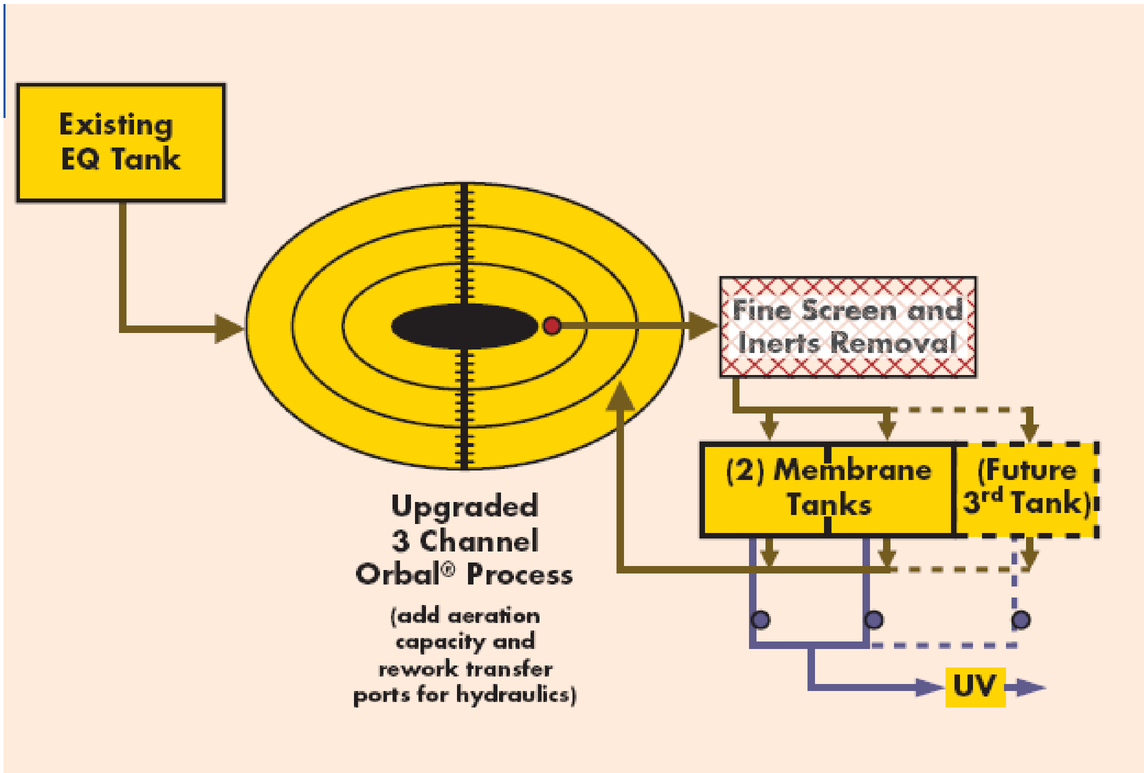

Figure 5. Calls Creek flow diagram (courtesy of Siemens/U.S. Filter)

Table 1.
Calls Creek results 2005

Parameter	Influent	Effluent		
	Average	Average	Max Month	Min Month
Flow (mgd)	0.35	--	0.44	0.26
BOD (mg/L)	145	1	1	1
TSS (mg/L)	248	1	1	1
Ammonia-N (mg/L)	14.8	0.21	0.72	0.10
P (mg/L)	0.88	0.28	0.55	0.12
Fecal coliforms (#/100 mL)	--	14.2	20	0
Turbidity (NTU)	--	0.30	1.31	0.01

has very low turbidity. The effluent has consistently met discharge limits.

Zenon Systems

General Electric/Zenon provides systems under the ZenoGem and ZeeWeed brands. The ZeeWeed brand refers to the membrane, while ZenoGem is the process that uses ZeeWeed.

Performance data for two installed systems are shown below.

Cauley Creek, Georgia. The Cauley Creek facility in Fulton County, Georgia, is a 5-mgd wastewater reclamation plant. The system includes biological phosphorus removal, mixed liquor surface wasting, and sludge thickening using a ZeeWeed system to minimize the required volume of the aerobic digester, according to information provided by GE. Ultraviolet disinfection is employed to meet regulatory limits. Table 2 shows that the removal for all parame-

Table 2.
Cauley Creek, Georgia, system performance

Parameter	Influent	Effluent		
	Average	Average	Max Month	Min Month
Flow (mgd)	4.27	--	4.66	3.72
BOD (mg/L)	182	2.0	2.0	2.0
COD (mg/L)	398	12	22	5
TSS (mg/L)	174	3.2	5	3
TKN (mg/L)	33.0	1.9	2.9	1.4
Ammonia-N (mg/L)	24.8	0.21	0.29	0.10
TP (mg/L)	5.0	0.1	0.13	0.06
Fecal coliforms (#/100 mL)	--	2	2	2
NO3-N (mg/L)	--	2.8		

ters is over 90 percent. The effluent meets all permit limits, and is reused for irrigation and lawn watering.

Traverse City, Michigan. The Traverse City Wastewater Treatment Plant (WWTP) went through an upgrade to increase plant capacity and produce a higher-quality effluent, all within the facility's existing plant footprint (Crawford et al. 2005). With the ZeeWeed system, the facility was able to achieve those goals. As of 2006, the plant is the largest-capacity MBR facility in North America. It has a design average annual flow of 7.1 mgd, maximum monthly flow of 8.5 mgd, and peak hourly flow of 17 mgd. The membrane system consists of a 450,000-gallon tank with eight compartments of equal size. Secondary sludge is distributed evenly to the compartments. Blowers for air scouring, as well as permeate and back-pulse pumps, are housed in a nearby building.

Table 3 presents a summary of plant results over a 12-month period. The facility provides excellent removal of BOD, TSS, ammonia-nitrogen, and phosphorus. Figure 6 shows the influent, effluent, and flow data for the year.

Operating data for the Traverse City WWTP were obtained for the same period. The mixed liquor suspended solids over the period January to August averaged 6,400 mg/L, while the mixed liquor volatile suspended solids averaged 4,400 mg/L. The energy use for the air-scouring blowers averaged 1,800 kW-hr/million gallons (MG) treated.

COSTS

Capital Costs

Capital costs for MBR systems historically have tended to be higher than those for conventional systems with comparable throughput because of the initial costs of the membranes. In certain situations, however, including retrofits, MBR systems can have lower or competitive capital costs compared with alternatives because MBRs have lower land requirements and use smaller tanks, which can reduce the costs for concrete. U.S. Filter/Siemen's Memcor package plants have installed costs of $7–$20/gallon treated.

Fleischer et al. (2005) reported on a cost comparison of technologies for a 12-MGD design in Loudoun County, Virginia. Because of a chemical oxygen demand limit, activated carbon adsorption was included with the MBR system. It was found that the capital cost for MBR plus granular activated carbon at $12/gallon treated was on the same order of magnitude as alternative processes, including multiple-point alum addition, high lime treatment, and post-secondary membrane filtration.

Operating Costs

Operating costs for MBR systems are typically higher than those for comparable conventional systems. This is because of the higher energy

Table 3.
Summary of Traverse City, Michigan, Performance Results

Parameter	Influent	Effluent		
	Average	Average	Max Month	Min Month
Flow (mgd)	4.3	--	5.1	3.6
BOD (mg/L)	280	< 2	< 2	< 2
TSS (mg/L)	248	< 1	< 1	< 1
Ammonia-N (mg/L)	27.9	< 0.08	< 0.23	< 0.03
TP (mg/L)	6.9	0.7	0.95	0.41
Temperature (deg C)	17.2	--	23.5	11.5

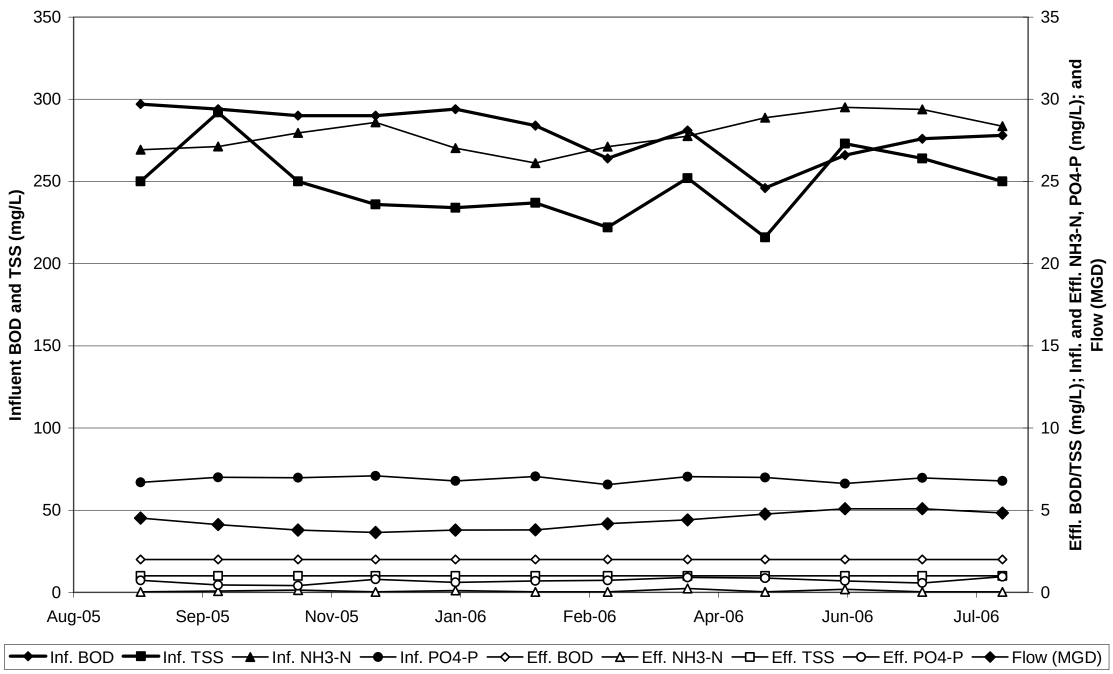

Figure 6. Performance of the Traverse City plant

costs if air scouring is used to reduce membrane fouling. The amount of air needed for the scouring has been reported to be twice that needed to maintain aeration in a conventional activated sludge system (Scott Blair, personal communication, 2006). These higher operating costs are often partially offset by the lower costs for sludge disposal associated with running at longer sludge residence times and with membrane thickening/dewatering of wasted sludge.

Fleischer et al. (2005) compared operating costs. They estimated the operating costs of an MBR system including activated carbon adsorption at $1.77 per 1,000 gallons treated. These costs were of the same order of magnitude as those of alternative processes, and they compared favorably to those of processes that are chemical-intensive, such as lime treatment.

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PRODUCT LITERATURE USED

Enviroquip/Kubota. Sales literature.

Siemens. Product literature. <http://www.usfilter.com/en/Product+Lines/Envirex_Products/Envirex_Products/envirex_mbr_xpress_packaged_plant.htm>.

Zenon. Case studies: Cauley Creek, Georgia. <http://www.zenon.com/resources/case_studies/water_reuse/CauleyCreek.shtml>.

Zenon. Case studies: Traverse City, Michigan. <http://www.zenon.com/resources/case_studies/wastewater/TraverseCity.shtml>.

REFERENCES

Crawford, G., G. Daigger, J. Fisher, S. Blair, and R. Lewis. 2005. Parallel Operation of Large Membrane Bioreactors at Traverse City. In *Proceedings of the Water Environment Federation 78th Annual Conference & Exposition*, Washington, DC, CD-ROM, October 29–Nov 2, 2005.

Crawford, G., A. Fernandez, A. Shawwa, and G. Daigger. 2002 Competitive Bidding and Evaluation of Membrane Bioreactor Equipment—Three Large Plant Case Studies. In *Proceedings of the Water Environment Federation 75th Annual Conference & Exposition*, Chicago, IL, CD-ROM, September 28–Oct 2, 2002.

Crawford, G., D. Thompson, J. Lozier, G. Daigger, and E. Fleischer. 2000. Membrane Bioreactors—A Designer's Perspective. In *Proceedings of the Water Environment Federation 73rd Annual Conference & Exposition on Water Quality and Wastewater Treatment*, Anaheim, CA, CD-ROM, October 14-18, 2000.

Fleischer, E.J., T.A. Broderick, G.T. Daigger, A. D. Fonseca, R.D. Holbrook, and S.N. Murthy. 2005. Evaluation of Membrane Bioreactor Process Capabilities to Meet Stringent Effluent Nutrient Discharge Requirements. *Water Environment Research* 77:162–178.

Fleischer, E. J., T. A. Broderick, G. T. Daigger, J. C. Lozier, A. M. Wollmann, and A. D. Fonseca. 2001. Evaluating the Next Generation of Water Reclamation Processes. In *Proceedings of the Water Environment Federation 74th Annual Conference & Exposition*, Atlanta, GA, CD-ROM, October 13–17, 2001.

Hermanowicz, S.W., D. Jenkins, R.P. Merlo, and R.S. Trussell. 2006. *Effects of Biomass Properties on Submerged Membrane Bioreactor (SMBR) Performance and Solids Processing*. Document no. 01-CTS-19UR. Water Environment Federation.

Metcalf & Eddy. 2003. *Wastewater Engineering, Treatment and Reuse*. 4th ed. McGraw-Hill, New York.

Wallis-Lage, C., B. Hemken, et al. 2006. *MBR Plants: Larger and More Complicated*. Presented at the Water Reuse Association's 21st Annual Water Reuse Symposium, Hollywood, CA, September 2006.

EPA
United States Environmental Protection Agency
September 2007

Appendix C – Wastewater Treatment Calculations

Proposed Membrane Treatment System Design Criteria

Putnam Lake Service Area

Raw Water Influent Characteristics

Influent Parameter	Units	Area 1	Area 2	Combined
Annual average flow rate	gpd	78,880	276,900	355,780
Design rated capacity	gpd	157,760	553,800	711,560
Peak hourly flow	gpd	315,520	1,107,600	1,423,120
Per capita equivalent	people	789	2,769	3,558
BOD	lb/d	134	471	605
TSS	lb/d	158	554	712
TKN	lb/d	28	100	128
Phosphorus	lb/d	5	18	24

Projected SPDES Permit Requirements (assumes surface water discharge)

BOD	mg/L	5	Daily Maximum
TSS	mg/L	10	Daily Maximum
Settleable solids	mg/L	0.1	
Ammonia - Summer	mg/L	1.5	Daily Maximum
Ammonia Winter	mg/L	2.2	
Phosphorus	mg/L	0.1	30-day average
Dissolved oxygen	mg/L	7	

Additional Conditions

3 log removal of Giardia Lamblia cysts

3 log removal of Enteric viruses

Turbidity level of less than 0.5 NTU in 95% of measurements

Turbidity instantaneous maximum of 5.0 NTU

Basis

Influent

Flow Peaking Factors

Max mo: Avg mo	2
Peak hour : Avg annual	4

Per Capita Water Quality Loads

Per Ten State Standards Para 11.253

BOD	0.17	lb/capita
TSS	0.2	lb/capita
TKN	0.036	lb/capita

Phosphorus concentration

NYSDEC Intermediate-sized Facilities

8 mg/L

SPDES Permit Basis

NYSDEC

Membrane Process Design Criteria

Water Quality Peaking factors (Peak hour : Average)		**Return stream loads**	
BOD	2	BOD	20%
TKN	2	TKN	20%

Design Influent Loads to Membrane Process

	Area 1		**Areas2**		**Combined 1+2**	
	BOD	**TKN**	**BOD**	**TKN**	**BOD**	**TKN**
Average	134	28	471	100	605	128
Return Stream	27	6	94	20	121	26
Influent peak hour	268	57	941	199	1,210	256
Return + influent peak hour	295	62	1,036	219	1,331	282

WAS generated

per TR-16 para 11.1.2: 1 dry ton of solids per 1 mgd typical. So, ratio is 1 mgd = 2000 lb

Given the stricter discharge limits, assume solids generated increases by 20%

1 mgd : 2,400 lb/d dry solids

So for design average flow rate of

Area 1	0.079	mgd
Combined Areas 1 + 2	0.356	mgd

The estimated WAS would be:

Area 1	189	lb/d
Combined Areas 1 + 2	854	lb/d

Aeration Needs

Amount of oxygen needed for BOD and TKN:	**Area 1**		**Areas 1 + 2**	
Average Membrane influent BOD load =	134	lb/d	605	lb/d
Return +Peak hour Membrane influent BOD load =	295	lb/d	1,331	lb/d

The COD Demand from BOD is 1.1 times BOD load, Ten States para 92.331

COD demand at avg BOD load =	**148**	lb/d	**665**	lb/d
COD demand at peak hour BOD load =	**325**	lb/d	**1,464**	lb/d

		Area 1	Areas 1 + 2
Average influent TKN load =		28 lb/d	128 lb/d
Return +Peak hour influent TKN load =		62 lb/d	282 lb/d
The amount of TKN used for cellular synthesis is assumed at		5% BOD load	
	at average BOD =	**1** lb/d	**6** lb/d
	at peak hour BOD =	**3** lb/d	**14** lb/d
TKN load adjusted for synthesis =	avg	**27** lb/d	**122** lb/d
	peak hr	**59** lb/d	**268** lb/d
The COD demand from TKN is 4.6 lb O2/lb TKN - Ten States para 92.331			
	COD demand at avg TKN load =	**124** lb/d	**560** lb/d
	COD demand at peak hour TKN load =	**273** lb/d	**1,231** lb/d
Influent COD demand:	average	**272** lb/d	**1,225** lb/d
	peak hr	**598** lb/d	**2,695** lb/d
COD leaving in effluent: assumed negligible - conservative assumption			
COD leaving as WAS: (see 7-Solids Handling)			
	sludge produced =	189 lb/d	854 lb/d
	% VSS =	70% Metcalf & Eddy, 2003, Table 14-4	
	The COD demand from VSS is	1.2 lb O2/lb VSS	
	COD demand leaving as WAS =	**160** lb/d	**723** lb/d
	To be conservative - use average WAS value for average conditions		

Oxygen returned to system from denitrification

Assume this is negligible since denitrification is not optimized

Actual Oxygen Required (AOR) = COD Demand In - COD demand leaving as WAS

	Area 1	Combined Areas 1 +2
at average load:	111 lb/d	502 lb/d
at peak hour load:	437 lb/d	1,972 lb/d

SOR (Standard oxygen required)

SOR with Fine Bubble Diffusers

alpha	0.55		Typ fine bubble diffuser. (Sanitaire Design Guide)
beta	0.95		typ. sat'n factor (Metcalf & Eddy, p 429)
DO field	**8.0**	mg/L	working DO concentration, SPDES Permit + 1 mg/L
AOR/SOR =		**0.33**	

AOR/SOR value used is typical for fine bubble diffuser Sanitaire design guide. To be calculated once permit established.

Fine bubble	Area 1		Combined Areas 1+2	
Loading	Average	Peak Hr	Average	Peak Hr
SOR (in lb O2/d)=	337	1,325	1521	5,975

Coagulant Dosage for Phosphorus Removal

Typical biological phosphorus uptake(not enhanced) =		1	mg/L	
Amount to be removed by chemicals		7	mg/L	
To reduce from	7 mg/L to	**1**	mg/L assume, coag:P ratio of	1 to 1
	1 mg/L to	0.1	mg/L assume, coag:P ratio of	4 to 1
	0.1 mg/L to	0.1	mg/L assume, coag:P ratio of	8 to 1
For alum: use ratio of Al g/mol per mol to P g/mol=		0.87		

So to reduce to 1 mg/L	5.2 mg/L	Assuming:		
To reduce to 0.1 mg/L	3.1 mg/L		9.1%	Al in alum
To reduce to 0.1 mg/L	0.0 mg/L		50%	alum solution unit weight
Total Al dose =	8.4 mg/L		11.1	lb/gal

	Al req'd	**Alum Req'd**		**30-day supply**		**P load to Lake (lb/yr)**	
	lb/d	**lb/d**	**gal/d**	**gal**	**# of totes**	**Avg Ann**	**Rated Capacity**
Area 1	5.5	60.5	5.5	164	0.6		
Combined Areas 1 +2	24.8	272.9	24.6	738	2.7	108.3	

Phosphorus Loads & Benefit to Lake	**Area 1**	**Area 2**	**Combined Areas 1+2**
Current P load - calculated, this report	281.81	0	281.81
Projected P Load - rated capacity	48.0	168.6	216.6
P load reduction to lake	233.8	-168.58	65.2

Proposed Membrane Treatment System Cost Estimate

Putnam Lake Service Area

Includes all properties identified in Area 1

Design rated capacity = 0.16 mgd = 157,760 gpd

Item	Units	Unit Cost	Quantity	Cost
Headworks	LS	$ 1,000,000	1	$ 1,000,000
Treatment, installed, package plant	$/gpd	$ 15	157,760	$ 2,366,400
Disinfection	LS	$ 500,000	1	$ 500,000
Subtotal - Processes + Installation				$ 3,866,400
Interior valves & piping	EA	5%	1	$ 193,320
Civil	EA	5%	1	$ 193,320
Yard piping	EA	5%	1	$ 193,320
Electrical and Instrumentation	EA	15%	1	$ 579,960
Subtotal				$ 5,026,320
Contingency	EA	25%	1	$ 1,256,580
Admininstration & maintenance bldg	LS	$ 500,000	1	$ 500,000
Engineering and Admin	EA	20%	1	$ 1,005,264
Location adjustment	EA	15%	1	$ 1,168,224.60
Land	$/Acre	200,000	2	$ 400,000
Total				$ 9,356,389

Proposed Membrane Treatment System Cost Estimate

Putnam Lake Service Area

Includes all properties identified in Combined Areas 1 and 2

Design rated capacity = 0.71 mgd = 711,560 gpd

Item	Units	Unit Cost	Quantity	Cost
Headworks	LS	$ 1,500,000	1	$ 1,500,000
Treatment to 0.1 mg/L	LS	$ 5,000,000	1	$ 5,000,000
Disinfection	LS	$ 1,500,000	1	$ 1,500,000
Subtotal - Processes + Installation				$ 8,000,000
Interior valves & piping	EA	10%	1	$ 800,000
Civil	EA	5%	1	$ 400,000
Yard piping	EA	5%	1	$ 400,000
Electrical and Instrumentation	EA	15%	1	$ 1,200,000
Subtotal				$ 10,800,000
Contingency	EA	25%	1	$ 2,700,000
Admininstration & maintenance bldg	LS	$ 500,000	1	$ 500,000
Engineering and Admin	EA	20%	1	$ 2,160,000
Location adjustment	EA	15%	1	$ 2,424,000
Land	$/Acre	200,000	2	$ 400,000
Total				$ 18,984,000
			Cost/mgd	$ 26,679,409

Appendix D – Cost Estimating Unit Prices

Work Item Description	Unit Price
1. 8” & 10” Sanitary Sewer (green space)	$150 LF
2. 8” & 10” Sanitary Sewer (pavement)	$175 LF
3. Pumping Stations (50-100 GPM wastewater)	$195,000 EA
4. Pumping Stations (100-200 GPM wastewater)	$225,000 EA
5. Pumping Station (50–100 GPM effluent)	$100,000 EA
6. Grinder Station (simplex)	$12,000 EA
7. Grinder Station (duplex)	$15,000 EA
8. 4” Force Main (green space)	$75 LF
9. 4” Force Main (pavement)	$100 LF
10. 4” Gravity Lateral	$75 LF
11. Connect 4” Gravity Lateral to Main	$600 EA
12. 4” Lateral to Grinder Station	$115 LF
13. 1.5” Force Main Lateral (assume 100 LF)	$3,500 EA
14. 2” Grinder Pump Force Main	$40 LF
15. Air Release Valves	$6,000 EA
16. Flushing Connections (1,000 LF intervals)	$2,600 EA
17. Grinder Station Electrical Service	$3,000 EA
18. Septic Tank Replacement (single)	$15,000 EA
19. STEP System (residential)	$20,000 EA
20. Septic Tank (5000 G – cluster)	$20,000 EA
21. Leachfield (cluster)	$15,000 EA
22. Leachfield (residential)	$12,000 EA
23. Abandon and Decommission Septic Tank	$3,000 EA

Appendix E – Cost Estimates

Alternative 1A - Gravity Collection System

AREA 1

Item	Quantity	Unit	Unit Price	Total
8" & 10" Sanitary Sewer (Green Space)	0	LF	$150	$0
8" & 10" Sanitary Sewer (Pavement)	26,000	LF	$175	$4,550,000
Manholes	104	EA	$4,500	$468,000
Pumping Station (50-100gpm)	6	EA	$195,000	$1,170,000
Pumping Station (100-200gpm)	1	EA	$225,000	$225,000
4" Force Main (green space)	0	LF	$75	$0
4 " Force Main (Pavement)	16,000	LF	$100	$1,600,000
4" Gravity lateral	14,350	LF	$75	$1,076,250
Air Release Valves	2	EA	$6,000	$12,000
Electrical Service	0	EA	$3,000	$0
Abandon and decommission septic tank	287	EA	$3,000	$861,000
Rock Removal Contingency	1	LS	$500,000	$500,000
			Subtotal	$10,462,250
			20% Contingency	$2,092,450
			Total Construction	**$12,554,700**
			25% Engineering, Legal & Misc.	$3,138,675
			ESTIMATED TOTAL PROJECT AREA 1 (2018)	**$15,693,375**

AREA 2

Item	Quantity	Unit	Unit Price	Total
8" & 10" Sanitary Sewer (Green Space)	0	LF	$150	$0
8" & 10" Sanitary Sewer (Pavement)	92,900	LF	$175	$16,257,500
Manholes	372	EA	$4,500	$1,672,200
Pumping Station (50-100gpm)	4	EA	$195,000	$780,000
Pumping Station (100-200gpm)	0	EA	$225,000	$0
4" Force Main (green space)	0	LF	$75	$0
4 " Force Main (Pavement)	8,000	LF	$100	$800,000
4" Gravity lateral	53,250	LF	$75	$3,993,750
Air Release Valves	0	EA	$6,000	$0
Electrical Service	0	EA	$3,000	$0
Abandon and decommission septic tank	1,065	EA	$3,000	$3,195,000
Rock Removal Contingency	1	LS	$2,000,000	$2,000,000
			Subtotal	$28,698,450
			20% Contingency	$5,739,690
			Total Construction	**$34,438,140**
			25% Engineering, Legal & Misc.	$8,609,535
			ESTIMATED AREA 2 PROJECT COST (2018)	**$43,047,675**
			ESTIMATED TOTAL PROJECT COST (2018)	**$58,741,050**

Alternative 1B - Grinder Pump/Pressure Sewer Collection System

AREA 1

Item	Quantity	Unit	Unit Price	Total
Grinder Station (simplex)	287	EA	$12,000	$3,444,000
Grinder Station (duplex)	0	EA	$15,000	$0
4" Force Main (green space)	0	LF	$75	$0
4 " Force Main (Pavement)	2,000	LF	$100	$200,000
4" Gravity lateral	0	LF	$75	$0
6" Lateral to Grinder Station	0	EA	$3,500	$0
1.5" Force main lateral (Assume 100LF)	40,350	LF	$35	$1,412,250
Air Release Valves	5	EA	$6,000	$30,000
Flushing Connections (1,000 LF Intervals)	27	EA	$2,600	$70,200
Electrical Service	90	EA	$4,500	$405,000
Abandon and decommission septic tank	287	EA	$3,000	$861,000
Rock Removal Contingency	1	LS	$250,000	$250,000
			Subtotal	$6,672,450
			20% Contingency	$1,334,490
			Total Construction	**$8,006,940**
			25% Engineering, Legal & Misc.	$2,001,735
			ESTIMATED AREA 1 PROJECT COST (2018)	**$10,008,675**

Area 2 - Outside 250 feet and within the service area

Item	Quantity	Unit	Unit Price	Total
Grinder Station (simplex)	1,065	EA	$12,000	$12,780,000
Grinder Station (duplex)	0	EA	$15,000	$0
4" Force Main (green space)	0	LF	$75	$0
4 " Force Main (Pavement)	0	LF	$100	$0
4" Gravity lateral	0	LF	$75	$0
6" Lateral to Grinder Station	0	EA	$3,500	$0
1.5" Force main lateral (Assume 100LF)	146,150	LF	$35	$5,115,250
Air Release Valves	4	EA	$6,000	$24,000
Flushing Connections (1,000 LF Intervals)	929	EA	$2,600	$2,415,400
Electrical Service	300	EA	$4,500	$1,350,000
Abandon and decommission septic tank	1,065	EA	$3,000	$3,195,000
Rock Removal Contingency	1	LS	$1,000,000	$1,000,000
			Subtotal	$25,879,650
			20% Contingency	$5,175,930
			Total Construction	**$31,055,580**
			25% Engineering, Legal & Misc.	$7,763,895
			ESTIMATED AREA 2 PROJECT COST (2018)	**$38,819,475**
			ESTIMATED TOTAL PROJECT COST (2018)	**$48,828,150**

Alternative 2B - Effluent Sewer Collection System

Area 1- Within 250 feet of the lake

Item	Quantity	Unit	Unit Price	Total
Pumping Station (100-200gpm)	1	EA	$225,000	$225,000
4" Force Main (green space)	0	LF	$75	$0
4 " Force Main (Pavement)	2,000	LF	$100	$200,000
1.5" Force main lateral (Assume 100LF)	40,350	LF	$35	$1,412,250
Air Release Valves	5	EA	$6,000	$30,000
Flushing Connections (1,000 LF Intervals)	27	EA	$2,600	$70,200
STEP System	287	EA	$15,000	$4,305,000
Rock Removal Contingency	1	LS	$250,000	$250,000
			Subtotal	$6,492,450
			20% Contingency	$1,298,490
			Total Construction	**$7,790,940**
			25% Engineering, Legal & Misc.	$1,947,735
			ESTIMATED AREA 1 PROJECT COST (2018)	**$9,738,675**

Area 2 - Outside 250 feet and within the service area

Item	Quantity	Unit	Unit Price	Total
Pumping Station (100-200gpm)	0	EA	$225,000	$0
4" Force Main (green space)	0	LF	$75	$0
4 " Force Main (Pavement)	0	LF	$100	$0
1.5" Force main lateral (Assume 100LF)	146,150	LF	$35	$5,115,250
Air Release Valves	4	EA	$6,000	$24,000
Flushing Connections (1,000 LF Intervals)	929	EA	$2,600	$2,415,400
STEP System	1,065	EA	$15,000	$15,975,000
Rock Removal Contingency	1	LS	$1,000,000	$1,000,000
			Subtotal	$24,529,650
			20% Contingency	$4,905,930
			Total Construction	**$29,435,580**
			25% Engineering, Legal & Misc.	$7,358,895
			ESTIMATED AREA 2 PROJECT COST (2018)	**$36,794,475**
			ESTIMATED TOTAL PROJECT COST (2018)	**$46,533,150**

OBG

THERE'S A WAY