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Regional Wastewater Management Plan

Understanding the Cost Factors of Wastewater Treatment and Disposal

MARCH 2013

Table of Contents

Introduction

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In most areas of the United States, including most of Massachusetts, centralized wastewater treatment plants and sewers—most often organized and managed on a regional basis—are used to treat and dispose of wastewater. Until the early 1980s, the federal government covered much of the capital cost of construction of that wastewater infrastructure, with homeowners covering operation and maintenance (O&M) costs through taxes and betterments.

In contrast, the vast majority of all properties on Cape Cod rely on on-site wastewater disposal, with the typical costs being a one-time expense for installation of an on-site septic system (if new construction) and periodic pumping of the system. Towns manage the few larger, off-site facilities, and treatment covers only small areas of those towns.

The Regional Wastewater Management Plan's Technology Assessment sections (Conventional and Green Infrastructure and Alternative Approaches) explored the suite of options available to treat and dispose of wastewater. For many of the more innovative options, it is difficult to estimate the costs because they are specific to the location or are undetermined. For example, the cost of widening an inlet or dredging to increase tidal flushing depends on the physics and morphology of the particular estuarine system. The use of eco-toilets may require multiple installations in a single dwelling, a contract for removal of the waste materials, and, if to be used extensively in the region, the creation of an industry to collect and process the waste materials as fertilizer.

Much more information is available about the costs of conventional treatment technologies from individual on-site septic systems to large centralized wastewater treatment facilities. This information can be used to provide guidance on three overarching questions:

- What is the difference in cost between using a number of smaller treatment systems instead of larger centralized wastewater treatment plants?
- Are there potential cost savings from regionalization?
- What are the ramifications of additional growth on the cost of wastewater infrastructure?

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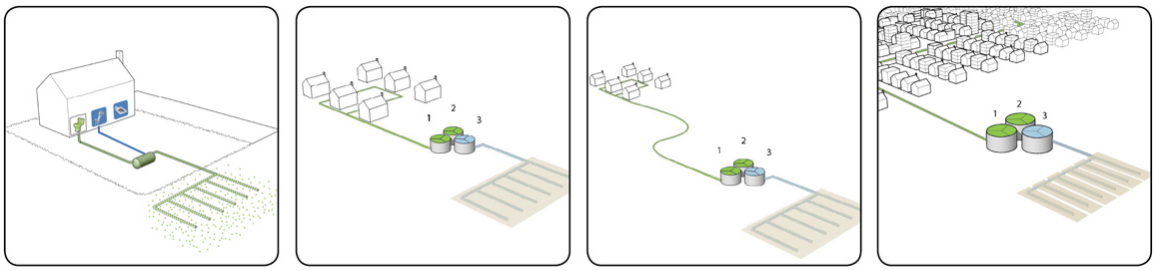
This document explores these questions. Information from the 2010 Barnstable County Wastewater Cost Task Force study is used to answer the first question. Information from the Regional Wastewater Management Plan: Cape-wide Cost Estimates is used to answer the last two.

Many terms have been used to describe different sizes and kinds of traditional wastewater treatment facilities, including centralized, satellite, cluster, and individual on-site. These terms will be used in this document as well, and the amount of flow will determine the terminology used. Figure UCF-1 illustrates the different sizes and kinds of wastewater treatment facilities.

- Centralized systems provide for most or all of a town's wastewater management needs and might serve portions of neighboring towns (wastewater flows in excess of 300,000 gallons per day; require a groundwater discharge permit).
- Satellite systems serve from 30 to 1,000 homes and are intended to treat and dispose of wastewater from one area (wastewater flows between 10,000 gallons per day and 300,000 gallons per day; require a groundwater discharge permit).
- Cluster systems serve up to approximately 30 homes with aggregate wastewater flows less than 10,000 gallons per day, regulated under Title 5.
- Individual on-site systems serve one property and are located on the parcel where the wastewater is generated, regulated under Title 5.

Costs of alternative and innovative systems are discussed later in this document.

FIGURE UCF-1: Sizes and Kinds of Wastewater Treatment



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Cost Comparison of On-Site, Cluster, Satellite, and Centralized Treatment

The Barnstable County Wastewater Cost Task Force summarized data on current costs to build and operate wastewater treatment systems of different sizes on Cape Cod. Information for the analysis of satellite and centralized systems came from 24 treatment facilities, the majority of which are located on Cape Cod and in southeastern Massachusetts in areas with similar soil types and conditions. Information about individual on-site wastewater systems and cluster systems came from interviews with suppliers, contractors, and developers; data from the Massachusetts Alternative Septic System Center, which is administered by the Barnstable County Department of Health and Environment and is located at the Massachusetts Military Reservation; and reports from the New Jersey Pinelands Commission.

COSTS OF ON-SITE SEPTIC SYSTEMS

CONVENTIONAL TITLE 5 SYSTEMS

Costs of treating wastewater on site vary depending on the technology used and site conditions. Based on a mix of 3-bedroom (80%) and 4-bedroom (20%) homes consistent with an average of 3.2 bedrooms per dwelling unit, this study showed that the average replacement cost for a Title 5 system ranges from $8,000 to $15,000, and a mounded system could cost as much as $30,000.

Massachusetts law allows a tax credit equal to 40% of the cost of design and construction of the repair or replacement of a failed septic system up to $15,000 for total expenses. The credit, up to $6,000, may be taken at a rate of no more than $1,500 per year over four years.

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The Barnstable County Community Septic Management Program provides loans for the replacement of failed septic systems at 5% interest over 20 years. Conditions include:

- The loan is secured by a lien against the property.
- The loan must be paid in full at the time of sale.
- The program is restricted to residential properties.
- There are income limitations.

ADVANCED ON-SITE DENITRIFYING SEPTIC SYSTEMS

Estimates of the cost of advanced denitrifying systems vary depending on the type of system and degree of nitrogen attenuation. The cost study referenced above estimated that an innovative/alternative (I/A) system that achieved an effluent nitrogen concentration of 19 milligrams per liter would cost an average of $24,000 with about $1,250 in annual operation and maintenance (O&M) costs. Individual advanced systems that achieved an effluent nitrogen concentration of 13 milligrams per liter were estimated to cost about $26,000, with $2,000 in annual maintenance expenses.

COSTS OF ZERO-DISCHARGE SYSTEMS

The cost of conventional on-site systems is based on the cost of the effluent capture, discharge, and soil absorption components of the system—components that are located outside of the building. Composting and urine-diverting toilets, tight tanks, and incinerating toilets include those components for gray water only. Costs for zero-discharge systems vary widely, depending on the kind of system installed and the number of systems installed. A single unit may cost less than $1,000, but the cost of retrofitting them to an existing dwelling unit varies. For example, a two-story home with bathrooms on each floor but on opposite sides of the home may require two units.

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COMPARATIVE COSTS OF CLUSTER, SATELLITE, AND CENTRALIZED FACILITIES

To compare the costs of different sizes of wastewater treatment facilities, the capital costs of 24 wastewater treatment facilities and the O&M costs from 21 facilities were analyzed. The capital costs of each wastewater treatment facility was calculated as the sum of:

- Basic construction costs for collection, transport to the treatment facility, treatment, transport to disposal, and disposal;
- Cost of engineering, planning, design, permitting, legal expenses, and a contingency for unexpected construction items; and
- Land costs, based on the nature and extent of the facilities.

The costs of O&M included labor, electricity, chemicals, laboratory analysis, repairs, equipment replacement, and administrative costs, including insurance and sludge disposal. Unit costs were computed by dividing construction costs and O&M by the associated wastewater flow.

The results, shown in Table UCF-1, clearly demonstrate that construction and O&M costs decline significantly as the system wastewater capacity increases. For more detailed information, see Figures 3 and 4 in the Barnstable County Cost Report.

TABLE UCF-1: Unit Construction and O&M Costs by Capacity (in gallons per day; gpd)

CAPACITY	UNIT CONSTRUCTION COST	UNIT O&M COSTS
10,000 gpd	$70 per gpd of capacity	$13 per gpd of average flow
100,000 gpd	$35 per gpd of capacity	$5 per gpd of average flow
1,000,000 gpd	$17 per gpd of capacity	$2 per gpd of average flow

SOURCE: Barnstable County Wastewater Cost Task Force, "Comparison of Costs for Wastewater Management Systems Applicable to Cape Cod," April 2010.

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COLLECTION COSTS

To estimate the cost of collection, data on the costs for gravity pipes, pressure pipes, grinder pumps, and pumping stations of various sizes were analyzed. It was assumed that 5% of the properties would require grinder pumps and that one pump station would be necessary for every 100 properties. For more details, see Figure 5 in the Barnstable County Cost Report, which illustrates the relationship between density (distance between properties) and the cost of a collection system, shows that cost vary directly with density of development.

COSTS PER POUND OF NITROGEN REMOVED AND SENSITIVITY ANALYSIS

Based on a set of underlying assumptions (e.g., land costs, wastewater flows, transport distances, and disposal location, among others), costs were estimated for 14 hypothetical scenarios of different-sized systems. Capital costs for collection, transport, treatment, and disposal and O&M costs were calculated as was the equivalent annual cost (amortized capital cost plus O&M). Based on the efficacy of nitrogen removal of the different kinds of systems, an equivalent annual cost per pound of nitrogen removed was calculated.

As shown in Table UCF-2, individual denitrifying systems have the lowest capital costs, primarily because they do not require a collection system. Centralized systems and large satellite systems have the lowest O&M costs. Combining both capital and O&M costs into an equivalent annual cost per property, centralized systems are the least expensive, especially when nitrogen-removal capability is factored into the calculation.

A sensitivity analysis was then undertaken in which the underlying assumptions were changed for each of the 14 scenarios. As noted above, a very significant cost driver for wastewater infrastructure other than on-site systems is the cost of collection. Therefore the sensitivity analysis held collection costs constant across all scenarios.

TABLE UCF-2: Cost per Pound of Nitrogen Removed Using Different Kinds of Wastewater Treatment

TYPE OF TREATMENT	ESTIMATED COST PER PROPERTY SERVED			EQUIVALENT ANNUAL COST* PER POUND OF NITROGEN REMOVED	
	CAPITAL COST	ANNUAL O&M	EQUIVALENT ANNUAL COST	DOLLARS ($) PER POUND OF NITROGEN	PERCENT (%) PREMIUM OVER 3.0 MILLION GALLONS-PER-DAY (MGD) CENTRALIZED SYSTEM
Individual Systems					
Title 5	$13,000	$110	$1,150	Not applicable	Not applicable
Nitrogen-removing: Current Practice	$24,000	$1,250	$3,180	$820	187%
Nitrogen-removing: Enhanced Current Practice	$26,000	$2,000	$4,090	$580	102%
Nitrogen-removing: For TMDL Compliance	$28,000	$3,200	$5,450	$770	169%
Cluster Systems					
Current Practice	$48,300	$1,050	$4,920	$820	186%
For TMDL Compliance	$52,000	$2,800	$6,940	$710	149%
Satellite Systems					
50,000 gpd	$55,100	$1,670	$6,080	$680	138%
100,000 gpd	$51,300	$1,360	$5,480	$590	109%
200,000 gpd	$47,700	$1,030	$4,860	$510	79%
300,000 gpd	$46,300	$860	$4,570	$470	64%
Centralized Systems					
1.5 mgd	$42,900	$500	$3,940	$305	7%
3.0 mgd	$40,900	$400	$3,680	$285	——

*NOTES:
Equivalent annual costs are based on 5%, 20-year financing.
Watershed-wide costs must consider the number of properties served and the average cost per property.

SOURCE: Barnstable County Wastewater Cost Task Force, "Comparison of Costs for Wastewater Management Systems Applicable to Cape Cod," April 2010.

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TABLE UCF-3: Cost per Pound of Nitrogen Removed, by System

TREATMENT SYSTEM	LOW	BASE CASE	HIGH
Individual N-removing Systems	$550	$770	$830
Cluster Systems – 8,800 gpd	$500	$710	$790
Satellite Systems – 50,000 gpd	$480	$680	$720
Satellite Systems – 200,000 gpd	$380	$510	$550
Centralized Systems – 1.5 mgd	$250	$305	$319
Centralized Systems – 3.0 mgd	$230	$285	$295

SOURCE: Barnstable County Wastewater Cost Task Force, "Comparison of Costs for Wastewater Management Systems Applicable to Cape Cod," April 2010.

The results (Table UCF-3) showed that larger systems were significantly less expensive per gallon of wastewater flow treated.

The sensitivity analysis revealed the effects of different assumptions on overall system costs. The most important factors were:

- Economies of Scale: Many cost components do not increase directly as flow increases.
- Density of Development: Collection is the most expensive component of wastewater infrastructure; therefore densely developed areas are the most cost effective as sewer length is minimized.
- Location of Effluent Disposal Sites: Disposal in a watershed that requires nitrogen removal will be more expensive because more properties will require sewering to remove enough additional nitrogen that otherwise would be returned in the effluent. Disposal in Zone IIs requires an increased level of treatment, and the associated cost often discourages disposal in these areas.
- Land Costs: Suitable land is scarce and expensive. Town-owned land or dual use of sites such as golf courses and ball fields can reduce costs. Town-owned land is especially important if a number of small systems are built, each with its own setbacks and buffer zones.

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Guidance on Selecting Different-sized Solutions

The report also suggested the conditions most favorable for or least favorable for individual denitrifying, cluster, satellite, or centralized systems.

APPLICABILITY OF INDIVIDUAL NITROGEN-REMOVING SYSTEMS

Individual denitrifying septic systems cannot provide the sole means of Total Maximum Daily Load (TMDL) compliance for a number of reasons. The capability of these systems to provide significant nitrogen removal restricts their applicability to watersheds where the necessary septic nitrogen removal is less than about 50%. Very large numbers of such systems would need to be built, at a very high cost, to contribute to a meaningful reduction in the nitrogen load of a watershed. The municipality would also need to undertake costly long-term monitoring to ensure the systems meet nitrogen-removal requirements and that systems are properly maintained.

CONDITIONS MOST FAVORABLE

The greatest benefit of individual denitrifying systems is the avoidance of a collection system because wastewater is treated and disposed on the same parcel where it is generated. In areas where the average length of collection pipe per property served would exceed 200 feet—and therefore be very costly to install—individual denitrifying systems should be evaluated, considering all costs as well as the administrative issues related to property access and TMDL compliance.

CONDITIONS LEAST FAVORABLE

On-site denitrifying systems are not applicable where septic nitrogen-control needs exceed 50%. Even in watersheds where smaller percentages

of nitrogen removal are needed, the very high cost—greater than $550 per pound of nitrogen removed—should preclude their consideration unless the collection system requires more than 150 feet per connection.

Unless larger-scale systems include very long transport distances to available treatment/disposal sites and effluent disposal must occur in very sensitive watersheds or in water supply Zone IIs, these systems need not be evaluated in detail except for serving less densely developed areas where not more than 50% of septic nitrogen must be removed.

APPLICABILITY OF CLUSTER SYSTEMS

Wastewater treatment systems with flows less than 10,000 gallons per day are significantly more expensive to build and operate than larger systems, but there are circumstances where they can be applicable. Although the Massachusetts Department of Environmental Protection (MassDEP) is not inclined to allow a series of cluster systems as the primary means of TMDL compliance (for many reasons similar to the issues related to individual systems), developing cluster systems under the Groundwater Discharge Permit Program may address MassDEP's concerns.

CONDITIONS MOST FAVORABLE

Cluster systems may be favorable in:

- Existing neighborhoods where small lots would have low wastewater collection costs, that are remote from proposed sewered areas, and that have nearby publicly owned vacant land;
- New cluster developments where a developer installs an alternative collection system and later turns the wastewater infrastructure over to the town;
- Shore-front areas near small, poorly flushed embayments where a cluster system can provide an early benefit of nitrogen control and later be converted to a pumping station in future phases of a centralized system.

Non-cost factors should also be considered, such as the need to maintain water balance within watersheds.

CONDITIONS LEAST FAVORABLE

Given their high cost—greater than $500 per pound of nitrogen removed—cluster systems do not warrant detailed consideration unless larger scale systems include very large transport distances to available treatment/disposal sites and effluent disposal occurs in very sensitive watersheds or in water supply Zone IIs.

APPLICABILITY OF SATELLITE SYSTEMS

Satellite systems are designed to serve portions of a town or large individual developments. (There are more than 50 satellite systems on Cape Cod, most of which are privately developed. Most of the publicly owned satellite plants serve schools, but the New Silver Beach facility in Falmouth is a good example of a municipal system serving a specific portion of a town.)

CONDITIONS MOST FAVORABLE

Satellite systems may be favorable in:

- A watershed in need of nitrogen control that is more than five miles from the existing sewer system or other areas or need and that has nearby publicly owned vacant land;
- New large-scale residential or commercial developments where the developer can install collection, treatment, and disposal facilities and later turn the infrastructure over to the town;
- An existing or proposed private facility that can be taken over by the town and expanded to provide wastewater service to existing nearby properties currently on septic systems, particularly if the town-wide system may be available for many years and the developer is prepared to proceed in the near future.

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Satellite systems of 150,000 gpd or larger have a distinct cost advantage over those 50,000 gpd and smaller.

CONDITIONS LEAST FAVORABLE

Satellite systems smaller than 100,000 gallons per day have limited applicability given their high cost—greater than $500 per pound of nitrogen removed. If centralized facilities exist or can be developed within five miles, satellite facilities do not warrant detailed consideration. If regionalization is possible and desirable, satellite options have an added disadvantage.

APPLICABILITY OF CENTRALIZED SYSTEMS

Centralizing wastewater infrastructure has both advantages and disadvantages from a cost perspective.

CONDITIONS MOST FAVORABLE

Centralized systems are likely to be the most viable wastewater systems where:

- Dense development exists in nitrogen-sensitive watersheds, especially if these areas are within three miles of suitable effluent treatment and disposal sites;
- Suitable treatment and disposal sites (outside sensitive watersheds and Zone IIs) are available at no or low cost.
- A high degree of nitrogen control is required, placing a cost premium on small-scale systems that discharge in sensitive watersheds.
- Opportunities are available for cost reductions through regionalization (see the Cape-wide cost estimate for more information about cost savings).

CONDITIONS LEAST FAVORABLE

Centralized systems are generally not favorable where:

- Development in nitrogen-sensitive watersheds is relatively sparse.
- Effluent disposal sites are remote, costly, and in water supply Zone IIs or nitrogen-sensitive watersheds.
- Only small amounts of nitrogen must be removed, allowing individual denitrifying systems to be applicable.
- Water balance considerations favor local disposal.
- Presence of nearby development or unacceptable impacts on natural resources preclude the use of otherwise favorable sites.