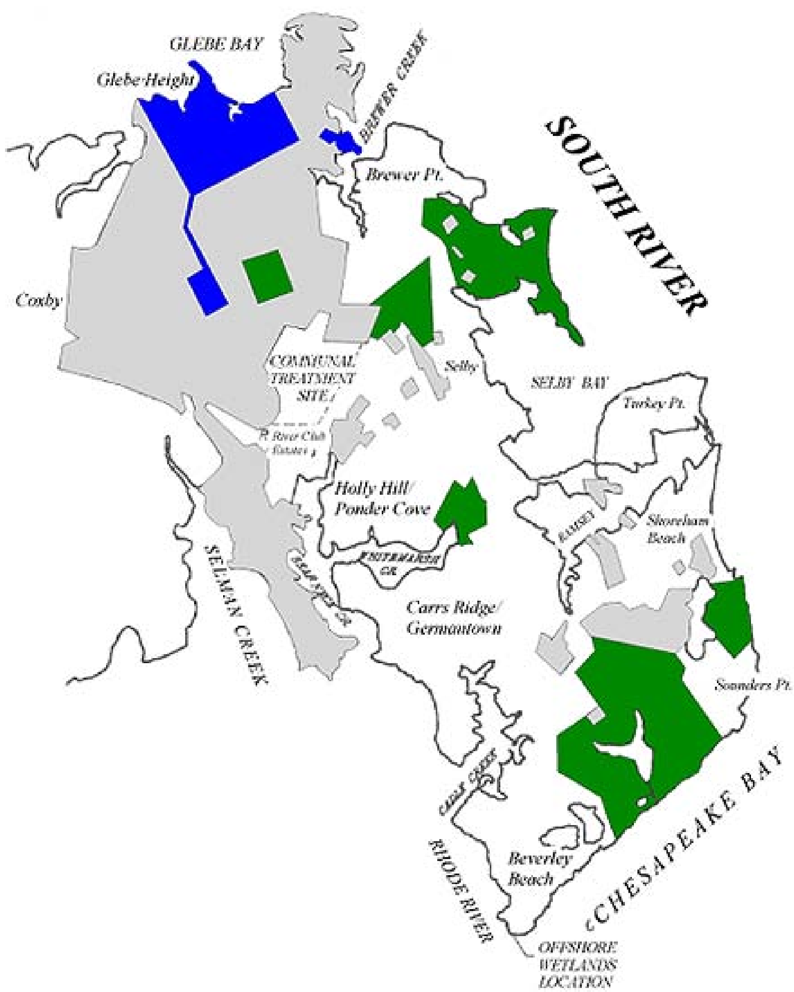
National Decentralized Water Resources
Capacity Development Project



Cluster Wastewater Systems Planning Handbook

Lombardo Associates, Inc.
Newton, Massachusetts

August 2004

Cluster Wastewater Systems Planning Handbook

Submitted by Lombardo Associates, Inc.
Newton, Massachusetts

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ABSTRACT

The *Cluster Wastewater Systems Planning Handbook* is an executive roadmap for the successful planning, design, and implementation of cluster wastewater systems within the full range of application types, including:

- Community-Wide Decentralized Wastewater Management
- Parcel Development
- Solution to an Existing Defined Wastewater Need

The handbook includes a manual of practice with specific case studies and examples to illustrate critical concepts and techniques.

Cluster wastewater systems can serve a small to large number of connections (two to hundreds of structures). Smaller cluster systems serving a few structures resemble onsite systems, while large cluster systems serving hundreds of structures tend to resemble centralized systems. Cluster systems generally disperse wastewater in subsurface dispersal systems, although surface discharge or water reuse is also practiced. Smaller cluster systems are permitted by health departments, while larger systems are permitted by state environmental protection departments.

The handbook outlines a comprehensive wastewater management planning process that enables communities and property owners to assess where and how cluster systems are appropriate. This process enables the development of an optimized decentralized wastewater management plan. The handbook outlines the planning steps:

1. Initial Data Collection and Preparation of a Community Profile
2. Needs Definition
3. Alternatives Screening and Development of a Final Preferred Solution Plan
4. Development of a Management and Implementation Plan

The challenges of advanced wastewater treatment are discussed, including:

- Nitrogen and phosphorus removal and disinfection
- Indirect water reuse
- Soil and hydrogeological issues
- Growth management and integration with land-use planning
- Regulatory issues

How these factors impact and are integrated within the planning process are discussed in detail, especially in Chapter 3.

The handbook provides technical and planning information on cluster wastewater system management and technologies to assist planners, engineers, property owners, and other stakeholders in developing and implementing cluster wastewater systems; however, the handbook is not a comprehensive guide to the engineering of cluster wastewater systems. For more information on particular issues, a wide variety of relevant leading publications and resources produced by the US EPA and other public and private sources are referenced throughout the handbook.

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1 INTRODUCTION

This handbook is designed to serve as an executive roadmap for the successful planning, design, and implementation of cluster wastewater systems. A manual of practice is included with specific case studies and examples to illustrate critical concepts and techniques.

Cluster systems are an important option for wastewater management in situations where onsite systems are impractical or where connecting to centralized wastewater systems is not financially or technically feasible. Cluster systems can also be used to address capacity issues with large centralized wastewater systems.

Generally, there are three types of wastewater systems:

- Onsite
- Centralized
- Cluster

Each system can consist of many combinations of wastewater collection, treatment, and dispersal/reuse technologies. While onsite systems serve an individual household or property and centralized systems serve large, high-density communities, cluster systems serve an intermediate number of structures with more than one and as many as hundreds of connections.

The differences between the three alternatives are:

- **Onsite Wastewater Systems—**Onsite systems collect, treat, and disperse wastewater on an individual property. Onsite systems are associated with low-density communities and developments such as rural residential and small commercial developments (such as village centers). Onsite systems generally consist of a treatment device (for example, a septic tank) and a subsurface dispersal system, but they can include many other components, such as secondary and tertiary treatment systems and drip dispersal systems.
- **Centralized Wastewater Systems—**Centralized systems are associated with high-density communities and developments such as cities and commercial areas. They generally consist of a collection system that gathers and transports wastewater from multiple generation points to one or more large centralized treatment facilities. These systems transport treated effluent to one or more points of dispersal, where it is typically returned to surface or ground waters.
- **Cluster Wastewater Systems—**Cluster systems can serve a small to large number of connections (two to hundreds of structures). Smaller cluster systems serving a few structures resemble onsite systems, while large cluster systems serving hundreds of structures tend to

resemble centralized systems. Cluster systems generally disperse wastewater in subsurface dispersal systems, although surface discharge or water reuse is also practiced.

For the purposes of this handbook, cluster systems are grouped into two types based upon regulatory jurisdictions, and five general categories based on size (Table 1-1).

Table 1-1
Cluster Wastewater Systems Characteristics

Type	Size of Cluster System	Range of Wastewater Flows (gpd)	Characteristics and Requirements
I	Small	<2,000	• Resembles large onsite system • Pretreatment after septic tank and prior to dispersal generally not required
	Medium	2,000–10,000	• Pretreatment may be needed depending on regulatory, site, and environmental issues
II	Medium-Large	10,000–25,000	• Pretreatment generally required; groundwater modeling and fate and transport analysis may be required; groundwater or surface water impact analysis generally important
	Large	25,000–50,000	• Pretreatment generally required • Groundwater mounding and fate and transport analysis required and important
	Very Large	>50,000	• Pretreatment required • Groundwater mounding and fate and transport analysis required and generally critical

Small- and medium-size cluster systems, referred to in this handbook as Type I cluster systems, are governed by state (or local) health departments, which have prescriptive codes for system design. Typically, communities apply the septic system code to Type I cluster systems.

Small cluster systems are typically large septic systems consisting of a septic tank and dispersal system. The dispersal system (soils) is part of the treatment system as well.

Medium cluster systems generally require a treatment component prior to the dispersal system. With this cluster system type, the dispersal system (soils) provides purified wastewater disinfection. With a disinfection component included as part of the treatment component, the dispersal system siting requirements may be less stringent.

The collection component of small- and medium-size cluster systems is generally a minor issue. Importantly, the collection component is generally not subject to state collection system design standards, but rather to acceptable practice.

All other cluster system types (**medium-large, large, and very large**) are referred to as Type II cluster systems. These systems are governed by state departments such as an US Environmental

Protection Agency (US EPA). These cluster systems are typically viewed as small sewers and must comply with state engineering requirements for wastewater collection, treatment, and dispersal/reuse systems. A number of states, such as Idaho and Massachusetts, have issued design guidelines for medium-large cluster systems.

The importance of groundwater mounding and effluent transport and fate are issues that distinguish between Type I and Type II cluster systems. Because Type I cluster systems transport smaller wastewater volumes, these issues can be addressed in a prescriptive manner, such as minimum setback and/or minimum depth to groundwater/limiting layer requirements. This approach simplifies project evaluation.

Depending upon state requirements, registered sanitarians are generally allowed to design small Type I systems, while registered professional engineers are required to design systems that are larger than small Type I systems.

In Type II cluster systems (and also in Type I systems depending on site conditions) groundwater mounding and effluent transport and fate issues can cause premature system failure and/or unacceptable adverse environmental impacts if they are not properly addressed. Mounding analysis is needed for subsurface dispersal systems to confirm that the dispersal system maintains aerobic conditions and state-specified minimum depths of unsaturated soils. Mounding analysis might determine that a site's dispersal capacity is lower than estimated based upon soil characteristics. Transport and fate analysis is necessary to assess the impact on downgradient environmentally sensitive receptors, such as water supply wells, wetlands, and other receptors. The projected impact on downgradient receptors may dictate higher purified wastewater treatment requirements.

Mounding analysis is not necessary for Type II cluster systems that discharge to surface water bodies. Effluent fate and transport analysis is important for these systems. Typically, this work is done in the form of Total Maximum Daily Load (TMDL) analysis. In many areas of the US, wastewater can represent a significant portion of streamflow, so discharge effluent standards might need to more rigorous. Stringent nitrogen and/or phosphorus removal requirements are common.

The required level of planning and commensurate costs for mounding and transport and fate analysis are site specific and increase as cluster system sizes increase. These project costs can be significant components of project development costs. This handbook provides screening techniques for mounding and transport and fate analysis in Chapter 3, *Typical Challenges and Emerging Issues for Cluster Wastewater Management*. In many situations, planning of cluster systems is best performed by first (or early in the planning phase) quantifying the capacities and constraints of the dispersal system. In addition to technical issues, planners need an early understanding of regulatory requirements for all cluster systems.

Water reuse systems are becoming more common due to water supply scarcities and limited or constrained dispersal options. As treatment requirements increase, the marginal costs to produce clean effluent for water reuse decline and thereby make water reuse economically more attractive. In these cases, the costs of the water reuse distribution system may become the primary determinant of economic viability. In a growing number of situations, water scarcity or dispersal system limitations may dictate the economic viability of water reuse.

Cluster systems can perform as well as the most advanced centralized wastewater treatment facility when measured by biochemical oxygen demand (BOD), total suspended solids (TSS), total nitrogen (TN), total phosphorus (TP), disinfection, and other parameters.

Cluster Systems within Various Contexts

Cluster systems can be used in a variety of contexts. This handbook addresses the following applications:

- Community-Wide Wastewater Management
- Parcel Development
- Defined Wastewater Needs Solution

Community-Wide Wastewater Management—Cluster systems enable communities to develop a rich array of wastewater solutions that optimize economic and environmental objectives and avoid the difficulties and adverse impacts of solely centralized or onsite options. The Concord, MA, and Mayo, MD, case studies described throughout this handbook illustrate this application.

Parcel Development—Cluster systems enable landowners and communities to optimize environmental and economic issues associated with land development. Many communities have subdivision regulations that encourage cluster development for land use purposes and provide incentives for cluster system use.

Defined Wastewater Needs Solution—Cluster systems can provide a wastewater management solution where onsite systems are not technically viable and sewers are prohibitively expensive, not available, or not desired due to unfavorable secondary impacts. This handbook focuses briefly on an application where a cluster treatment system (sometimes referred to as a satellite plant) is used to address inadequacies of centralized sewer systems (Landers 2003) (White 2001). Centralized sewer system failures are usually related to capacity, such as combined sewer overflow (CSO) problems.

Some communities and residents view cluster systems as a threat since they may enable development of previously unbuildable land. The land use and growth implications of cluster systems are significant and should be addressed in a proactive manner. Cluster systems eliminate the reliance on sewer availability for land use or reliance on site ability to comply with prescriptive septic system codes. In this regard, cluster systems are an opportunity and they can be a compelling factor for improved land use planning. From a proactive perspective, cluster systems can enable development to occur in a more environmentally and economically favorable manner. From a reactive perspective, cluster systems can open up land that was considered unbuildable and/or allow higher densities.

Regardless of the context in which cluster systems are used, the growth stimulation of their sewering component has been a significant issue (and sometimes a barrier) associated with their use. The growth management issue and mitigation options are discussed in Chapter 3.

Importance of Cluster Systems to Decentralized Wastewater Management

Decentralized wastewater management is defined as the integration of onsite, cluster, and centralized systems in an economically and environmentally optimal manner within a sustainable management framework that is consistent with land-use and growth plans. Cluster systems play a critical role in decentralized wastewater plans by enabling an optimal mixture of onsite, cluster, and centralized systems to be achieved in area-wide (town, county, and other local areas) wastewater management.

Handbook Objectives

This handbook has two objectives. First, it outlines a comprehensive wastewater management planning process that enables communities to assess where and how cluster systems are appropriate, and thereby enables the development of an optimized, decentralized wastewater management plan. The handbook outlines planning steps from initial data collection to the development of a final preferred solution plan. The challenges of soil and hydrogeological issues, growth management, land-use planning, public participation, and regulatory issues, and how these factors impact the planning process, are discussed in detail, especially in Chapter 3.

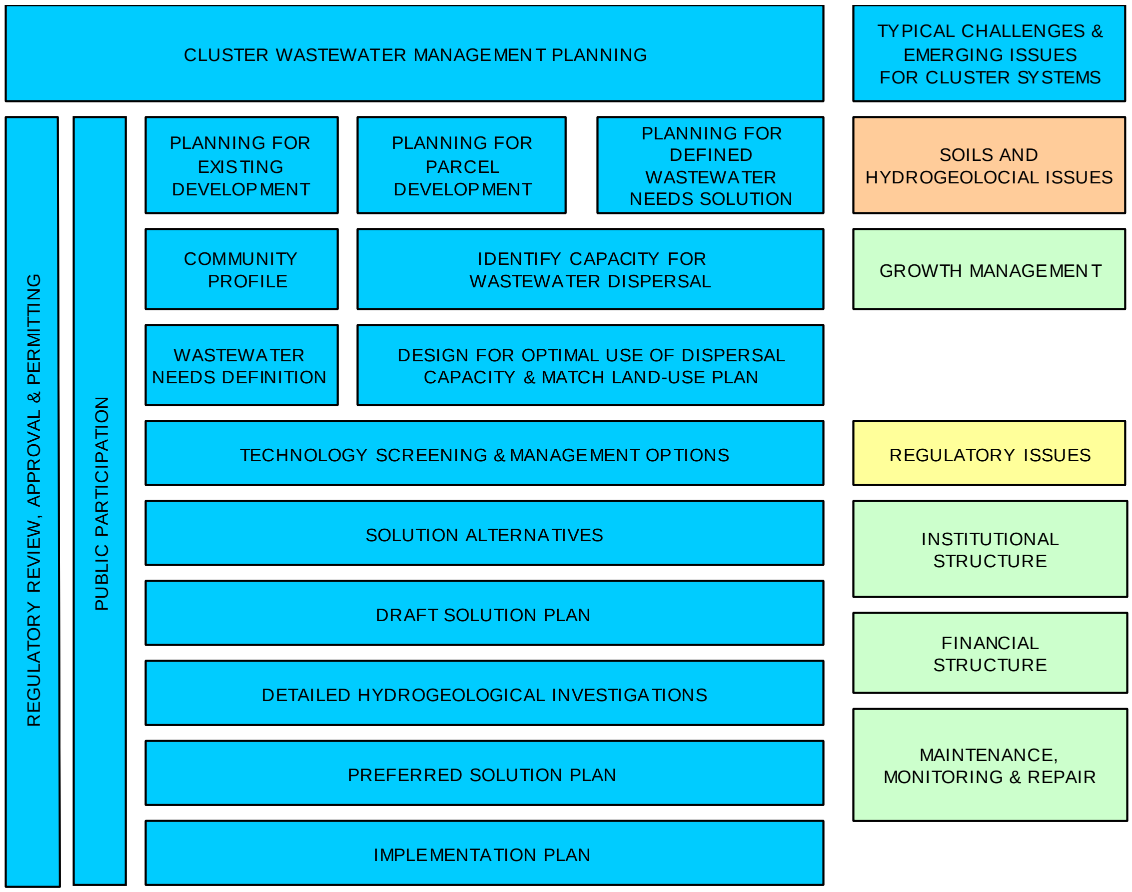
Second, the handbook provides technical and planning information to assist land-use planners, engineers, developers, and other stakeholders in developing and implementing cluster wastewater systems. The handbook presents the operation principles, typical applications, design parameters, and operation and maintenance requirements for specific wastewater collection, treatment, and dispersal technologies appropriate for cluster systems.

The handbook is not a comprehensive guide to the engineering of cluster wastewater systems or decentralized wastewater management. A wide variety of relevant leading publications and resources produced by the US EPA and other public and private sources are provided throughout the handbook for obtaining more in-depth information on particular issues.

Cluster Systems Planning

Figure 1-1 depicts a schematic of the cluster wastewater management planning process. The initial phases of cluster wastewater planning depend on whether the system is being developed for an existing community, a parcel development, or a defined wastewater need. Regardless of the context in which this planning takes place, cluster systems result from comprehensive planning that integrates the technical, environmental, regulatory, economic, financial, political and management issues.

Figure 1-1
Cluster Wastewater Systems Planning Process



Cluster systems within community-wide wastewater management plans begin with the development of a community profile based on socioeconomic, demographic, water resources, soils, geologic, political, and other data. At this stage, existing land-use plans should be considered, as well as how wastewater planning is to be compatible with these plans. Many land-use plans (that is, zoning) are developed when only onsite and centralized sewer options are viable, revising the land-use plans might be appropriate to allow cluster wastewater systems. Revising land-use plans can be a long and complicated process replete with legal and political challenges, especially when property rights are being addressed. The benefits of improved land-use plans may warrant this effort in certain locales. Chapter 3 presents some techniques that have been used to address property rights and land-use plan revisions.

The community profile is followed by a wastewater needs assessment. Detailed lot-by-lot analysis has proven to be a highly effective technique to perform such wastewater needs assessments. This analysis identifies properties that require off-site solutions and thereby the minimum areas requiring sewers. The detailed lot-by-lot approach has been in use on a limited basis since at least the early 1980s. This approach has become increasingly widespread since the advent in the 1990s of powerful computerized geographical information systems (GIS) software and the increasing availability of GIS data. This handbook describes the detailed lot-by-lot technique and opportunities for greater optimization through this analysis. Whether using a detailed lot-by-lot basis or an area-wide basis, the needs assessment process is the same, with the level of detail varying (site-specific conditions versus averages, respectively).

In the new parcel development context, the handbook recommends that the initial wastewater planning step consist of determining wastewater dispersal or disposal capacity and designing the parcel development to optimize this dispersal capacity.

Planning for defined wastewater needs requiring a solution also begins with identifying wastewater dispersal or disposal capacity, followed by considering water reuse and expansion of the area of consideration.

Following the initial planning steps, the wastewater management planning process is the same for the three context types and consists of:

- Screening technology and management options
- Evaluating and ranking technical solutions
- Identifying capacity for wastewater dispersal
- Drafting a solution plan
- Investigating hydrogeological or surface discharge (detailed)
- Developing a preferred solution plan
- Defining an implementation plan
- Establishing institutional structure
  - Management
    - Administration
    - Maintenance
    - Repair/replacement
    - Use regulations
    - User-charge system
  - Financing
  - Scheduling

Public participation is important at all stages of planning, as well as during the implementation process. Communities and private entities must develop and maintain public awareness of wastewater issues and planning efforts in order to sustain public support for the necessary wastewater solutions. The structure of the public participation program will depend on the context of the cluster system application.

Regulatory requirements should be identified during the initial stages of cluster system development. In addition to health department and/or state environmental regulatory agency requirements, the location and/or size of a cluster system may require compliance with other regulatory requirements, such as those associated with working within wetland buffers, near historical sites, or other protected areas. System size may require preparation of environmental assessment reports. Consideration of regulatory issues is critical throughout the planning process.

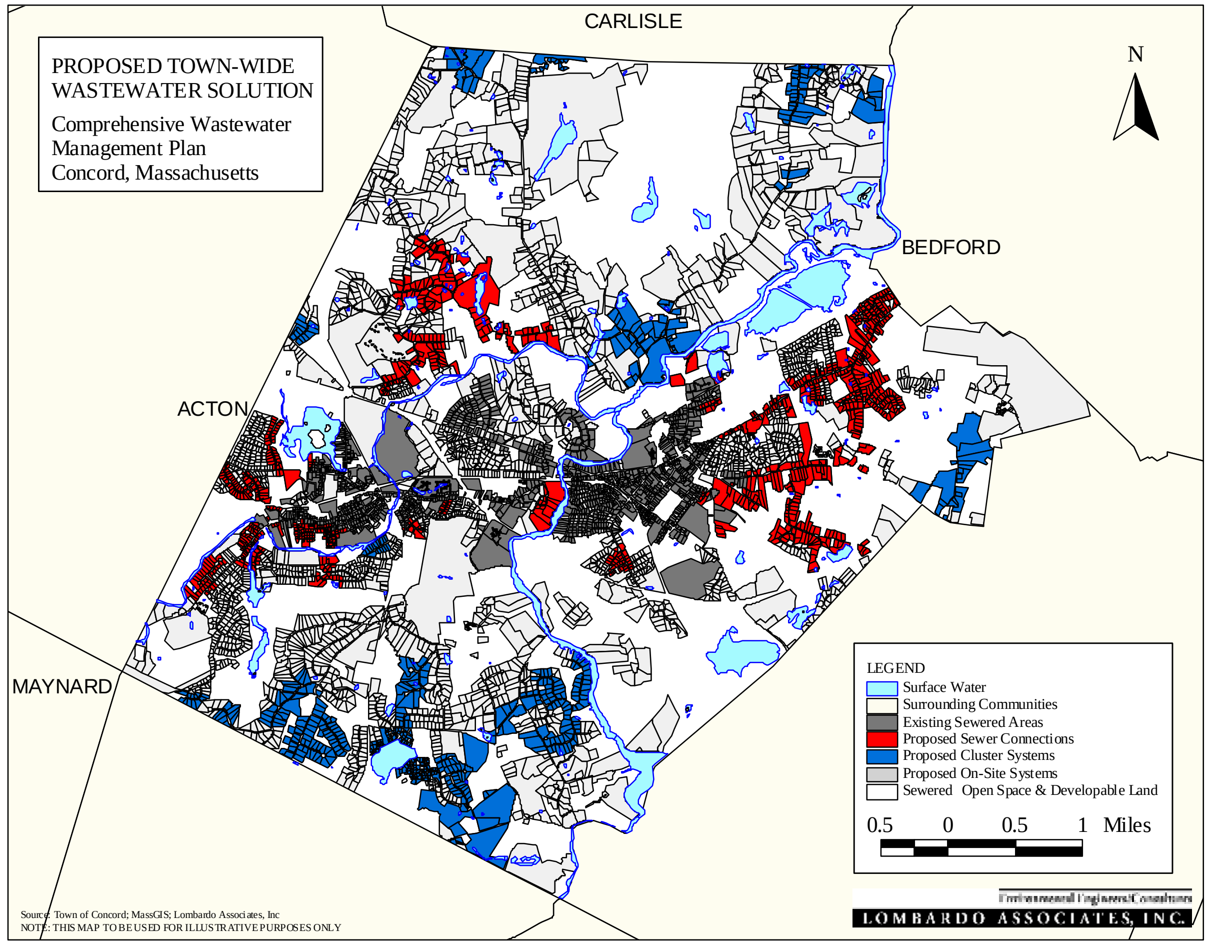
Regulatory requirements for cluster systems—especially for public health protection, which vary depending on the jurisdiction and system size—may limit the location and options for dispersal. Also, in part due to potential growth stimulation effects of cluster systems, some states only allow cluster systems to be used for correcting existing wastewater needs and not for new development.

Development of a management system as critical to the success of a cluster plan. A management system not only provides direction for implementing the wastewater plan, but also includes tools for permanently maintaining the cluster system plan. There are public, private, and combined options for wastewater management. Traditionally, centralized wastewater systems have been managed publicly, while onsite and cluster systems have been managed privately, with some general public oversight. The lack of management and oversight of cluster wastewater treatment plants was a major cause of their performance difficulties in recent decades. Consequently, many states that allow cluster systems require long-term operations and maintenance programs and user-charge systems that provide for system replacement when the wastewater system reaches the end of its useful life. Responsible Management Entities (RMEs) are also necessary for the proper functioning of cluster systems and certification that water quality is being protected as planned. RMEs can be public or private entities.

For the community context, the planning process should result in a vision map that illustrates areas where onsite systems are suitable, where centralized sewer systems are appropriate, and where cluster systems are appropriate. Figure 1-2, Figure 1-3, Figure 1-4, and Figure 1-5 present examples of vision maps for projects that have been implemented (Woodstock, NY in the early 1980s and Mayo, MD in the late 1980s) and recent planning projects (Concord, MA in 2001 and Portsmouth, RI in 2003).

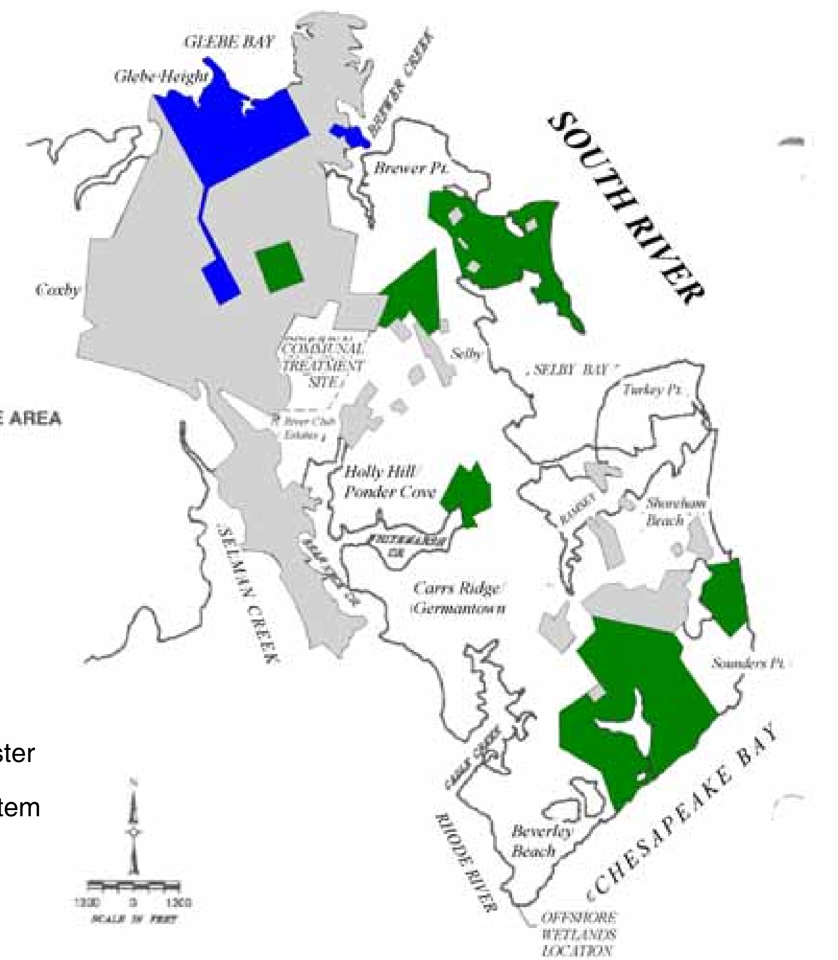
Figure 1-2
Cluster Systems Vision Map for Concord, Massachusetts

	Maximum Alternative
Included Parcels Requiring Off-Site Solutions	387
Included Parcels With Other Wastewater Needs	266
Included Parcels With No Identified Wastewater Needs	726
Build-Out Potential	166
Total Parcels Included in Off-Site Solutions	1,495
Parcels Requiring Off-Site Solutions Within Existing Sewer Area	35
Parcels Requiring Off-Site Solutions to be Addressed by Variances	15
Non-Problem Systems	2,304
Total Existing Developed, Unsewered Parcels	3,849



Source: Lombardo Associates, Inc. (2000)

Figure 1-3
Cluster Systems Vision Map for Mayo Peninsula, Maryland

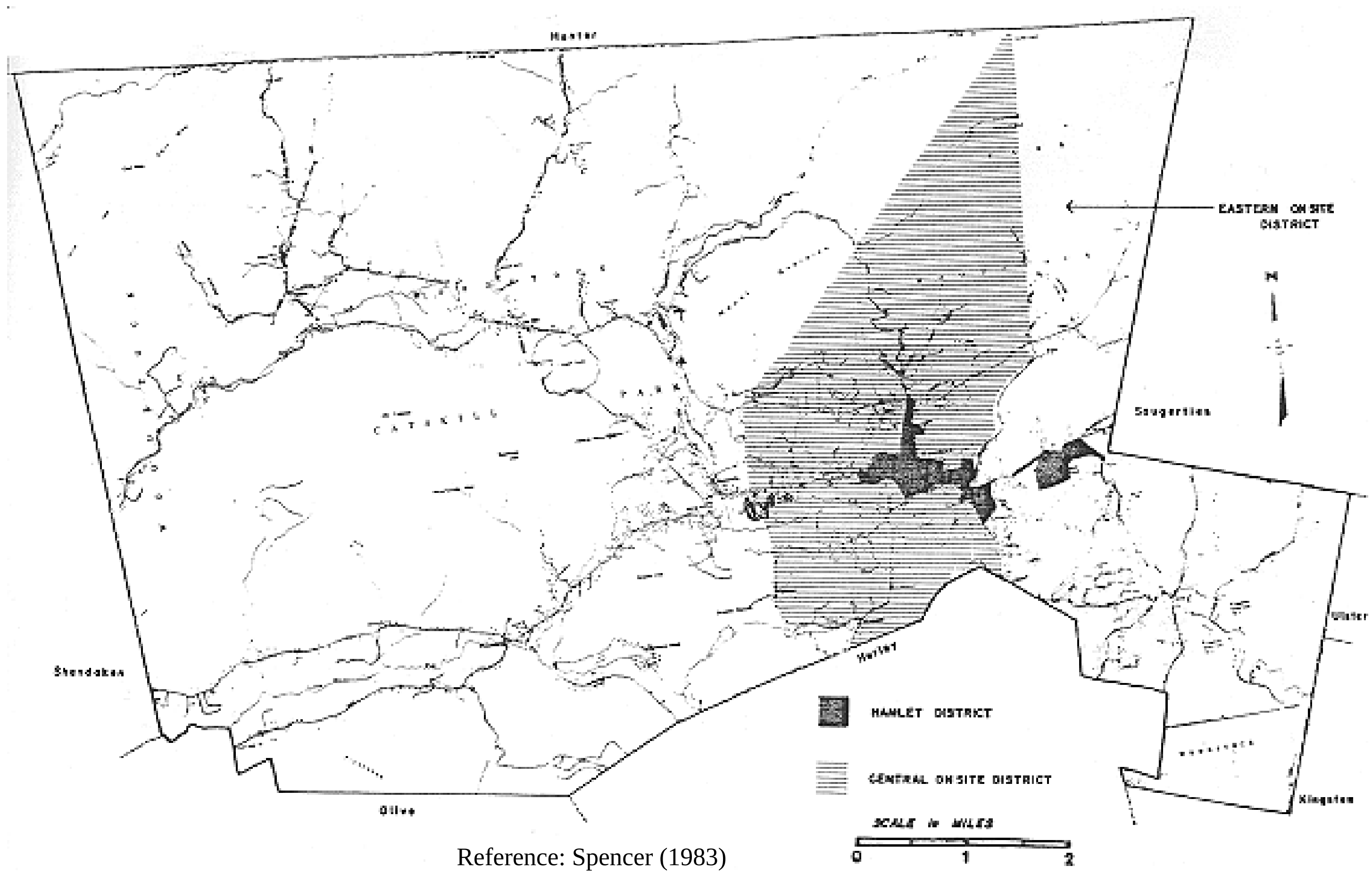


Overview

- Variety of cluster systems
- Decentralized plan consisting of
  - Subsurface discharging cluster
  - Subsurface discharging system
- Independent of regional system

Source: Lombardo & Neel (1986)

Figure 1-4
Cluster Systems Vision Map for Woodstock, New York



Reference: Spencer (1983)

Overview

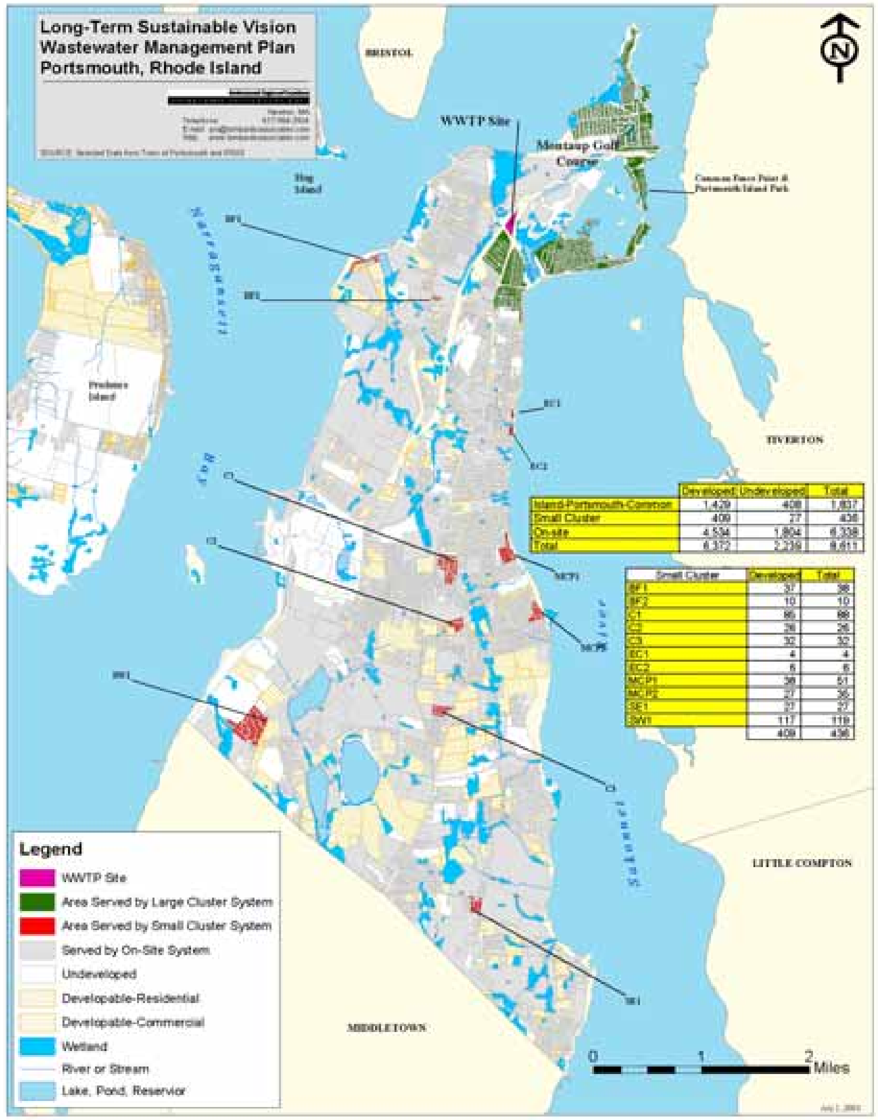
- A Type II surface discharging cluster system serving 432 properties in the commercial hamlet area
- Seven small Type I cluster systems in the onsite wastewater districts. Each cluster generally served two to three properties.

Figure 1-5
Cluster Systems Vision Map for Portsmouth, Rhode Island

Overview

- Twelve Type I cluster systems
- Large Type II system with a golf course subsurface dispersal system
- Lower cost salvaging enabled for 4,534 onsite systems

Source: Lombardo Associates, Inc. (2003)



Handbook Organization

Chapter 2, *Cluster Wastewater Management Planning* details the wastewater management planning process. Chapter 3, *Typical Challenges and Emerging Issues for Cluster Wastewater Management* provides more in-depth information on soils and hydrogeological issues, growth management, public participation, and regulatory issues—four key issues for wastewater management with cluster systems. Chapter 4, *Cluster Wastewater System Management Approaches* presents options for cluster systems management. Chapter 5, *Decentralized Wastewater Technologies* provides description, performance, application, and design parameters for technologies suitable for cluster systems wastewater collection, treatment, and dispersal/reuse. Case studies are used throughout the handbook to illustrate important concepts, and flow charts emphasize the decision-making process with respect to cluster systems planning, design, and implementation.

2 CLUSTER WASTEWATER MANAGEMENT PLANNING

Wastewater management planning for cluster systems involves numerous steps, from initial data gathering to final development of the implementation plan (Figure 2-1). While the initial steps required to develop a cluster wastewater management plan differ for communities, new parcel development, and defined wastewater needs, the final steps of the planning process are the same for all (Figure 2-1 and Figure 2-2). The purpose of this chapter is to describe the community wastewater planning process so community leaders, planners, and consultants can understand how to define the need for cluster systems and determine where they are appropriate and viable. The following sections detail all of the planning steps communities need to follow.

The importance of the needs definition process step cannot be overemphasized. Many wastewater plans have been developed that propose sewering solutions to large areas of a community based upon the perceived need to provide off-site (that is, sewering) solutions. To satisfy this perceived need, planners generally propose a large centralized system at great expense. When detailed needs definition is performed, the areas requiring sewers can be significantly reduced, making cluster systems an option. The Holliston, MA case study illustrates how a precise needs definition using lot-by-lot analysis resulted in a $28 million decentralized plan versus a $65 million plan with an area-wide subjective needs analysis (Lombardo Associates, Inc. 2002b).

In addition to outlining key concepts related to each step in the cluster systems planning process, this chapter presents details from two planning case studies to illustrate how communities can proceed. The first case follows the town of Concord, MA, as it developed a comprehensive wastewater management plan, including cluster systems, in the year 2000. The second case follows Portsmouth, RI, as it developed a town-wide decentralized wastewater management plan in 2002. These cases provide examples of planning for cluster systems on a community scale and addressing the needs of both existing and future development.

Assessing how cluster systems can be used as part of a community wastewater plan would be impossible without discussing how they can be integrated with onsite and centralized systems to produce an optimal wastewater management plan. Once the context in which cluster systems are needed and can be used is understood, then they can be successfully developed and implemented.

Cluster systems are used in three application contexts in this handbook:

- Community-Wide Wastewater Management
- Parcel Development
- Defined Wastewater Needs Requiring a Solution

Figure 2-1
Steps for Cluster Wastewater Management Planning

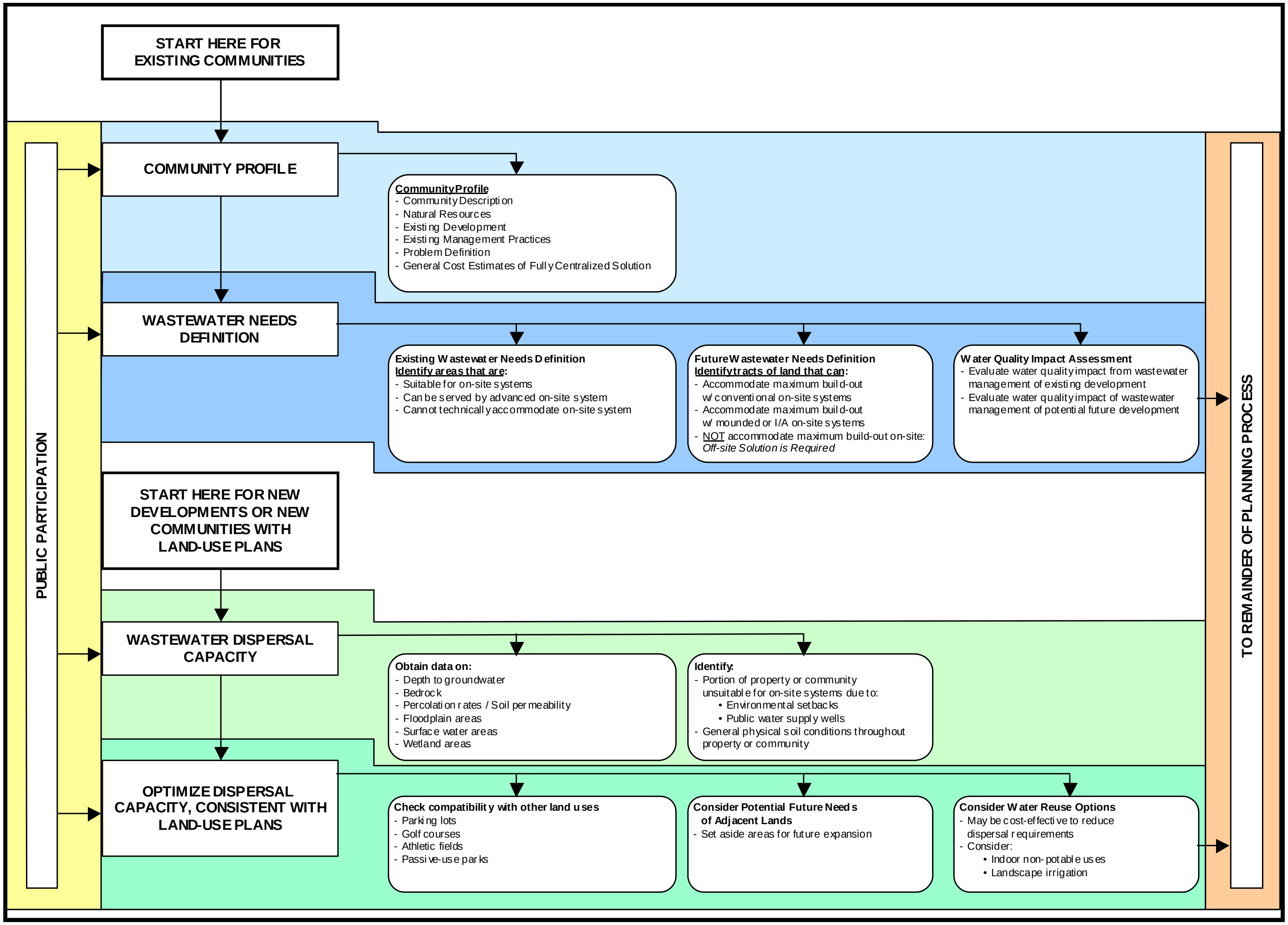
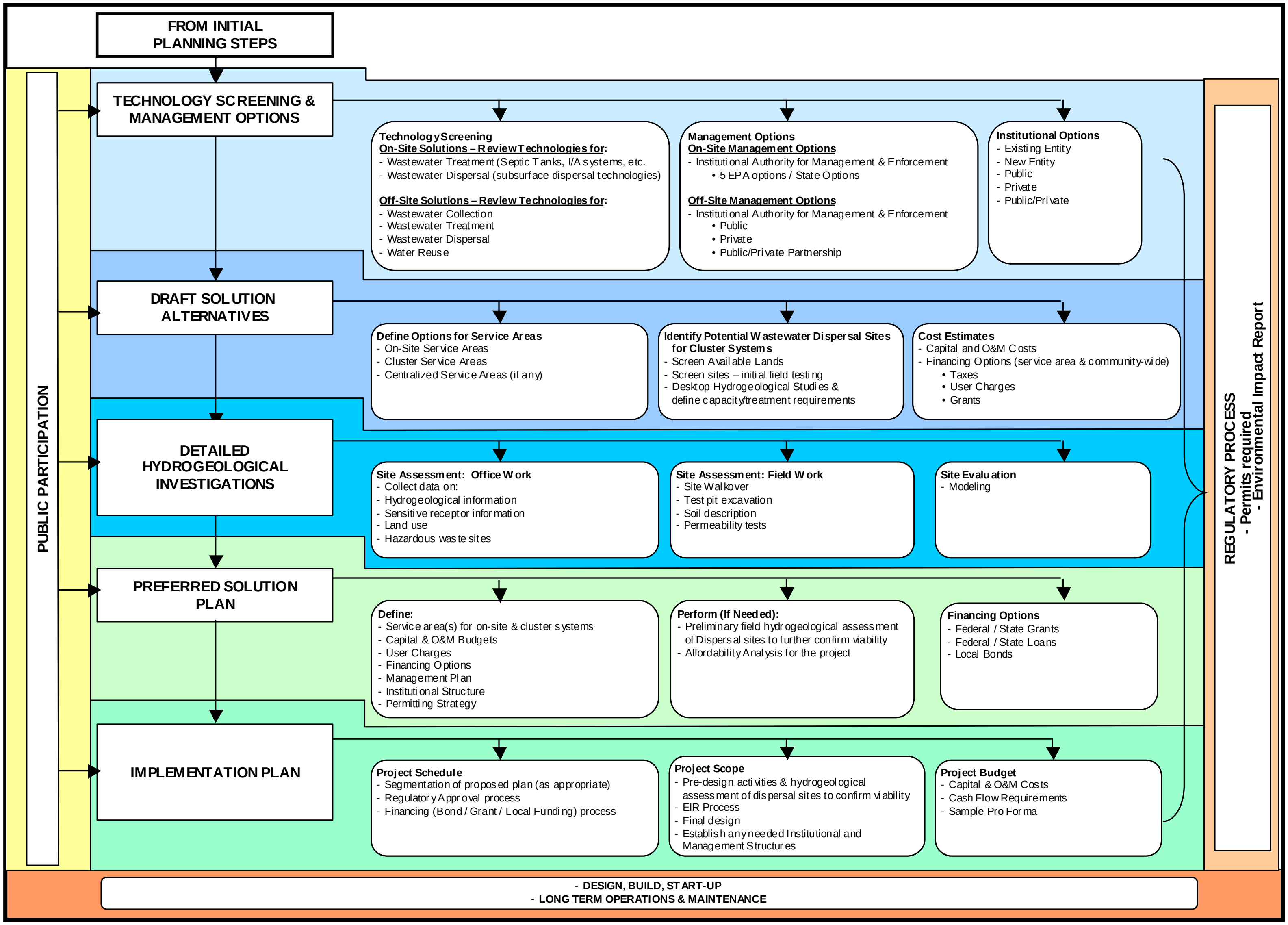


Figure 2-2
Final Steps for Cluster Wastewater Management Planning



While wastewater management planning for communities is primarily the domain of public agencies, private developers acting as property owners direct the planning for parcel development. Property owners, public, and/or private (or a combination), direct the development of a solution for a defined wastewater needs situation. Wastewater engineers are an integral part of planning for all three applications as consultants to the property owners or community leaders responsible for area-wide planning.

Wastewater management planning for communities can be challenging. Historic development practices, unplanned growth, and changing usage patterns for existing development all make it difficult and costly to resolve wastewater management problems and define wastewater needs. Further, the implications of existing land-use plans for wastewater planning need to be considered. Planning for parcel development tends to be more straightforward than planning for communities since development patterns can be better optimized to the physical constraints and capabilities of the land. Planning for large areas and/or new communities presents an opportunity to develop a comprehensive wastewater management plan that optimally matches the physical capacity of the land and water ecosystem with the planned development patterns of the community. Planning for defined wastewater needs is also fairly straightforward. Development of a viable solution that is cost-effective and environmentally compatible is the challenge for every situation.

The comprehensive decentralized wastewater planning technique described in this chapter is designed to assist planners and engineers dealing with undefined or poorly defined wastewater needs. For planners addressing well-defined wastewater needs, a simplified version of the planning process detailed here may still be helpful (that is, without the Community Profile and Needs Definition steps shown in Figure 2-1).

Community/Project Profile

The first step in the wastewater planning process is to develop a community or project profile, or statement of existing conditions. The community profile serves to:

- Familiarize the stakeholders within the community, past planning efforts, and the need for the wastewater management plan
- Identify key issues and problems that will require special focus
- Determine the availability of key data required for subsequent steps in the planning process

To accomplish these objectives, planners will need to compile, synthesize, and present data from a wide variety of sources on many different topics. Table 2-1 outlines the data that should be included in the community profile. The community profile does not need to be an exhaustive inventory of information; rather, it should be a comprehensive, focused compilation of existing relevant information and data that is pertinent to wastewater management.

For most communities, not all of the data listed in Table 2-1 will be available. Other information can often be used as surrogates when the desired data is nonexistent, unavailable, or prohibitively expensive to obtain. Suggested data surrogates are listed where applicable.

Table 2-1
Community Profile Data

Data
Population, Demographic, Cultural Characteristics • Population (*age distribution, recent and historical growth trends, growth projections*) • Relevant cultural and historical characteristics
Economic Characteristics of the Population, Industries, and Community • Median household income • Major industrial, commercial, professional activity • Town finances *(recent annual budgets, major expenditures, debt profile, total property valuation)*
Land Use • Residential, commercial, industrial data • Zoning • Existing land use • Development potential and build-out analysis • Determine the need to update the comprehensive land-use plan as part of this effort
Natural, Hydrological, and Physical Features *Natural Features* • Location • Climate *Hydrological Features* • Surface waters, watersheds, and wetlands • Floodplains • Groundwater aquifers—location and characterization • Water supply and source water protection areas *Physical Features* • Topography, areas of steep slope • Geology • Surficial geology • Soils

Table 2-1
Community Profile Data (Cont.)

Existing Wastewater Infrastructure	
Existing Centralized and Cluster Infrastructure Service Areas • Collection systems, • Treatment systems, • Dispersal/Reuse: Type, age, condition, capacity, availability • System ownership management	**Existing Onsite Infrastructure Service Areas** • Septic system design information • Septic system ownership • Septage pumping/repair and maintenance records
Existing Water Supply Infrastructure	
Community-Wide and Neighborhood Systems • Water source (wells and surface water withdrawal) • Service areas • Water usage • Source Water Assessment Programs (SWAP)/Source Water Protection Plans (SWPP)	**Properties on Individual Wells** • Well location • Water usage
Existing Management, Institutional, and Regulatory Environment	
• Department of Health regulations • Department of Public Works • State regulations • User fees	• Existing water/wastewater responsible management entities (RMEs) • Local units of government • Other utility RMEs

Throughout preparation of the community profile, it is helpful to keep these objectives in mind:

- Provide a broad, comprehensive, contextual introduction to the community
- Identify key issues relevant to wastewater management
- Identify key data needed for subsequent steps of the planning process

Execute professional judgment when pursuing information or degree-of-detail that does not efficiently address these objectives.

Depending on the locale, much of the data useful for cluster wastewater management planning is now or is becoming available in digital GIS formats from various governmental offices ranging from the local to national levels. Some towns, counties, and states have compiled Internet-based GIS data clearinghouses where a surprising variety and depth of data are now available. Many federal agencies that produce the data or maps used in the analysis also have websites where their various data layers are available for purchase or direct download. Examples of web-based GIS resources useful for wastewater management are listed in Table 2-2.

Table 2-2
Internet Resources for GIS and Community Information

Internet Address	Information Available
www.census.gov	Data and analysis from the 2000 US Census. Earlier census data also available.
www.esri.com/data/online/index.html	• Spatial address indexed road (TIGER) files • Floodplain maps produced by Federal Emergency Management Agency (FEMA) • USGS topographic maps (not free—USGS topographic maps are available for free download at many state GIS web sites) • Orthophotography (not free—orthophotography is available for free download at many state GIS web sites)
www.nwi.fws.gov	National Wetlands Inventory (NWI) maintained by the US Fish and Wildlife Service. (Derived from 1:250,000 scale maps)
www.state.ma.us/mgis/giswww.htm	Excellent listing of on-line GIS clearinghouses for all 50 states, and many non-governmental clearinghouses.
ngmdb.usgs.gov/	Database of USGS maps, publications, and reports pertaining to surface and groundwater resources.
www.nrcs.usda.gov/about/organization/regions.html	Contact information for local National Resource Conservation Service (NRCS) offices.
www.ftw.nrcs.usda.gov/stssaid.html	Index of regional soil surveys (1996 and newer) available for direct download from NRCS.
www.state.XX.us	Home page for all states (insert the state's two-letter postal code for "XX"). GIS resources can be found through these pages.
www.uri.edu/ce/wq/ www.deq.state.or.us/wq/onsite/onsite.htm www.epa.gov/owm/ www.nesc.wvu.edu/nsfc/ www.barnstablecountyhealth.org/AlternativeWebpage/index.htm www.onsiteconsortium.org/ www.deh.enr.state.nc.us/oww/ www.o2wa.org/ www.ces.purdue.edu/onsite/ www.towtrc.state.tx.us/ www3.extension.umn.edu/water/ www.vdh.state.va.us/onsite/index.htm	Technical and regulatory information on Type I cluster systems

Case Study: Community Profile for Concord, MA

The Concord community profile incorporated data from the public works department and planning board, as well as the US Census Bureau, the US Geological Survey, and the Natural Resources Conservation Service. Some of the key characteristics of the community the planners identified were:

- Total area of 25.9 square miles, including 1.0 square miles of surface water bodies
- Population of 15,200
- Development potential of 647 potentially developable parcels on 212 existing sub-dividable lots and 85 grandfathered lots
- Variable depth to bedrock
  - Rises to surface in some locations
  - Over 100 feet deep in other locations
- Largely well-drained soil with moderate to rapid permeability and depths to groundwater typically greater than six feet below ground, with numerous pockets of soils with moderate to rapid permeability and seasonally high groundwater between 18 to 36 inches below ground surface
- Reliance on groundwater as sole water supply source
- 5,570 developed properties with:
  - 1,721 properties sewered by conventional gravity sewer systems with discharge to the Concord River
  - 3,720 properties with septic systems

Wastewater Needs Definition

This section addresses the wastewater needs definition, including:

- Approach
- Purpose
- Required Data
- Lot-by-Lot Wastewater Needs Definition Methodology
- Products of the Wastewater Needs Definition

Approach

There are a variety of ways to perform the wastewater needs definition (Lombardo 1978; Joubert *et al*. 2003, 2004; US EPA 1980, 1988). The fundamental questions and issues raised and answered by needs analyses have often been answered by relatively generalized studies that analyze conditions on, at best, the precinct or neighborhood level. There are many difficulties with using this kind of large study area approach:

- Field conditions and land uses may vary widely within individual study areas.
- Analyses typically apply smoothing or averaging techniques to available data, restricting opportunities to pinpoint specific causes of identified wastewater needs and to optimize subsequent solution alternatives.

In practice, two major problems result from using the generalized approach:

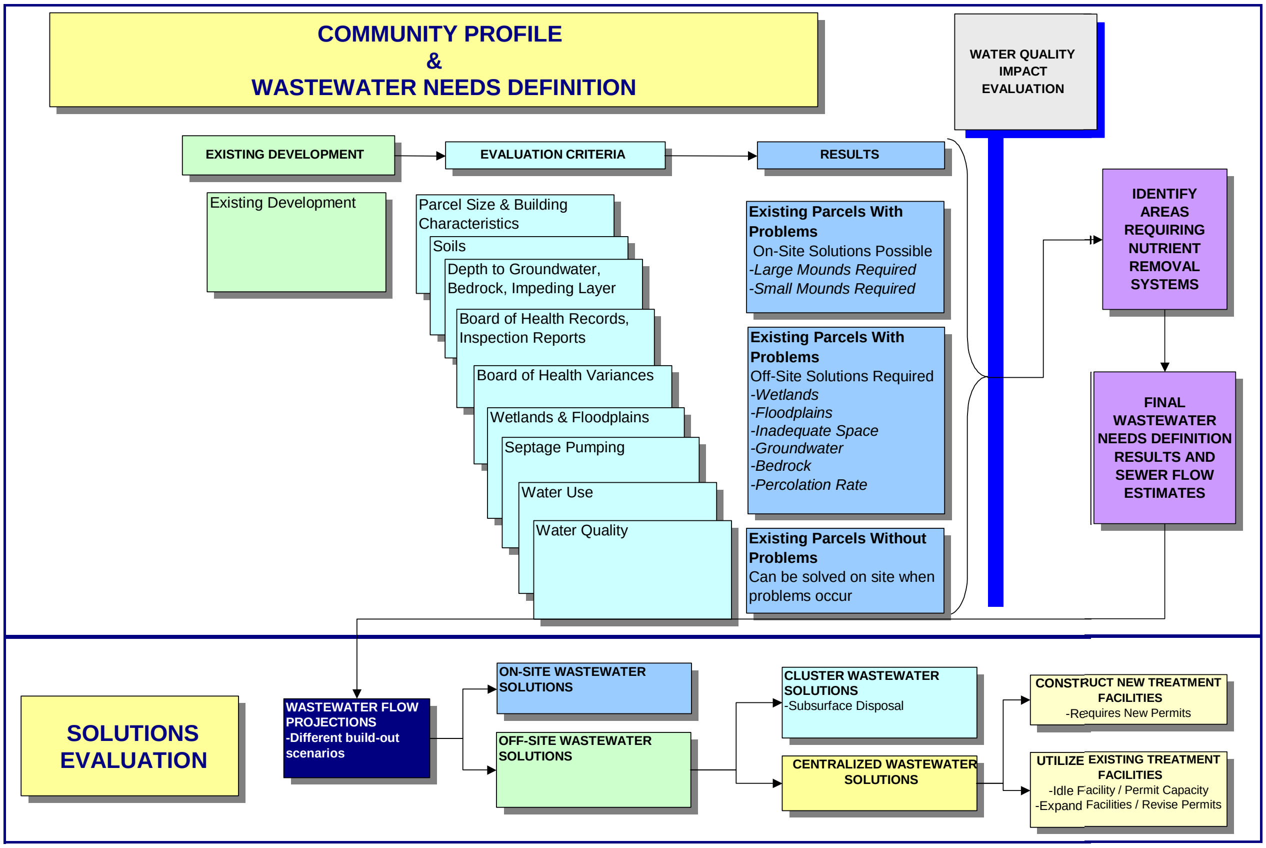
- Overlooking small areas with wastewater needs
- Grossly overestimating wastewater needs

There are large public capital expenditures involved in wastewater management. Considerable public health and environmental implications result from improper wastewater management. For these reasons alone, detailed lot-by-lot wastewater needs definition can have clear financial advantages over more generalized, less accurate approaches. Unfortunately, some wastewater planning studies have defined wastewater sewering needs using a qualitative ranking in which 50 percent of the community needs sewers by definition.

When possible, the preferred method for performing the wastewater needs definition is by a detailed lot-by-lot analysis. In this approach, illustrated in Figure 2-3, the community reviews all available information for each lot and determines whether it may have an existing wastewater problem or future need when its existing system fails. This determination is based on physical data, current regulations, and design flows. This approach is the most accurate means of determining wastewater needs. With the use of computerized GIS, it has become one of the most cost-effective methods as well. Such GIS analysis should be supplemented with homeowner validated input (Clark 2001). Property owners in the Concord, MA case study were sent the results of the analysis. For the six percent who did not initially agree with the conclusions, further communication eliminated any disagreements. Depending on data availability, the detailed lot-by-lot analysis will determine lots that require off-site solutions based upon:

- Lot size
- Soil type and characteristics
  - Hydraulic conductivity
  - Depth to limiting layer
- Onsite well or community water supply service
- Wastewater treatment system design requirements

Figure 2-3
Wastewater Needs Definition Process for Existing Wastewater Needs



The detailed lot-by-lot approach is:

- **Fact-Driven**—This helps to minimize the debate and controversy that can surround the wastewater planning process.
- **Transparent**—The conclusions are easily traceable back to the source data, factors, and considerations driving the wastewater planning process. When the identified wastewater needs or proposed wastewater solution for a parcel or neighborhood requires review or revision, it is addressed easily by returning to the base data and identifying the specific information and factors responsible for the decision. Experience has shown that this transparency can help to build overwhelming agreement with the wastewater needs defined with this method. Transparency can build credibility.
- **Easily Understood**—The straightforward analytical approach demystifies wastewater management planning, both for stakeholders and the general public. This enables all participants to engage and fully understand, contribute, and support the wastewater management planning process.

- **Consensus Building—**The transparent analytical approach and concise outcome generated by the detailed lot-by-lot approach helps to build consensus and support within the community by emphasizing facts and objectivity. By developing a broad base of support for the wastewater planning process, this method helps the community to focus on creative alternatives for community wastewater solutions based on a sound foundation of needs definition, rather than circuitously debating the existence, magnitude, cause, and location of wastewater problems and needs.
- **Focused on Optimization—**By efficiently disarming polarizing issues with rational, factually-driven discourse, the detailed lot-by-lot approach focuses resources on optimizing solutions, which provides projects with considerably greater value.
- **Engaging—**By addressing the issues associated with a person's property, projects become real to the public.

The detailed lot-by-lot approach allows for maximum flexibility in evaluating various solution options. In an existing community, the detailed lot-by-lot approach should be applied to parcels with existing onsite systems—not to parcels connected to a centralized sewer. For new development, the detailed lot-by-lot method should be applied to parcels where onsite systems are in fact a viable option, which may require preliminary analysis of soil characteristics.

Due to the interdisciplinary nature of cluster wastewater planning, wastewater planners generally need to depend on outside consultants to assist in the planning process. The kind of consultants needed will depend upon the complexities of the project and the skills of the lead planning organization.

Case Study: Development of Wastewater Needs Definitions for Holliston, MA

The Town of Holliston, MA recently developed wastewater needs definitions using both a general area-wide analysis and specific lot-by-lot method. The lot-by-lot method resulted in a $27 million sewer and cluster system capital cost plan, compared to a $65 million sewering plan based on an earlier area-wide needs definition (Lombardo Associates, Inc. 2002b). The 54 percent lower capital cost based on the lot-by-lot wastewater needs definition easily justifies the marginal incremental cost, if any, of the more detailed needs definition approach.

The additional cost of using the lot-by-lot GIS approach depends on the status of existing information. For communities with little existing GIS information, the setup costs may be prohibitive. These issues should be addressed in the project scoping phase.

Basic components of the GIS lot-by-lot approach are linked to the assessor's database on parcel characteristics and include preparation of:

1. Parcel maps—digitized tax maps
2. Digitized NRCS soils maps
3. Ortho-Photos—building footprints
4. Environmentally sensitive area maps such as
    - Wetlands
    - Flood plains
    - Water supply recharge areas

Purpose

Building upon the community profile, the wastewater needs definition provides the basis for determining where off-site solutions (such as cluster systems) are needed. The wastewater needs definition answers fundamental questions about existing wastewater management needs and practices in the community. A detailed, analytical manner is implemented to answer these questions, which include:

- Where is existing wastewater management practice adequate and why?
- Which wastewater management approach (onsite or off-site) might be appropriate for future planned or zoned development and what are the determining factors? (Off-site approaches are cluster or centralized treatment.)

Specifically, the wastewater needs definition should:

- Classify each parcel’s ability to accommodate an onsite wastewater system according to whether the parcel can:
  - Accept a conventional septic system
  - Accommodate an onsite solution, Innovative/Alternative (I/A) technology, mound, or other onsite system
  - Not accommodate an onsite wastewater solution, requiring an off-site solution (sewer or cluster system)
- Identify the limiting factor(s) for parcels unable to accommodate a conventional or alternative onsite septic system.
- Address data quality issues and implications through a sensitivity analysis.
- Include an estimate of the cost for a completely centralized wastewater management solution.
- Undergo a public validation process, which enables the public (property owners) to individually review and comment on their specific wastewater needs designation. This practice builds public support and buy-in for subsequent solutions.
- Define preliminary sub-areas of wastewater needs by developing wastewater flows and characterizations for each area based on the detailed lot-by-lot results. The sub-areas are groupings of individual lots requiring off-site solutions and do include properties that could rely on onsite systems. This inclusion of “non-problem” lots in a sewering solution (cluster or centralized) can be a polarizing issue in the development of cluster wastewater systems. Checkerboarding districts, as described in Chapter 3, is a method to address this issue.

By combining all of this information, the wastewater needs definition sets the stage for evaluating potential wastewater solutions by precisely defining sub-areas requiring a cluster or centralized solution. Depending on the community’s existing infrastructure and defined wastewater needs, off-site wastewater solutions may include cluster systems or centralized sewer systems.

Required Data

The first step in the wastewater problem definition process is to assemble and integrate the data required for the analysis. Data gathering and compilation is a critically important part of the needs definition process, because the wastewater needs definition will only be as accurate as the data inputs to the analysis. Much of the data is collected in the community profile, and the existing status of any additional needed data will likely already be known.

Figure 2-3 indicates some of the key data used in the detailed lot-by-lot analysis. As was the case for the community profile, not all of this information is vital, and not all of it is generally available for any given community. Limited budgets must be wisely allocated to fill in data gaps in a prioritized manner.

Lot-by-Lot Wastewater Needs Definition Methodology

The wastewater needs definition methodology should identify properties that are suitable for continued long-term reliance upon onsite systems. There are several steps to take in this analysis.

The wastewater needs definition should identify:

- Specific parcels and areas that are currently exhibiting onsite wastewater problems
- Properties that are likely to require off-site wastewater solutions in the future, that is, an onsite, “code-compliant” solution is not possible when the existing system fails.

This process ensures that the community will have a sustainable plan as onsite wastewater problems occur in the future, and as new portions of the community are developed. The analysis should define problem areas in two ways:

1. **Existing Problems Definition—**This analysis identifies properties currently exhibiting septic system functional or performance-related problems. The databases are analyzed for symptoms of functional failure. Additionally, nutrient (nitrogen and phosphorous) impacts on groundwater and surface waters should be estimated to identify areas likely to be contributing excessive nutrients to the surface or groundwater bodies to identify areas requiring nutrient removal systems.

2. **Functional Problems—**Functional problems (that is, the system does not operate as planned or designed) are those properties where the proper functioning of the septic system is impaired with resulting public health problems and nuisance conditions. Symptoms that might indicate such problems include:

   - Excessive septage pumping
   - Surface breakout
   - Plumbing backups (that are not due to plumbing problems, but rather the system not being capable to accept wastewater flow)

- Serious failure to meet current requirements (for example, straight pipes)
- Excessive water use (this data can be used to identify potential problem areas due to hydraulic overloading)

Performance Problems

Performance problems are issues causing the septic system to treat wastewater inadequately for the current and future conditions. Symptoms of such problems include:

- Excessive nutrient (nitrogen and phosphorous) release to groundwater and surface waters.
- Inadequate bacterial treatment, which may result in bacterial water quality degradation of groundwater and surface waters.

The following minimum guidelines are suggested to determine the adequacy of bacterial treatment and may be superceded by local requirements:

1. Minimum of two feet of unsaturated soil for dispersal systems receiving septic tank effluent (STE).

2. Minimum of one foot of unsaturated soil for dispersal systems receiving pretreated and disinfected effluent.

Nitrogen- and phosphorus-related performance problems require a watershed analysis to determine if septic system contributions—in many states referred to as non-point sources—are excessive and in need of reduction.

Parcels that do not comply with these criteria are deemed to have problem/inadequate dispersal systems requiring replacement. Because historical practices for groundwater measurements may have underestimated depth of seasonal high groundwater levels, many dispersal systems were installed on sites that periodically violate the minimum depth-to-groundwater recommendation. For example, in the Concord, MA Wastewater Facility Plan performed by Lombardo Associates, Inc., an analysis of historical (1980–1995) practices of groundwater measurements and current techniques suggests that historical practices underestimated seasonal high depth-to-groundwater by two feet.

The parcels identified as having problems by this analysis do not necessarily require off-site wastewater solutions. Depending on the geographical distribution density and the likely causes of the problems, onsite solutions may be possible. Noting the locations of these areas is important for the cost-effectiveness analysis process.

Long-Term Problems Definition (Existing and Future Parcels)

This method is used to identify properties that can rely on onsite systems as a viable long-term solution and properties that will require an off-site solution when they fail. Communities can develop a sustainable, comprehensive wastewater management plan using this approach.

For this method, the suitability of onsite systems as a viable long-term solution should be assessed for each lot by evaluating septic system design criteria, parcel characteristics, and site restrictions on a lot-by-lot basis. Properties unable to accommodate an onsite system should be designated as requiring an off-site solution (or a variance, as later discussed).

In addition to identifying parcels that require off-site solutions over the long term, this analysis should also identify parcels that, in the future, are likely to have problems that can be corrected on site. This analysis produces a concise, lot-specific map and list of the problem properties in the study area(s). This list should include information about parcels that

- Currently exhibit septic problems and require immediate solutions
- Require off-site solutions in the long term (when their existing systems fail) due to:
  - Environmental (location) restrictions (such as wetland buffers or other protected areas)
  - Inability to meet groundwater separation requirements
  - Unfavorable physical site conditions (lot size, hydraulic conductivity, or other conditions)
- Can rely on repairing septic systems onsite but will require:
  - Increased vertical separation (such as mounds)
  - Advanced pretreatment systems

Even though parcels can be solved on site, it may be more cost-effective to solve them off site, as assessed in the *Cost-Effectiveness Analysis* section. The lot-by-lot approach enables an easy review of the data that produced a given problem classification on a parcel. Generating a comprehensive, digital, lot-specific justification for the problem classification has several benefits, including:

- Making the needs analysis robust to review and critique
- Garnering public support and confidence in the conclusions of the wastewater needs definition, which is critically important
- Defining the minimum areas that require sewers—by cluster or centralized techniques

The definition of the long-term wastewater needs for a study area becomes the basis for developing wastewater solution alternatives that are technically, environmentally, and economically optimized for the area's specific needs over both the short and long term. When finalized, these solution alternatives will become the basis for the community's comprehensive sustainable wastewater management plan.

Watershed Water Quality Evaluation

In many areas, water quality has deteriorated due to inadequate wastewater management practices. Bacterial, nitrogen, and/or phosphorus contributions may be the cause of impaired water quality.

Numerous analytical and computer models exist to enable planners to assess the implications of existing and future wastewater practices on water quality. The models can be simple, such as mass balances, to sophisticated models that integrate hydrology and the complex water quality processes, such as Hydrologic Simulation Program-Fortran (HSPF), in the US EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) package. The US EPA supported models are listed in Table 2-3 and can be found at www.epa.gov/waterscience/wqm/.

Other assessment techniques include DRASTIC, which involves Depth of water, Recharge, Aquifermedia, Soilmedia, Topography, vandose zone Impact, and hydraulic Conductivity. (Aller *et al*. 1987) and MANAGE, that is, Method for Assessment, Nutrient-Loading and Geographic Evaluation (Joubert *et al*. 1999), which are described in the EPA Onsite Manual (US EPA 2000).

Table 2-3
US EPA Supported Models

Model	Description
BASINS: A Powerful Tool for Managing Watersheds	A multi-purpose environmental analysis system that integrates a geographical information system (GIS), national watershed data, and state-of-the-art environmental assessment and modeling tools into one convenient package.
Enhanced Stream Water Quality Model, Windows (QUAL2E)	Simulates the major reactions of nutrient cycles, algal production, benthic and carbonaceous demand, atmospheric reaeration and their effects on the dissolved oxygen balance. It is intended as a water quality planning tool for developing total maximum daily loads (TMDLs) and can also be used in conjunction with field sampling for identifying the magnitude and quality characteristics of nonpoint sources.
AQUATOX: A Simulation Model for Aquatic Ecosystems	AQUATOX is a freshwater ecosystem simulation model. It predicts the fate of various pollutants, such as nutrients and organic toxicants, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants. AQUATOX is a valuable tool for ecologists, water quality modelers, and anyone involved in performing ecological risk assessments for aquatic ecosystems.
CORMIX for Mixing Zones	A mixing zone model that can be used to assess water quality impacts from point source discharges at surface or sub-surface levels.
WASP6	WASP6 is an enhanced version of the Water Quality Analysis Simulation Program (WASP). This version runs more quickly than previous versions of WASP, and allows for graphical presentation of results. This version includes kinetic algorithms for: • Eutrophication/conventional pollutants • Organic chemicals/metals • Mercury • Temperation, fecal coliform, and conservative pollutants

Table 2-3
US EPA Supported Models (Cont.)

Model	Description
EPA Center for Exposure Assessment Modeling	The Center for Exposure Assessment Modeling (CEAM) was established in 1987 to meet the scientific and technical exposure assessment needs of the United States Environmental Protection Agency as well as state environmental and resource management agencies. CEAM provides proven predictive exposure assessment techniques for aquatic, terrestrial, and multimedia pathways for organic chemicals and metals.
EPA Watershed/Water Quality Modeling Technical Support Center	The Watershed/Water Quality Modeling Technical Support Center assists US EPA regions, state and local governments, and their contractors by providing access to technically defensible tools and approaches that can be used to develop TMDLs, waste load allocations, and watershed protection plans.

Products of the Wastewater Needs Definition

In order to properly support subsequent wastewater management planning activities and areas needing cluster systems, the wastewater needs definition should produce the following:

1. Wastewater Needs Definition Results
   - Classify each parcel's ability to accommodate an onsite wastewater system
     - Able to accommodate conventional septic system
     - Able to accommodate onsite only solution with I/A technology and/or mound
     - Likely unable to accommodate onsite wastewater solution; off-site solution (centralized sewer or cluster system) will be required
   - For those parcels unable to accommodate an onsite system, identify the limiting factors preventing an onsite system
2. Sensitivity Analysis

   A thorough sensitivity analysis performed on the parameters used to develop the wastewater needs definition results is important. **Use of actual soils data to calibrate the USDA Natural Resource Conservation Service soils maps is essential**, as discussed in Chapter 3. The sensitivity analysis will enable an understanding of the impact of the various parameters on the results.

3. Public Validation of Results

   Many communities elect to perform a public validation of the wastewater needs definition results in a variety of ways. A combination of public meetings and notification mailers is effective. By asking property owners to personally review and confirm or dispute their specific needs definition, the communities are giving the public the opportunity to individually review and guide the wastewater planning process, which encourages the participants to buy into the project outcomes.

4. Design Information for Solution Development and Evaluation

   - Design flows (current and design/build-out conditions)
   - Nutrient loadings for water quality impact evaluations
   - Estimated cost of onsite solution for cost-effectiveness analysis

5. Watershed Analysis

   The watershed analysis demonstrates that target water quality goals will be achieved and provides the basis for performance needs that require correction.

By defining all of this information, the wastewater needs definition sets the stage for evaluating potential wastewater solutions. Depending on the community's existing infrastructure and defined wastewater needs, off-site wastewater solutions may include cluster systems and centralized sewer systems.

The role of community task forces and outside consultants can be critical in this and other steps in the planning process. Community task forces can perform the important roles of:

- Presenting the project findings in lay terms, since much of the information will be discussed in informal settings
- Being a conduit for expression of local concerns to the planning team

For controversial projects, it may be wise to retain independent experts to render opinions on the project findings and/or efficacy of the proposed solutions. Reaching out to critical stakeholder groups can produce harmonious discussions rather than antagonistic, confrontational ones.

Case Study: Proposed Large Cluster System for Mayo, MD

A proposed large cluster system of 460,000 gpd (900,000 gpd at build-out) in Mayo, MD was to serve 2,300 existing and 4,600 anticipated properties at build-out and was to discharge into Chesapeake Bay in an area within 1,000 feet of active shellfishing and water contact recreation.

Professors from the Massachusetts Institute of Technology were retained to perform modeling studies on water dispersion patterns and dilution predictions. Professors from Johns Hopkins University and the University of Maryland were retained to provide independent opinions in the issues of public health and oyster physiology.

Meetings were initiated with the Maryland Commercial Shellfishing groups to discuss issues of concern. A boat trip was held with the oystermen to review the proposed discharge location and oyster shellfishing issues.

The lead Maryland State regulator of shellfish issues was proactively involved in numerous meetings and review of preliminary plans.

The result of the use of these independent experts and outreach efforts was a community buy-in of the wisdom and viability of the proposed plan with a community vote in favor of the decentralized plan by a margin of 7-1 (Lombardo Associates, Inc. 1985).

Case Study: Wastewater Needs Definition in Concord, MA

A lot-by-lot wastewater needs definition approach was used to define the wastewater needs in Concord. Data were collected from various sources and consolidated into a GIS database. These data included, among others:

- Lot size
- Location of environmentally sensitive areas
- Soil suitability
- Depth to groundwater
- Water consumption

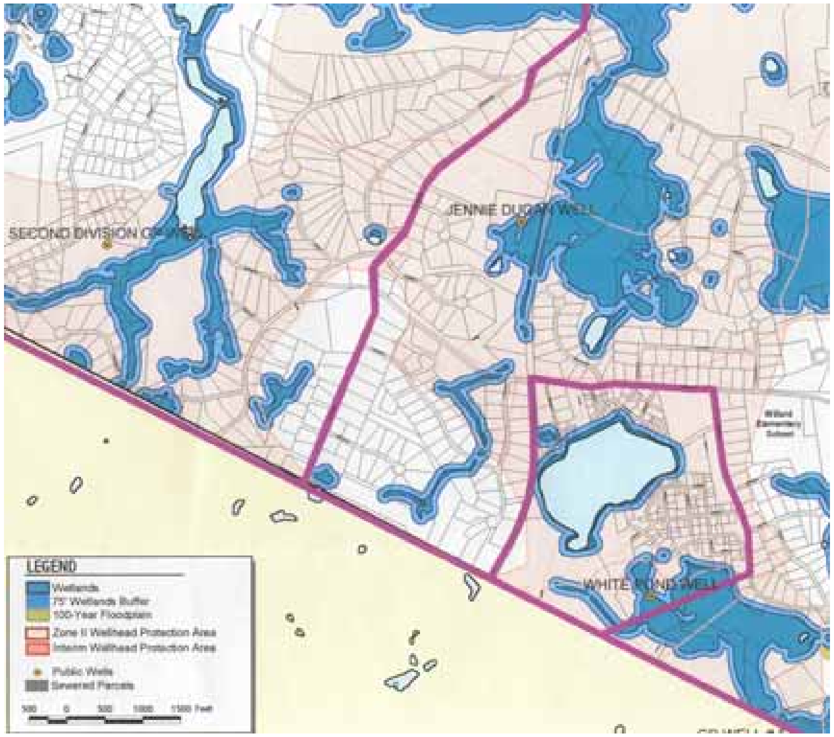
Examples of maps produced with some of these input data are shown in Figure 2-4. The data were then analyzed using GIS software to produce a lot-by-lot definition of wastewater needs, as shown in the map in Figure 2-5. For each lot it was determined whether an onsite solution was possible or an off-site solution was required.

The wastewater needs were defined for the 934 developed parcels requiring solutions (out of a total of 5,570 developed properties) in Concord as follows:

Properties Requiring Off-Site Solutions	**437**
Off-site solutions required by wetlands or floodplains	222
Off-site solutions required by inadequate space	215
Properties Accommodating Onsite Solutions	**497**
Likely to fail Title 5 property transfer (~3.25´ mound above ground level required)	121
Likely to provide inadequate treatment (~1.75´ mound above ground level required)	334
Excess septage pumping (4+ pumps/year)	20
Excessive water consumption (165 gpd per bedroom)	22
Total Properties Requiring Solutions	**934**

Figure 2-4
Examples of Information Consolidated into GIS Database for Needs Assessment for a Concord Neighborhood

(a) Environmentally Sensitive Areas



(b) Soil Suitability

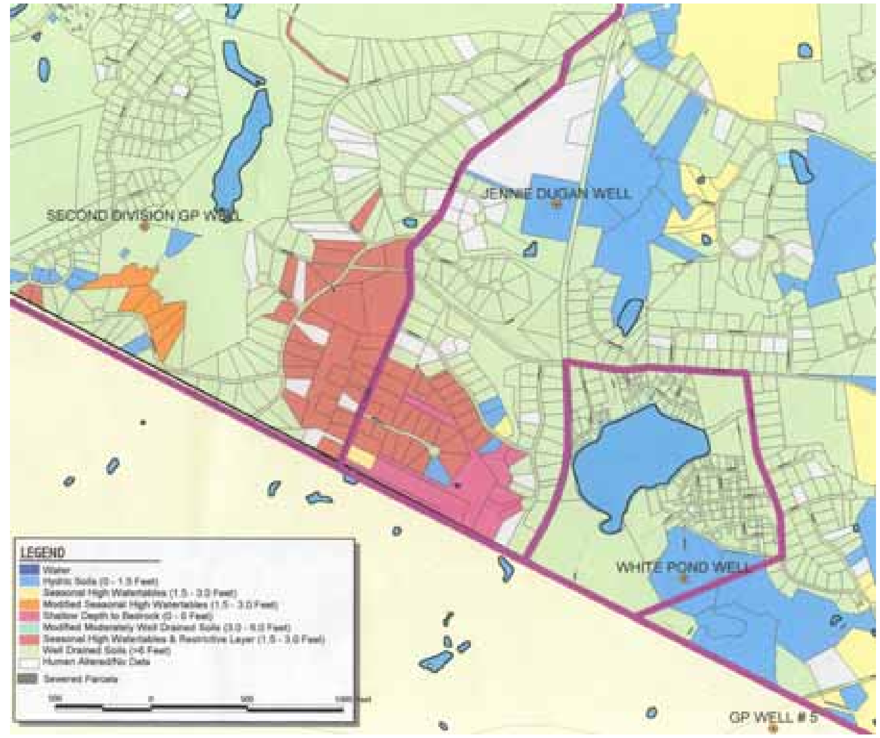
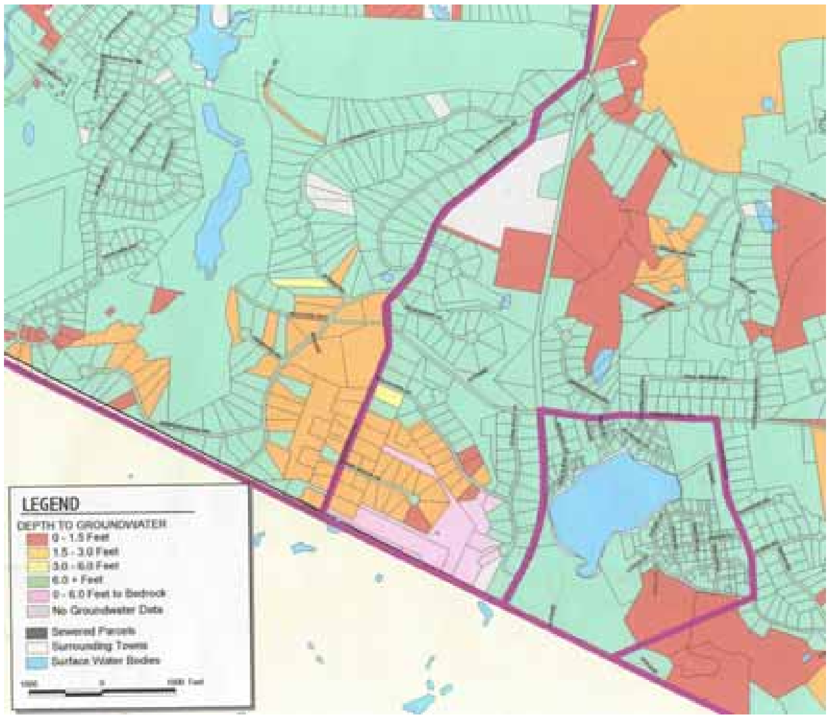


Figure 2-4
Examples of Information Consolidated into GIS Database for Needs Assessment for a Concord Neighborhood (Cont.)

(c) Depth to Groundwater



(d) New and Recently Repaired Septic Systems

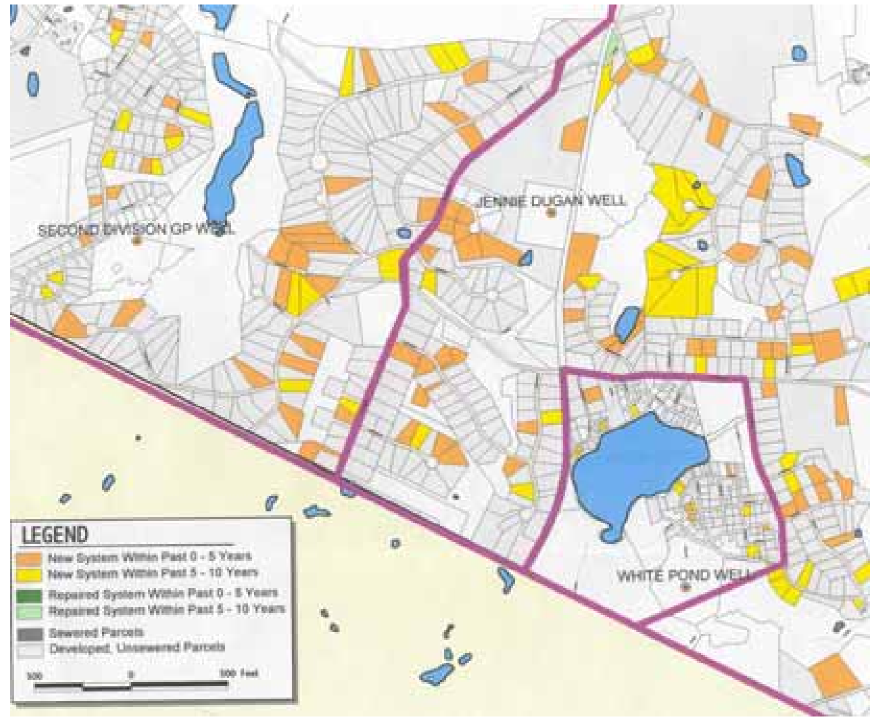
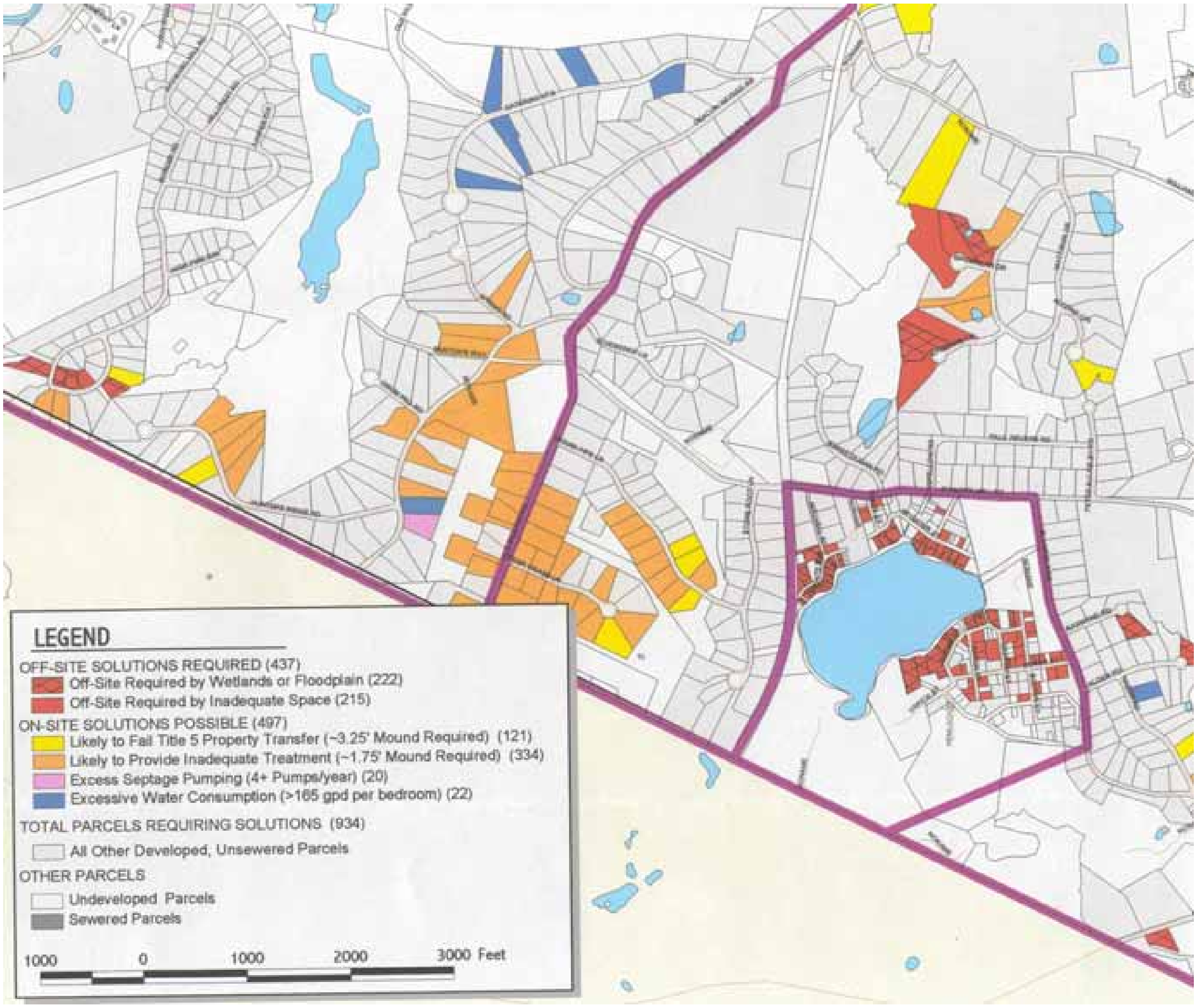


Figure 2-5
Wastewater Needs Definition Results for a Concord Neighborhood



Wastewater Dispersal Capacity—Parcel Development and Defined Wastewater Need Solutions

The first step in cluster system planning for a parcel development or defined wastewater needs is to perform an assessment of all wastewater dispersal restrictions and soil conditions. For subsurface dispersal, this assessment will require data on:

- Depth to groundwater
- Depth to bedrock
- Soil characteristics (such as permeability and structure)
- Floodplain areas
- Surface water areas
- Wetland areas
- Drinking water source/protection (including key aquifers and groundwater resources)

For surface dispersal, the assessment will require a review of TMDL requirements and/or preliminary determination by the appropriate regulatory agency of treatment requirements.

The process will establish:

- Portions of the property or community unsuitable for wastewater dispersal due to environmental conditions, including water supply wells.
- The general physical soil conditions throughout the property or community, providing an indication of areas that are suitable for subsurface wastewater dispersal systems and typical design parameters.

To avoid future problems, planners should consider maximum development potential allowed by zoning/land-use/master plans to ensure the wastewater plan is suitable for the long term and that any future build-out or infill will not create wastewater needs or problems. In many cases, concerns about the impact of future growth may be significant. This issue can be addressed in part by determining if the wastewater needs and solution types would be markedly different without and with the consideration of future growth. If the solution type does not change, that conclusion eliminates the volatile concern that growth is driving sewering. (Alternative means of addressing this issue through rezoning, land planning, and innovative growth management are discussed in the *Growth Management and Land Use* section of Chapter 3.)

The optimal sites for cluster wastewater subsurface dispersal systems will likely be the same areas that are suitable for onsite septic systems; however, the converse is not necessarily true. Depending on the size of the subdivision or community (and the expected design flows of the cluster system), the feasible sites for a cluster dispersal system may be limited by hydrogeological considerations, such as groundwater mounding. Drip distribution dispersal systems are a technique that can be used on sites with challenging hydraulic conductivity or other site-constraining conditions; however, land area requirements can be extensive for this technology.

Wastewater dispersal capacity and treatment requirements should be specified for each site. At this stage, this analysis should be preliminary, sufficient to determine that a general, viable development plan can be established. The plan will be refined later.

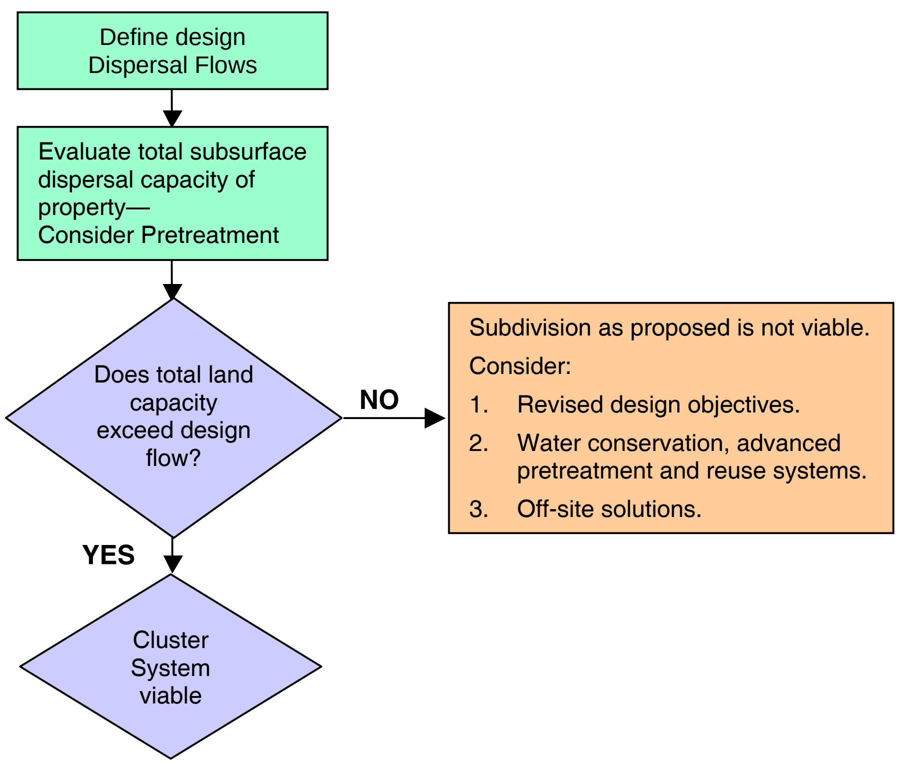
Once the wastewater dispersal capacity has been evaluated and quantified, a designer must develop a plan that optimally utilizes the finite wastewater dispersal capacity of the property or community.

If the total available wastewater dispersal capacity is less than the wastewater design flows from the study area, then one of the following courses must be taken:

- For parcel development, revise the development objectives to reduce the total wastewater flows from the parcel.
- Evaluate a water conservation and/or reuse system to reduce the total wastewater design flow.
- Find another location off site to supplement available wastewater dispersal capacity.
- Consider additional wastewater treatment, as dispersal area requirements may be lower for higher-treated wastewater and certain areas may be available with a higher-purity-treated wastewater.

If the available dispersal capacity exceeds the design flow, then the proposed cluster system is feasible. Figure 2-6 presents a simple flowchart outlining the cluster subsurface dispersal system planning process to this point.

Figure 2-6
Flowchart of Cluster Subsurface Dispersal System Planning Process



Compatibility with the Land-Use Plan

A wastewater plan that supports and is consistent with the land-use plan should be developed. Communities may be interested in refining land-use plans to direct development toward a growth center or away from environmentally sensitive areas. The wastewater plan should be sensitive to these issues.

Compatibility of Wastewater Systems with Other Uses of Common Space

The cluster system's subsurface wastewater dispersal system may be compatible with other open space or common space elements of a community. Subsurface dispersal systems are frequently compatible with the following common or open space types:

- Athletic fields and greens
- Golf courses
- Public right-of-ways
- Parks

Consider Potential Future Needs of Adjacent Lands

If the soils or hydrogeology of the area surrounding the study area are generally difficult (such as low wastewater dispersal capacity), and the study area has excess wastewater dispersal capacity, it may be desirable to set aside area for future expansion of the dispersal system. By retaining this dispersal capacity for future use, a community retains greater flexibility in future wastewater planning efforts.

Depending on the entity ultimately responsible for the wastewater system (public or private utility, or other entity), this excess capacity can bring future benefits as a wastewater dispersal solution for future growth.

Wastewater Reuse Opportunities

If an area has challenging dispersal system constraints, wastewater reuse may be a cost-effective option to reduce wastewater dispersal requirements. There are two major categories of reuse in residential applications:

- Indoor non-potable uses (for example, toilet flushing)—although this option has not been allowed except in a high-rise building in New York City due to concerns over cross-connections
- Landscape irrigation

Commercial and industrial firms may have more water reuse opportunities, such as cooling tower make-up and process water.

Technology Screening and Management Options

The objective of technology screening is to develop a short-list of viable technologies well-suited to the specific conditions and requirements of the defined wastewater needs. This screening will simplify the solutions evaluation process by limiting the solutions evaluated to technologies appropriate for the community.

All cluster wastewater management systems have three basic components:

- Collection
- Treatment (including sludge/septage or residuals management)
- Dispersal/reuse

For each of these three basic components, any specific technology can be analyzed and compared to others, developing options for a cluster system. Table 2-4 illustrates the full range of wastewater management components. Within each cell in the matrix of Table 2-4 there are a wide variety of wastewater technologies available, which are briefly described in Chapter 5, *Decentralized Wastewater Technologies*.

Table 2-4
Decentralized Wastewater Alternatives Matrix

	System		
Component	**Onsite**	**Cluster**	**Centralized Sewer**
Collection	X	✓	✓
Treatment	✓	✓	✓
Dispersal/Reuse	✓	✓	✓

The technologies that can be implemented in a cluster system range in scale from a communal septic tank and leach field (for small cluster systems) to an advanced treatment plant capable of purifying large wastewater flows for reuse. Each candidate technology must be evaluated for a given site in terms of its

- Appropriateness in producing required wastewater purification
- Estimated costs
- Environmental impacts

Key issues associated with cluster systems can include:

- Regional water balance/interbasin transfer
- Potential surface water quality impacts
- Indirect water reuse
- Growth stimulation management
- User-charge systems

Technologies available for cluster wastewater management are described briefly in the following section. Chapter 5 provides further details on these technologies.

Numerous websites provide information on wastewater management technologies, including:

- www.epa.gov/owm/mtb/mtbfact.htm
- www.epa.gov/owm/mtb/decent/technology.htm

At the conclusion of the technology evaluation process, the planner should have a short-list of technologies suitable for the cluster system. As solution alternatives are considered, the primary determinants in the final technology selection typically are:

- Financial (capital and operation and maintenance (O&M) costs)
- Long-term reliability and regulatory compliance
- Land requirements
- O&M requirements
- Management program requirements
- Community preference and perceptions
- Long-term reliability and regulatory compliance

Wastewater Collection

Many factors must be considered in the selection of an appropriate wastewater collection system, including:

- Costs (capital and annual O&M)
- Development density
- Wastewater volume to be conveyed
- Topography
- Depth to bedrock or groundwater
- Sensitive environmental resources

The collection system alternatives for a cluster system include:

- Conventional Gravity Systems—with pump stations as needed
- Septic Tank Effluent Systems—gravity and low-pressure as dictated by local conditions
- Grinder Pump—low-pressure systems
- Vacuum Systems

Wastewater Treatment

The treatment technology options for cluster systems can include nearly all options available for onsite and centralized systems. The list of appropriate technologies for a specific application will be determined by the following criteria:

- Influent wastewater characteristics (residential, commercial, industrial, or other types)
- Treatment requirements (effluent standards)
- Capital and annual O&M costs

- Daily or seasonal flow patterns
- O&M requirements
- System reliability/redundancy requirements
- System footprint and location requirements

Wastewater treatment technologies available for cluster systems are generally the same for onsite systems and centralized systems, adjusted for the size of the cluster system. Onsite technologies are more appropriate for smaller cluster systems, and centralized technologies are more appropriate for larger cluster systems, although some technologies are effective at the full range of flows. As an example, more sophisticated treatment systems may become preferable to land-intensive and passive treatment systems, as the design flow for a cluster system increases and the site requirements are more restrictive.

Table 2-5 presents a list of potential unit processes appropriate for use in cluster systems.

Table 2-5
Wastewater Treatment Technologies Suitable for Cluster Systems

Pretreatment		
Septic Tank (ST)	Anaerobic Upflow Filter (following ST)	
Secondary Treatment		
Fixed Film Processes	**Suspended Growth Processes**	**Integrated Fixed-Film and Suspended Growth**
Rotating Biological Contactor	Oxidation Ditch	
Trickling Filter	Activated Sludge	
Vegetated Submerged Beds	Sequencing Batch Reactor	
Constructed Wetlands	Membrane Bioreactor	
Recirculating Media Filters		
Intermittent Media Filters		
Tertiary Treatment		
Nitrogen Removal Phosphorus Removal	Membrane Processes	
Disinfection		
Ultraviolet (UV)	Chlorine	Ozone

Wastewater Dispersal

Of the three components of cluster wastewater systems (collection, treatment, and dispersal/reuse) dispersal options for a given cluster system are typically the most limiting and site-specific.

Choosing the appropriate dispersal technologies for a specific cluster system will be largely influenced by the following criteria:

- Availability of suitable sites (that is, proper hydraulic conductivity, depth to limiting layer, and site hydrogeology) of sufficient size
- Total quantity of treated wastewater to be dispersed (design flows)

Minimum wastewater treatment requirements are established by state codes. Sensitive receptors impacted by the dispersal system may dictate higher effluent quality requirements of the treatment system.

Treated wastewater dispersal options fall into the two general categories:

1. Surface water dispersal
2. Subsurface soil dispersal, either by gravity or pressure

Surface water dispersal requires a National Pollutant Discharge Elimination System (NPDES) permit, along with extensive monitoring and reporting requirements. Some states discourage or prohibit this option for very small cluster systems.

Subsurface soil dispersal is a common method used for cluster systems. The major types of subsurface dispersal are:

- Trenches—using a variety of media
- Beds—covered and open
- Drip distribution

Wastewater reuse is becoming an increasingly common and accepted solution for cluster system wastewater management. Purified wastewater is most commonly reused for:

- Landscape irrigation
- Domestic non-potable uses (such as toilet flushing) where allowed
- Commercial/industrial water

Wastewater reuse can be a cost-effective alternative where subsurface dispersal is limited or expensive. The additional capital costs of purified wastewater reuse distribution systems can be manageable when they are installed concurrently with other utility systems. If properly designed, they can be an attractive attribute of the study area.

Ownership and Management Options

The ownership and management options for cluster systems consist of:

- Public
- Private for-profit
- Private non-profit

Management responsibilities for cluster systems generally include:

- Ownership
- Administration
  - Ownership management
  - Program management for implementation of capital improvements
  - Use regulation
  - Regulatory compliance reporting
  - Customer service, billing, and collections
  - User-charge system
  - Financial
- Operations
  - Monitoring
  - Maintenance and repair
  - Replacement

Within these broad definitions, there are many variations of successful management structures. Four examples of management options for cluster systems are:

- **Large urban public utility—**The Mobile Area Water and Sewer System has begun implementation of several cluster wastewater treatment and dispersal systems in the high-growth areas of Mobile, Alabama. Four such facilities have recently begun operation, and they serve new schools, new commercial, and new residential development (White 2001).
- **Regional, private for-profit company—**Tennessee Wastewater Systems, Inc. owns and operates wastewater systems for homes and businesses across the state of Tennessee. The residential communities are typically 40 homes or more, while commercial systems range from a single customer to shopping centers. User charges are regulated by the Tennessee Public Service Commission (Pickney 2001).
- **Regional not-for-profit public utility cooperatives—**The Rural Electric Cooperatives are member-owned not-for-profit utilities that receive support from the National Rural Electric Cooperative Association. Although traditionally focused on providing electricity, the co-ops are increasingly interested in water supply and wastewater management. Of the more than 900 cooperatives in existence, a number in Minnesota, Kentucky, Missouri, Alabama, and North Carolina are involved in ownership and management of cluster wastewater systems (Drake 2003).
- **Local government public utility—**The Loudon County Sanitation Authority in Leesburg, Virginia owns and/or operates seven cluster wastewater systems for institutions, subdivisions, and communities. The smallest community served is 55 houses, while the largest is a new subdivision that will eventually contain 255 homes (Danielson 2003).

Many existing communities already have an existing ownership and wastewater management infrastructure. Depending upon the nature and scope of the responsibilities held by the existing management entity, it may or may not be appropriate for that entity to manage the new cluster system. For example, the management entity serving a community with no existing off-site wastewater management infrastructure might be ill-equipped (in terms of necessary personnel, experience, and equipment) to take over management of a new cluster system. For such a community, general options would be to:

- Add the responsibility to the existing management entity and train staff for the new responsibilities
- Develop a new public entity to perform management of the cluster system(s)
- Outsource the management responsibilities to a private entity and retain owner oversight for the system

Management options and innovative management approaches are discussed in detail in Chapter 4, *Cluster Wastewater System Management Approaches*.

More generally, US EPA recommends five model management programs for decentralized systems:

- System inventory (awareness of maintenance needs)
- Management through maintenance contracts
- Management through operating permits
- Responsible Management Entity (RME) operation and maintenance
- RME ownership and management

Each of these model management programs is described in Table 2-6, and at www.epa.gov/owm/mtb/decent/index.htm.

Table 2-6
Overview of Management Model Objectives

Management Model	Objectives	Basic Features
Management Model 1 ***Inventories and Maintenance Reminders***	• Owner awareness of permitting program, installation, and O&M needs • Compliance with codes, regulations	• Only conventional onsite systems • Prescriptive design/site requirements • Owner education to improve O&M • Inspections only during construction and complaint evaluations • Create and maintain system inventory
Management Model 2 ***Maintenance Contracts***	• Maintain prescriptive program for sites that meet code criteria (MP 1)	• Prescriptive design/site requirements • Allowances for specified alternatives where code is not met

Table 2-6
Overview of Management Model Objectives (Cont.)

Management Model	Objectives	Basic Features
Management Model 2 ***Maintenance Contracts (Cont.)***	• Permit only approved alternative systems on sites not quite meeting criteria	• O&M contracts and reporting required for alternative systems • Inspections and owner education as in MP 1 • Create and maintain inventory
Management Model 3 ***Operating Permits***	• Onsite system designs based on site conditions and performance requirements • System performance assumed by O&M task completion and verified through permit renewal inspections	• Wider variety of designs allowed • Performance of required O/M tasks governs operating permit renewal • Onsite Wastewater Treatment System (OWTS) monitoring/inspections required • Property sale and change-of-use compliance-assurance inspections • Create and maintain inventory
Management Model 4 ***Responsible Management Entity Operation and Maintenance***	Responsible public or private entity assumes O&M and inspection/monitoring responsibilities for all systems in management area	• Performance governs acceptability • Operating permits ensure compliance • All systems are inspected regularly • Monthly/yearly fees support program • Owner responsible for all costs • Create and maintain inventory
Management Model 5 ***Responsible Management Entity Ownership***	• Public or private RME owns and operates all systems in management area • Similar to centralized sewer system service approach	• Performance governs acceptability • All systems are inspected regularly • Monthly/yearly fees support program • Users relieved of all O&M responsibilities • RME funds installation and repairs • Create and maintain inventory

Regulatory agencies have typically required management models 1 and 2 for smaller Type I cluster systems; however, higher levels may be appropriate in certain situations. For larger Type II cluster systems, regulators usually require a blended management model of models 3 through 5, with groundwater discharge or surface water discharge (NPDES) permits as the operative technique. If there is one system owner, the model needs to be an RME.

A mixture of ownership and management options is common. Many publicly owned systems are managed in varying degrees by private entities, commonly referred to as public-private partnerships. An owner can outsource any or all of the management activities for a cluster system. Ownership can be held by a public utility, such as a sewer district or Department of Public Works, or a private for-profit or non-profit entity.

The user-charge systems for new development cluster systems can be lower than existing development because the capital cost for the system is included with the purchase price of the connected property, that is, house or commercial facility. Typical cluster system user charges are shown in Table 2-7.

Table 2-7
Typical Cluster System User Charges

Development	Capital Costs	Annual O&M Costs
New Parcel	Included in building cost (1)	$35/month (2)
Existing	Highly variable and site-specific <$12,000 to $25,000+	$35–$45/month (2)

(1) Typically, $8,000 to $15,000
(2) Pickney 2001

For existing developments (in the community-wide context), the capital costs are usually apportioned into the following components:

- Connect fee
- Assessment fee (in some states referred to as a betterment fee)
- Amortized (usually 20 years) capital portion with annual payment added to O&M
- Other and non-user sources
  - Property assessment
  - Special/innovative taxes
  - Grants/loans

Solution Alternatives

Once the technology screening has yielded a short list of potentially feasible technologies, the planner has enough information to address alternatives on a community-wide basis. The community next undertakes an objective screening process based on clear criteria.

Develop Study Areas for Solutions

Planners can identify candidate areas for cluster systems by screening out areas where onsite systems or centralized solutions are most suitable. Unless there are appropriate community reasons to add criteria, the process for screening areas for onsite, cluster, or centralized service should follow an objective process.

The criteria should include:

- Technical viability and regulatory compliance
- Environmental acceptability
- Economic competitiveness

Methods to perform these objective analyses are presented within this handbook.

The solution alternatives developed for each of these study areas may consist of:

- **Continued use of onsite systems—**If the needs of the study area do not require an off-site solution (as in areas requiring mounded systems or I/A technologies) then onsite solutions could still be cost effective. If the area is very small and relatively isolated from other study areas, it may be environmentally acceptable and economically wise to request variances for those isolated systems instead of proposing a small cluster system.
- **Cluster systems—**This alternative should be selected if the needs of the study area require an off-site solution or if a cluster system might be more cost effective or otherwise preferable to onsite or centralized systems.
- **Centralized sewer system—**If the size of the study area is very large or if the study area is close to an existing centralized sewer system, then a centralized sewer system may be a cost effective option. Alternative collection technologies should be considered to convey the wastewater to the central sewer. Note that the difference between a cluster and centralized system may only be semantics in certain situations.

Preliminary Hydrogeological Site Evaluations for Subsurface Dispersal Options

For each study area, planners should identify promising wastewater dispersal sites/options. Planners can complete an initial identification of potential dispersal sites by screening properties using existing available information and the requirements of the local and state codes. This screening should include considering criteria such as:

- Lot size
- Minimum depth to groundwater or limiting layer
- Soil characteristics, primarily hydraulic permeability

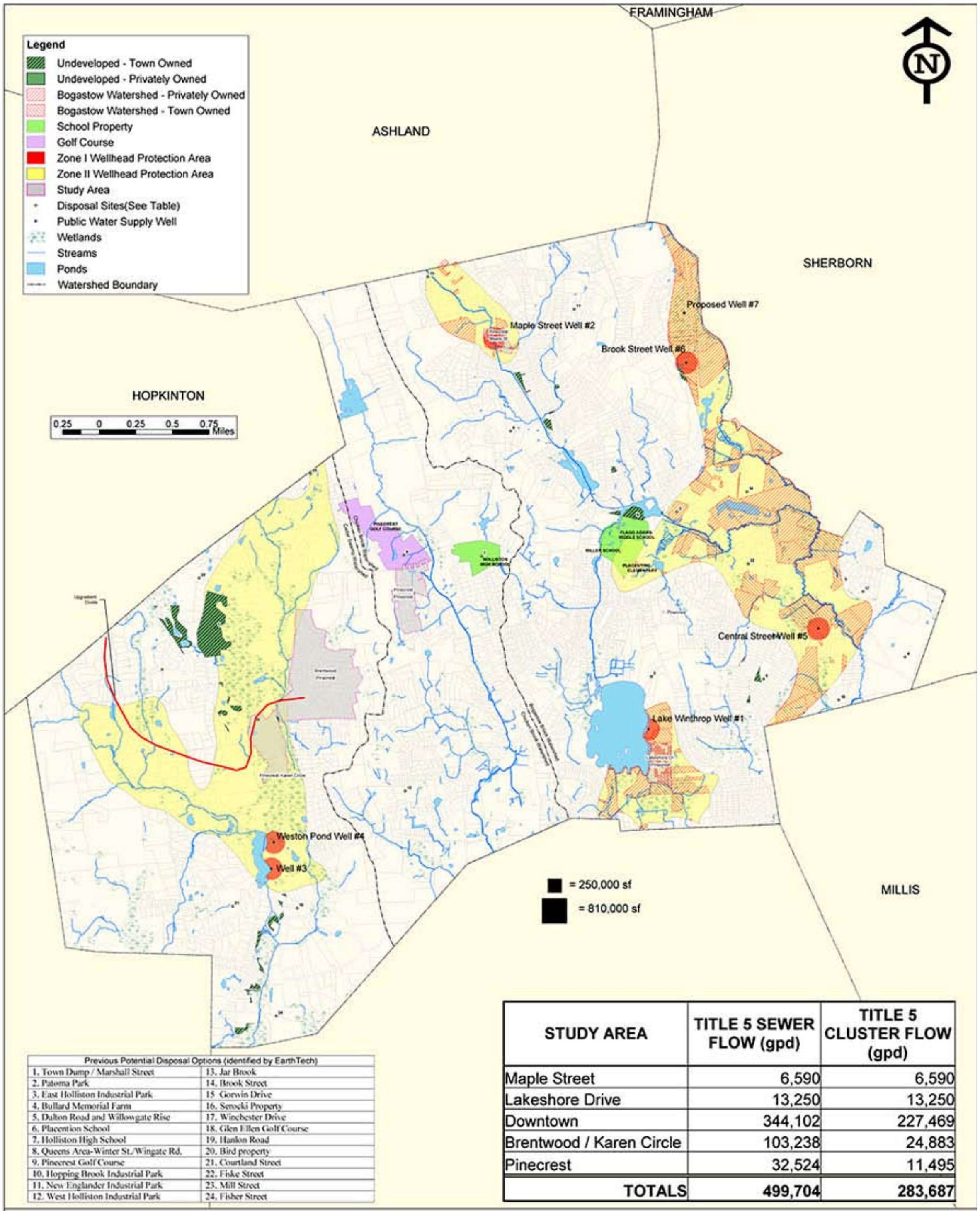
Additional factors for assessment include:

- Development status
- Proximity to study areas
- Proximity to environmentally sensitive areas

This analysis will typically generate a manageable short list of potential subsurface dispersal sites. Examples of maps showing potential subsurface dispersal sites for three communities developed by using objective criteria and GIS data are shown in Figure 2-7, Figure 2-8, and

Figure 2-9. The town of Holliston, MA (Lombardo Associates, Inc. 2002b) identified important viable sites using the GIS screening technique (see Figure 2-7). These sites were not previously identified by conventional wastewater planning techniques.

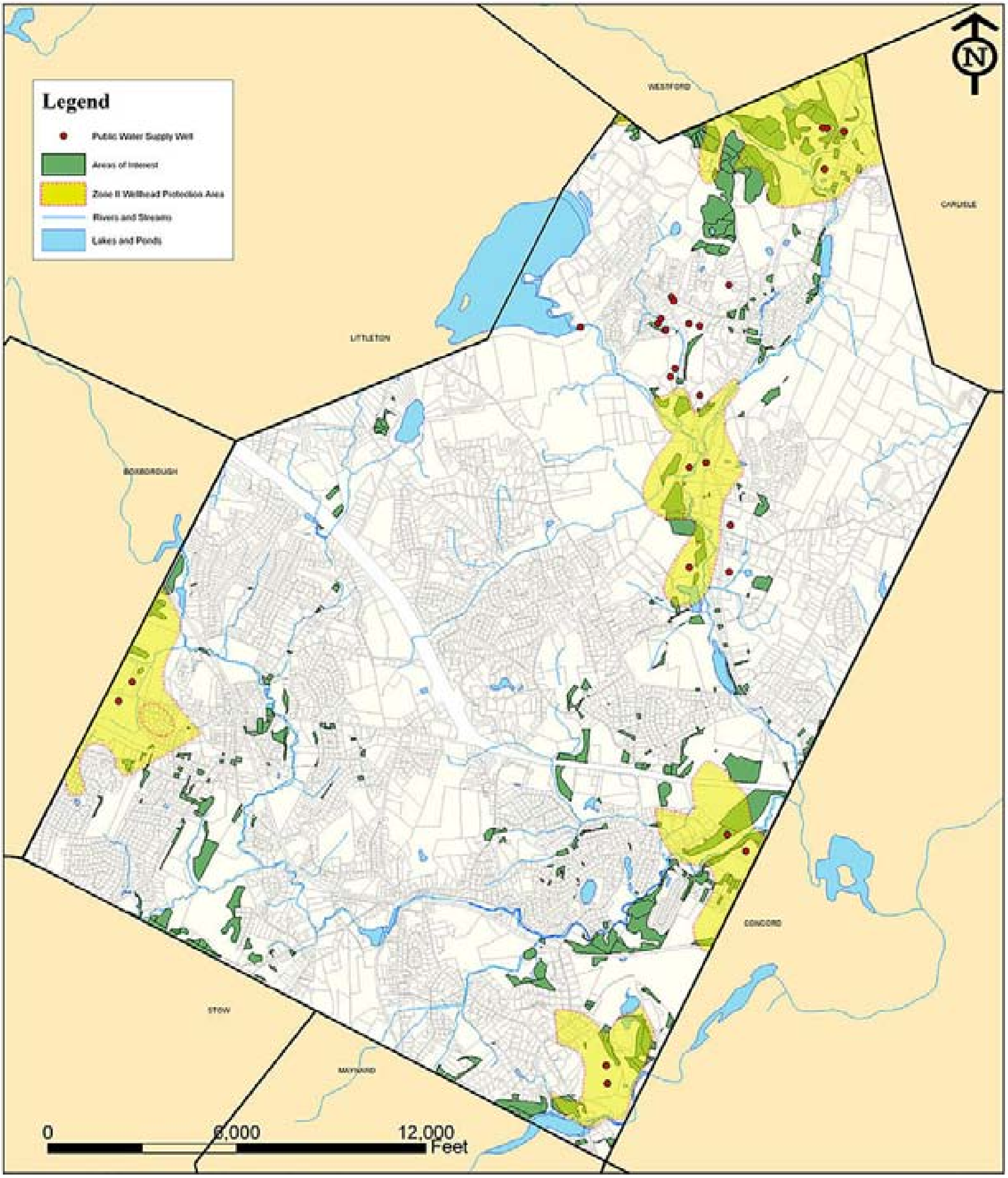
Figure 2-7
Potential Dispersal Sites for the Town of Holliston, MA



Previous Potential Disposal Options (identified by EarthTech)	
1. Town Dump / Marshall Street	13. Jar Brook
2. Patoma Park	14. Brook Street
3. East Holliston Industrial Park	15 Gorwin Drive
4. Bullard Memorial Farm	16. Serocki Property
5. Dalton Road and Willowgate Rise	17. Winchester Drive
6. Placention School	18. Glen Ellen Golf Course
7. Holliston High School	19. Hanlon Road
8. Queens Area-Winter St./Wingate Rd.	20. Bird property
9. Pinecrest Golf Course	21. Courtland Street
10. Hopping Brook Industrial Park	22. Fiske Street
11. New Englander Industrial Park	23. Mill Street
12. West Holliston Industrial Park	24. Fisher Street

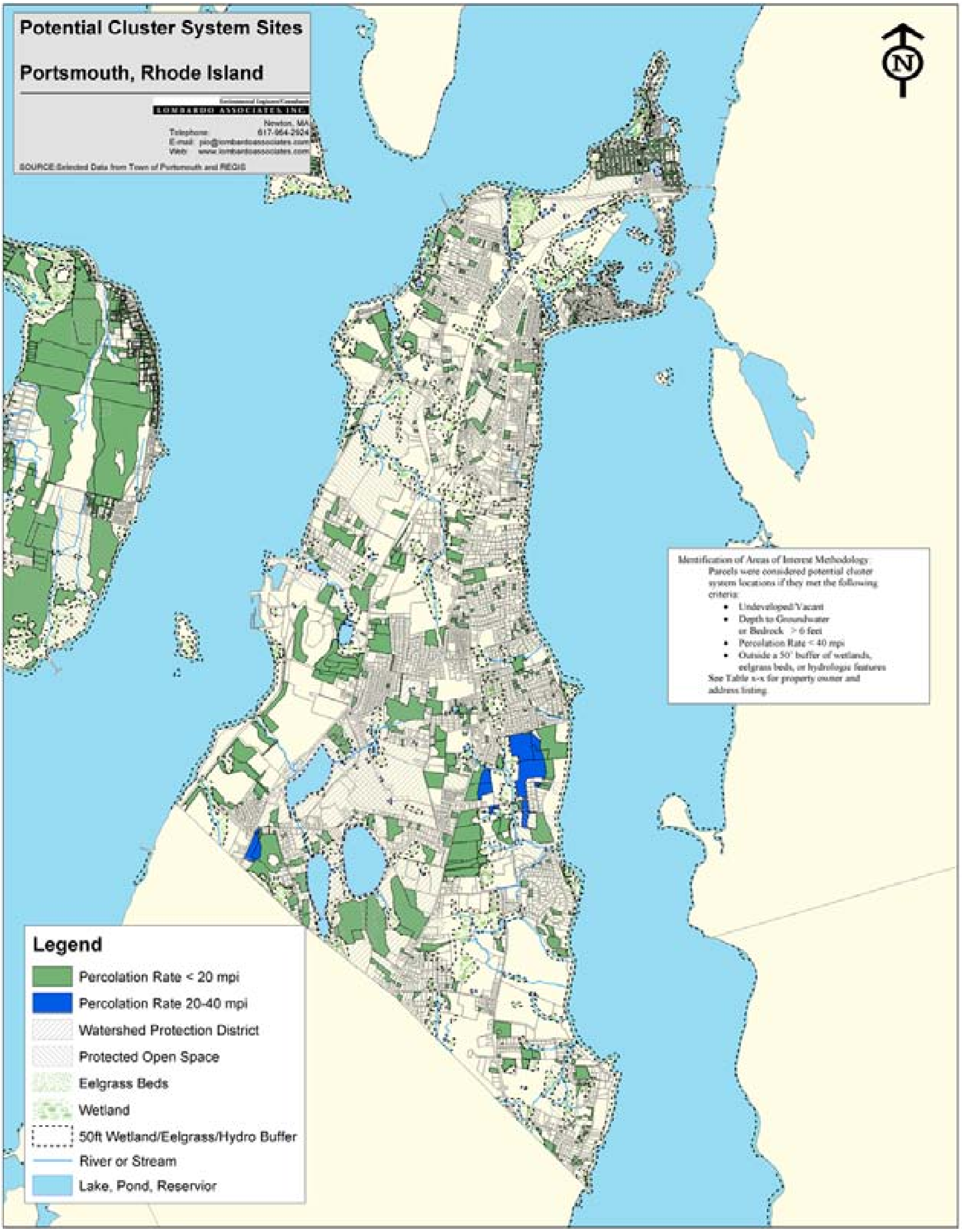
STUDY AREA	TITLE 5 SEWER FLOW (gpd)	TITLE 5 CLUSTER FLOW (gpd)
Maple Street	6,590	6,590
Lakeshore Drive	13,250	13,250
Downtown	344,102	227,469
Brentwood / Karen Circle	103,238	24,883
Pinecrest	32,524	11,495
TOTALS	**499,704**	**283,687**

Figure 2-8
Potential Dispersal sites for the Town of Acton, MA



Source: Lombardo Associates, Inc. (2003)

Figure 2-9
Potential Dispersal Sites for the Town of Portsmouth, RI



Once the dispersal site short list has been generated, preliminary hydrogeological site evaluations should be developed for the most promising sites. These site investigations consist of desktop studies that will estimate the site's capacity for effluent dispersal based on available technical information. The site capacity investigation should include:

- Groundwater mounding estimates
- Estimated flow paths
- Time-of-travel to nearby sensitive receptors (wells, surface waters, and other receptors)

If good published data is lacking, site screening should be performed in the field, such as test pit excavations and soil sieve analysis. An analysis of the cumulative impact of all proposed cluster systems needs to be performed for projects with multiple sites.

The site capacity estimates developed by the preliminary hydrogeological site evaluation will then be used in the cost effectiveness evaluation. Issues and methods for hydrogeological site evaluations are discussed in detail in Chapter 3.

Surface Water Discharge Considerations

Surface water discharge systems, where allowed, require an NPDES permit. Most states have been delegated authority by US EPA to administer the NPDES permit system through their Environmental Protection Departments. Obviously, a receiving water body must be accessible to the proposed cluster system for surface discharge to be viable.

The permit will typically specify the maximum flow allowed and concentration and/or mass limits of water quality constituents of concern. Typical ranges of water quality constituents of concern and potential discharge limits are shown in Table 2-8.

Table 2-8
Water Quality Constituents of Concern and Potential Discharge Limits

Constituent	Potential Discharge Limit
Biochemical Oxygen Demand (BOD)	5–30 mg/l
Total Suspended Solids (TSS)	5–30 mg/l
Total Nitrogen (N)	<10–20 mg/l, if regulated
Ammonia-Nitrogen (NH_4^+-N)	<2–5 mg/l, if regulated
Total Phosphorus (P)	<0.1–1 mg/l, if regulated
Fecal Coliform	<200–2,000 per 100 ml
e. coli	<126–235 per 100 ml
Enterococcus	<24–104 per 100 ml

Discharge standards are determined by computer modeling of the assimilative capacity of the water bodies to determine the TMDLs that can be discharged to the water body and still maintain water quality standards. Many receiving water bodies are subjected to the anti-degradation rule, which restricts the use, if any, of the assimilative capacity of a water body. The anti-degradation rule may be applied to new development.

Case Study: Cluster System Direct Discharge Requirements for Winona, WV

The 70-home village community of Winona, WV required a community based cluster wastewater system to eliminate direct discharges. The discharge affected water quality in a creek with extensive recreational activities. Due to the lack of viable subsurface dispersal sites, a surface discharge was proposed. West Virginia, like many states, has a process for establishing effluent requirements for direct discharge wastewater treatment facilities.

Minimum wastewater design flows are established by state regulation and resulted in a treatment flow of 33,000 gallons per day (gpd). Based upon the state's TMDL analysis, the state established effluent requirements of:

BOD	30 mg/l
TSS	30 mg/l
NH_4-N	4 mg/l
Fecal Coliforms	<200 per 100 ml

Treatment options that could meet those effluent requirements were then developed for the village.

As of 2004, states will be required to set nutrient criteria or adopt US EPA-issued nutrient criteria for freshwater bodies. The limits for 17 Ecoregions are located at www.epa.gov/waterscience/standards/nutrient.html.

Nutrient criteria documents have been prepared for lakes and reservoirs, rivers and streams, and wetlands and are available at the same web site. A summary of the US EPA freshwater criteria is shown in Table 2-9.

Table 2-9
Range of US EPA Nutrient Criteria for 17 Freshwater Ecoregions

Nutrient	Criteria
Lakes and Reservoirs	
Total phosphorus	0.008–0.037 mg/l
Total nitrogen	0.100–0.780 mg/l, with one Ecoregion at 1.27 mg/l
Chlorophyll a	1.90–12.35 ug/l
Rivers and Streams	
Total phosphorus	0.010–0.067 mg/l, with one Ecoregion at 0.128 mg/l
Total nitrogen	0.120–0.900 mg/l, with one Ecoregion at 2.18 mg/l
Chlorophyll a	1.08–3.75 ug/l
Turbidity	1.30–7.83 FTU/NTU, with one Ecoregion at 17.50

Nutrient criteria exist for some saltwater bodies as well. Nutrient criteria for estuaries and coastal areas (such as embayments) are challenging to develop; they are site-specific primarily due to the hydrodynamic characteristics (such as flushing) of the coastal area. Near-field and far-field analyses may be necessary to determine the appropriate nutrient criteria. Although nitrogen is the usual nutrient of concern in saltwaters, phosphorus limitations may exist.

As the nutrient standards are being developed, planners should check with US EPA and state regulators on the latest criteria.

Nitrogen Removal

Nitrogen has been identified in the nutrient-related declines of shellfish and aquatic plant life in Chesapeake Bay, Florida coastal areas, Cape Cod, the hypoxic "dead zone" in the Gulf of Mexico, and Long Island Sound. The aquatic changes that occur with nitrogen enrichment include an increase in the abundance of macro-algae with the loss of eelgrass and crustaceans. Excessive sea lettuce growth in coastal embayments can cause fatal conditions for crustaceans.

The following quality classifications, further described in Table 2-10, have been recommended for coastal areas:

- Water quality is excellent when the nitrogen concentration is less than 0.30 ppm, which corresponds to background levels in some marine waters.
- Good to moderate quality (up to 0.50 ppm of nitrogen) still supports most shellfish and avoids most algal growth.
- Higher concentrations of nitrogen cause more serious and offensive effects. Levels of nitrogen greater than 0.70 ppm, for example, represent "severely degraded quality" water that most people would not like to be near, let alone swim in.

Table 2-10
Coastal Embayments Water Quality Classifications Based on Nitrogen Concentrations—Specific to a Cape Cod, MA Embayment

Classification	Nitrogen Concentration (mg/l)	Description
Excellent Quality	<0.30	Dense eel grass, plentiful scallops and other shellfish, high oxygen levels for fish
Good Quality	0.30 to 0.39	Some eel grass/scallops, high productivity of other shellfish; rare oxygen depletion
Moderate Quality	0.40 to 0.49	Little eel grass/scallops, high productivity of other shellfish; occasional oxygen depletion; some phytoplankton blooms and macro-algae

Table 2-10
Coastal Embayments Water Quality Classifications Based on Nitrogen Concentrations—Specific to a Cape Cod, MA Embayment (Cont.)

Classification	Nitrogen Concentration (mg/l)	Description
Significant Impairment	0.50 to 0.70	No eel grass/scallops, limited other shellfish; some large phytoplankton blooms, more frequent oxygen depletion, periodic fish kills, occasional macro-algae accumulation/odors
Severe Degradation	>0.70	Near-complete loss of other shellfish/benthic animals; periodic near-complete loss of oxygen in bottom waters, lift-off algal mats, drift algae and increased frequency of odor problems

Source: Howes *et al.* 2003

In water supply recharge areas, a total nitrogen limit of 10 mg/l nitrate-nitrogen has historically been used, as it is the US Public Health Service limit for drinking water. Many states have methodologies (NJ OSP 1988; NJPDES 2002; Idaho DEQ 2002) for determining treated wastewater nitrogen effluent requirements, taking into account other land uses to produce an average 10 mg/l nitrogen at the property line. On Cape Cod, MA, where groundwater is a sole-source aquifer, a requirement of 5 mg/l nitrogen exists to provide a margin of safety. For further information, see www.mass.gov/dep/brp/dws/noticewb.htm.

Many parts of the US are performing TMDL studies in coastal areas. The Massachusetts Estuary Project (www.mass.gov/dep/smerp/smerp.htm) will provide water quality, nutrient loading, and hydrodynamic information for 89 estuaries in Southeastern Massachusetts. This information will be combined through the use of a linked watershed/estuary model that will predict the water quality changes that will result from land-use management decisions, including wastewater treatment discharges. The establishment of nitrogen effluent requirements will result from this study.

Phosphorus Removal

Phosphorus removal technologies can achieve low levels, but costs increase significantly as effluent requirements become more stringent. Whether phosphorus removal can be integrated with other treatment processes, such as biological nutrient removal (BNR) in activated sludge systems and the reductive iron dissolution (RID) technique for fixed-film processes, significantly affects treatment costs. Keplinger *et al*. (2003), provide an analysis of phosphorus removal costs for small-flow wastewater treatment plants.

Since receiving streams in many parts of the US may be predominantly wastewater flow during low flow periods, the nutrient criteria may become the wastewater treatment system's effluent requirements. For example, a Michigan facility is currently required to meet a 0.03 mg/l summertime discharge requirement for phosphorus (Stephens 2003). Further, treatment plants in the Florida Keys are required to meet a 3 mg/l effluent limitation for total nitrogen and a 1 mg/l effluent limitation for total phosphorus. Florida Everglades effluent requirements are 0.010 mg/l total phosphorus.

To meet this challenge, US EPA Onsite Community Demonstration Projects have been underway in LaPine, OR (www.deq.state.or.us/wq/onsite/LaPine.htm) and Table Rock Lake, MO (www.trlwq.org/demo.htm) to evaluate nitrogen and phosphorous removal technologies, respectively, for small flow applications. The Water Environment Research Foundation has funded a project to examine Sustainable Technology for Achieving Very Low Nitrogen and Phosphorus Effluent Levels, which is due for completion in August 2004, and is specifically examining large flow facilities. These nutrient removal issues will become more active in the coming years.

Case Study: Phosphorous Requirement Dictated by Environmentally Sensitive Receptor in Northport, MI

A cluster wastewater treatment system was developed for the 123 year old Northport Point Cottage Owners Association (NPCOA) community in northern Michigan. This community is highly seasonal and has two to three cottages occupied during the winter months and up to 100 cottages occupied during the summer season. Wastewater generation varies greatly from 1,000 gallons per day to up 60,000 per day during peak periods. Design of the wastewater facility includes the existing cottages and the potential for 25 additional cottages, as well as several recreational, maintenance, and office buildings.

The wastewater treatment system designed for the NPCOA utilizes a pressurized collection grid that receives effluent from cottage septic tanks. The wastewater will be treated with recirculating textile filters before discharge to soil absorption fields, constructed with trenches utilizing a pressure distribution system and infiltrator chamber system.

Site investigations and a hydraulic study identified 120,000 square feet of absorption area available, requiring a mounded absorption system to address groundwater mounding. Design flow rate for the treatment facility is 60,000 gallons per day. The treatment system absorption field utilizes a trench system that has a loading rate of two gallons per square feet per day. A 100 percent reserve area is provided.

Phosphorus Treatment

Based upon soils analysis, engineers estimated that it would take seven years before the site's soil phosphorous absorption capacity would be exceeded and breakout would occur to a downgradient wetland. The project owners elected to install a phosphorous removal system to meet Leelanau County's requirement of 0.5 mg/l in wells downgradient of the dispersal system, just prior to the wetland.

The selected technology was ferric chloride addition with a continuous backwash filter.

***Courtesy of**:*
Mr. Richard Raetz
Global Remediation Technologies (GRT)
Traverse City, MI

Emerging Contaminants

Emerging Contaminants is the term used to describe the group of chemicals in personal care products (PCP) and pharmaceuticals that are found in wastewater and have recently been identified in water resources, including water supplies. These chemicals include endocrine disruptors, which have caused significant environmental and public health concerns. The emerging contaminants field is rapidly evolving as more is learned about the exact chemicals, their fate in wastewater treatment processes, their transformation and transport through the subsurface and surface water environment, and their impact on aquatic and human life. An US EPA web site offers information on emerging contaminants: www.epa.gov/endocrine/.

From a cluster wastewater system planning perspective, planners should use the indirect water reuse guidelines (see the *Effluent Dispersal Requirements* section in Chapter 3) as the recommended methodology for addressing this issue. Unfortunately, no guidelines have been established yet for general water quality impact evaluation of emerging contaminants. Understanding transport and fate of dispersal purified wastewater effluent is a critical first step in addressing environmental and public health impacts. Subsurface dispersal has the advantage of additional treatment in the subsurface environment; however, the quantification of this treatment is in its infancy. Drewes *et al*. (2003) describes the fate of pharmaceuticals during groundwater recharge (that is, subsurface dispersal) of secondary treated wastewater. In general, maximizing treatment and subsurface (when used) retention time will mitigate this issue.

Pathogen Considerations

Pathogens are a serious concern in water quality protection for public health purposes. The pathogens most commonly identified and associated with waterborne diseases can be grouped into three general categories: bacteria, protozoans, and viruses (US EPA 2001). Since pathogenic organisms are difficult to identify and isolate, indicator organisms are used to indicate the presence of human pathogenic organisms. Fecal coliform, *e. coli*, and enterococcus are the indicator organisms typically used, with a greater reliance on *e. coli* and enterococcus as reliable indicators (US EPA 2001). US EPA's Ambient Water Quality Criteria for Bacteria—1986 recommended the use of enterococci for marine waters and *e. coli* or enteroccoci for fresh waters. Septic systems that fail hydraulically (subsurface breakouts) or hydrogeologically (inadequate soils to filter pathogens) can adversely affect downgradient surface water (Horsley and Witten 1996).

Proper design and siting of wastewater cluster systems should provide the proper protection from pathogenic organisms. Excessively permeable soils may require disinfection or, as is performed in New Jersey, replacement of fast-draining soils with properly graded, slower-draining sand that provides proper disinfection.

US EPA (2002) provides guidance on implementing bacterial water quality criteria, including summaries of state regulations and relevant research. Bathing beaches water quality issues have received recent attention under the US EPA Beach Program as directed by the Beaches Environment Assessment and Coastal Act of 2000. US EPA (2001) also provides modeling techniques for estimating fecal coliform loads from failing septic systems. Planners should consult www.epa.gov/waterscience/beaches for the latest information on these issues.

Cluster systems can eliminate the concern of pathogenic organisms by providing a disinfection treatment unit and/or adequate depth of unsaturated soils in the dispersal system.

Cost-Effectiveness Evaluation

Once a range of viable technical solution alternatives has been generated, a cost effectiveness evaluation should be performed to determine the best solution based on economic criteria. The cost analysis reduces the number of solution alternatives under consideration by eliminating or ranking solutions that are not cost effective. The evaluation of each solution for each study area should include the life cycle costs (LCC). LCC are the capital cost estimate for the solution plus the future annual O&M costs discounted to their present value, less the present value of salvage at the end of the analysis period.

Cost effectiveness analysis is the economic technique used to compare various options to determine the least costly option of all the technically viable approaches for a particular situation. The analysis uses the technique that is commonly referred to as present worth (PW), LCC or present value (PV). The technique is essentially the same for all terms. The planning period (usually 20 years) and interest rate (set by the Water Resources Council at 5.5 percent in 2003) need to be specified. The term LCC will be used in this handbook.

The equations for LCC are:

LCC = Capital Costs + PV O&M cost for planning period – PV Salvage Value at the end of the planning period

Salvage Value = (Septic System Age/Useful Life) × Replacement Cost

Construction Cost = Quantities × Unit Prices for Major Items + Miscellaneous Equipment Allowance + Construction Contingency and Inflation Allowance

Development Costs = Engineering + Financing + Administrative and Miscellaneous Costs + Land

Capital Cost = Construction Costs + Development Costs

Cost information can be obtained from recently bid projects in the area or locations implementing similar systems, adjusted for local conditions, use of means construction cost, or other methods. When implementing a new technology in an area, it may be desirable to have a contractor outreach program to demystify perceived risks or to bring in an experienced contractor to team with local firms.

When developing the LCC for each solution alternative, it is important to consider the potential cost reductions possible through the use of alternative collection systems. Since the collection system component costs typically represent a large percentage (for example, 70 percent) of a total wastewater management system's cost, considerable attention needs to be placed on:

- The need for collection
- Collection component technology

Alternative collection systems can be 50 to 70 percent of the cost of conventional gravity sewers, especially in high groundwater and bedrock areas. Since alternative collection systems include an on-property component, planners need to include on-property costs of the conventional sewer option to perform a fair comparison.

Note on Failure Rate

Septic system failure rates are critical components of cost-effectiveness analyses because failure rates are another method for stating economic useful life. A failure rate is defined as the number of newly failing septic systems per year divided by the total number of septic systems in the study area.

The number of septic systems that are in failure mode divided by the number of systems in the study area is the percent of failed systems.

There is a significant difference between failure rate and the number of systems in failure mode. The percent of systems in failure mode will include failed systems that have not been repaired—which may be due to a number of reasons, including situations where no onsite solution is possible.

Septic system failure rates of one to two percent are common in communities with good management programs. The economic use life of septic systems with these failure rates (compounded) is important to know. These rates are:

Annual Failure Rate (%)	Economic Useful Life (yrs)[1]
1.0	70
1.5	50
2.0	35

1. Derived by compounding the failure rate (such as, at 1.0% per year failure rate, 100% of systems will fail in 70 years).

Case Study: Solutions Study Area and Cost Effectiveness Analysis in Concord, MA

In Concord, the wastewater needs assessment identified 934 of the 3,849 existing unsewered parcels as requiring a wastewater solution. Of these, 497 would require off-site solutions. Two alternative solutions were proposed for off-site planning:

- The *minimum off-site solutions* alternative, which would require developing off-site treatment plans for parcels that could not have onsite systems because of wetland buffer or floodplain requirements or inadequate space.
- The *maximum off-site solutions* alternative, which would require developing off-site treatment plans for all parcels covered under the minimum off-site solutions alternative plus the parcels that were likely to provide inadequate treatment or fail property transfer inspections.

The solution alternatives were compared based on preliminary hydrogeological considerations, direct discharge regulatory considerations, cost effectiveness, and water quality impacts using the process outlined in the previous section. The preliminary cost effectiveness analysis (CEA) was performed by sub-area (or collection of properties) for each alternative to identify whether connection to the existing sewer system or service by a localized cluster system would be more cost effective for a given sub-area. All costs were expressed on a present value basis. Sample results from the CEA are shown below. Note that FAN refers to “Further Analysis Needed.”

Example of Cost Effectiveness Analysis Results For Concord (Sorted by Unit Sewer Connection Cost)

Sub-Area	Distance to Sewer Individual Study Areas (Feet)*	Sewer Connection Cost	Design Flows (Title 5 Flows) (gpd)	Unit Sewer Connection Cost ($/gpd)	Results (1)
1	100	$10,000	46,200	$0.22	Sewer
2	100	$10,000	30,030	$0.33	Sewer
3	400	$40,000	99,880	$0.40	Sewer
4	230	$23,000	23,100	$1.00	Sewer
5	100	$10,000	4,840	$2.07	Sewer
6	100	$10,000	4,290	$2.33	Sewer
7	650	$65,000	17,270	$3.76	Sewer
8	100	$10,000	1,760	$5.68	Sewer
9	900	$140,000	22,000	$6.36	Sewer
10	100	$10,000	1,430	$6.99	Sewer
11	1,850	$235,000	31,240	$7.52	Sewer
12	1,345	$134,500	16,940	$7.94	Sewer
13	800	$80,000	7,150	$11.19	FAN
14	1,800	$230,000	19,910	$11.55	FAN
15	100	$10,000	770	$12.99	FAN
16	2,800	$330,000	24,090	$13.70	FAN
17	7,500	$800,000	53,020	$15.09	FAN
18	900	$140,000	8,910	$15.71	FAN
19	1,700	$220,000	13,640	$16.13	FAN
20	7,500	$800,000	41,360	$19.34	FAN
21	1,050	$155,000	6,820	$22.73	FAN
22	8,000	$850,000	32,450	$26.19	FAN
23	12,000	$1,250,000	16,060	$77.83	Cluster
24	7,400	$740,000	8,800	$84.09	Cluster
25	5,300	$580,000	5,060	$114.62	Cluster
26	4,300	$480,000	4,180	$114.83	Cluster
27	14,000	$1,450,000	12,320	$117.69	Cluster
28	8,500	$900,000	4,070	$221.13	Cluster
29	7,500	$800,000	3,520	$227.27	Cluster
30	16,000	$1,650,000	4,730	$348.84	Cluster
31	16,000	$1,650,000	4,290	$384.62	Cluster
32	17,000	$1,750,000	2,640	$662.88	Cluster
33	11,000	$1,150,000	1,320	$871.21	Cluster

(1) Sewer option for <$10/gpd. Cluster option for >$50/gpd.

At the conclusion of the cost effectiveness evaluation, all study areas will be in one of two categories:

- A specific solution (onsite, cluster, or sewer) is clearly most cost effective.
- More detailed analysis is needed to determine the most cost-effective solution.

Water Quality Impact Evaluation—Watershed Basis

Water quality impact issues should be addressed on a preliminary basis before any final technology selection. Once a solution appears to be cost effective, the community should perform a water quality impact evaluation to assess any likely impact on local water bodies, including surface waters and groundwater aquifers of the screened options. The water quality impact evaluation should assess nutrient, bacterial, and other loadings from wastewater and other sources within the local watershed and sub-watershed(s). This evaluation will determine if higher than planned treatment levels are required.

TMDLs have been determined or are in the process of being determined for many watersheds. These TMDLs should be consulted early during the planning process to sensitize the planner to the issues and constraints associated with required wastewater treatment levels and dispersal options, especially surface discharge options.

Basic to all of the water quality impact techniques is an understanding/quantification of the project area's hydrogeology and surface water hydrology. This information is necessary to understand where the dispersed effluent travels and to assess impacts on the receiving water body.

This section examines water quality impact issues associated with:

- Nitrogen
- Phosphorus
- Bacterial
- Emerging Contaminants

Standards are addressed for:

- Subsurface Dispersal Systems—Indirect Water Reuse
- Surface Discharge Systems

Nitrogen

Subsurface Transformations—Unless there is a supportable, scientific basis (as discussed in Chapter 3), investigators should not assume that nitrogen removal occurs in the subsurface environment. McCray *et al*. (2003) provides a summary of the literature on subsurface nitrogen removal in septic systems that is relevant for cluster systems.

Impact Analysis—Groundwater nitrogen dilution models are used to determine cluster system compliance with groundwater standards, typically 10 mg/l nitrogen. In coastal or environmentally sensitive areas (such as the New Jersey Pinelands area), the groundwater standard may be more restrictive.

TMDL Analysis—For the cluster wastewater system, the total mass of nitrogen being discharged can be calculated as:

Mass Discharged (lb/day) = Flow (gpd) × Concentration (mg/l) × 0.00000834

If the mass discharged is within the TMDL limits allocated for the proposed cluster system category, the engineer can assume the water quality impact is acceptable. If not, then the study should determine the required treatment level to be within the TDML limit. Nutrient trading may be an option in the watershed that should be examined.

Depending on site conditions, it may be necessary to estimate nitrogen contributions in sub-watershed areas, since localized impact conditions may occur.

Phosphorus

Subsurface Transformations—McCray *et al*. (2003) provides a summary of the literature on subsurface phosphorus removal in septic systems that is relevant for cluster systems. Lombardo (2004) describes the conditions under which subsurface phosphorus removal can be expected to occur. Chapter 3 further addresses this issue.

TMDL Analysis—For the cluster wastewater system, the total mass of phosphorus being discharged can be calculated in the same manner as described previously under TMDL Analysis for nitrogen.

Bacterial

Bacterial water quality standards should be met by maintenance of the minimum depth of unsaturated soils for subsurface discharging systems (as discussed previously in this section) and disinfecting surface discharging systems.

Emerging Contaminants

No standards exist for emerging contaminants. Check the US EPA web site www.epa.gov/endocrine for further information.

The Spring 2004 issue (peer-reviewed papers) of *Groundwater Monitoring & Remediation* is focused entirely on pharmaceuticals and personal care products. Also, the National Groundwater Association sponsors an international conference in the fall on pharmaceuticals and endocrine disrupting chemicals in water.

Subsurface Dispersal Systems—Indirect Water Reuse

As discussed in Chapter 3, the following standards, which are the basis for the California standards, should be met unless more stringent or appropriate regulations exist (Crook *et al*. 2001*)*:

- Time of travel to water supply well greater than six months; preferably two years
- Percent of water supply that is wastewater derived less than two percent

When the percent of water supply that is wastewater derived is greater than two percent, treatment levels and subsurface transformation need to be examined to maintain a total organic carbon (TOC) level that is less than 1 mg/l per RWC where RWC is the percent of water supply that is derived from purified wastewater (Crook *et al*. 2001).

A number of states (California, Florida, Massachusetts, and others) have explicit reuse standards.

Surface Discharge Systems

Standards for surface discharge systems are usually dictated by the state regulatory agency issuing the NPDES permit. Any water quality impact evaluation should be performed in the following manner:

1. Assess existing nutrient, bacterial, and other loadings under current development and wastewater management conditions. For larger cluster systems or in environmentally sensitive areas, model predictions should be validated with data from field observations.

2. Predict water quality conditions at build-out conditions under the planned wastewater management practices.

3. Estimate water quality conditions under each of the solution alternatives for existing and build-out conditions.

4. Revise proposed treatment levels to be within acceptable water quality impacts.

Draft Solution Alternatives and Implementation Options

The results of the solutions evaluation will generate a range of draft solution alternatives. The range of draft alternatives will reflect the optimal wastewater management approaches, consistent with community and stakeholder wastewater management objectives, physical site conditions, and regulatory requirements. The report should present their economic attributes.

The following implementation options should be specified for each draft solution alternative:

- Service areas
  - Extent
  - Existing and build-out number and type of properties/structures served
  - Existing and build-out design wastewater flows
- Technology options for
  - Collection
  - Treatment
  - Dispersal/reuse
- Cost estimates/financial plans
  - Life cycle cost estimate
  - Estimated project financing costs (user charges, connection fees, taxes)
  - Affordability considerations
- Management options for
  - Operation and maintenance
  - Capital repair and replacements
  - Financial management
  - Customer service operations
- Institutional/ownership options, either
  - Public entity
  - Private non-profit entity
  - Private for-profit entity
  - Combination/hybrid/partnership
- Regulatory and permitting requirements

Case Study: Financing Options in the Draft Solution Alternatives for Concord, MA

In the draft implementation plan for the Town of Concord, user charge and financing options were prepared for both the minimum and maximum off-site solution alternatives. The financing plan relied on betterments (that is, connection fees) and sewer use fees, as well as property taxes. Connection fees could be applied on a one-time or annual basis. (Refer to the *Financing Options* section of Chapter 4 for specifics on these and other financing tools.) The user charge and financing options for the *minimum off-site alternative* solution (that is, the solution requiring off-site treatment for parcels limited by wetland buffer or floodplain constraints) were presented for two scenarios: one where connection fees provided 75 percent of the total estimated capital cost ($16,250,000) of the project, and one where connection fees provided 50 percent of the capital cost. The following table shows a comparison of the two scenarios presented.

User Charge by Category of User (Charge is expressed on an *annual* basis)	**Scenario 1***	**Scenario 2****
New Sewer Users (650 users)		
Connection fee	$1,635	$1,090
Property tax	29	58
Sewer use fee	554	596
Total	**583**	**654**
Existing Sewer Users (1,721 users)		
Current charges	$554	$554
Property tax	29	58
Sewer fee increase	0	42
Total	**583**	**654**
Onsite System Users (3,199 users)		
Property tax	$29	$58
Capital Cost Distribution		
Sewer system users	10%	20%
Property tax	15%	30%
Connection fee	75%	50%

* Connection fee = $18,750 per connection or 75% of capital costs; no sewer fee increase

** Connection fee = $12,500 per connection or 50% of capital costs; sewer fee and property tax increases

Presenting financing options for both scenarios enabled the community to select a financing plan that reflected its preferences for how costs should be distributed among the users of the sewer system as well as the town residents in general.

Detailed Hydrogeological Investigations

Once a set of draft solution alternatives has been developed, the community should proceed with detailed hydrogeological investigations at promising dispersal sites. Because the preferred solutions for some study areas may be uncertain and the detailed hydrogeological investigation can be costly, performing the detailed investigations in a phased manner is usually wise (see Chapter 3).

For some communities, it may be appropriate to defer the detailed investigations until after an implementation plan is developed and authorized by the community to avoid costly evaluation of sites that might not be used. There are risks associated with deferring the detailed investigations, because prospective subsurface dispersal sites may not be viable, resulting in potentially higher capital costs or other complications for the management plan as other sites are evaluated. The appropriate type of testing is dependent upon:

- Project complexities and uncertainties
- Availability of existing data

The hydrogeological investigations discussed in detail in Chapter 3 are:

1. Initial Field Testing
   - Site walkover
   - Test pit excavations and data collection
2. Site Evaluation and Modeling
3. Site Tests for Hydraulic Conductivity

(Repeat investigations 2 and 3 as needed with simple to sophisticated techniques.)

The detailed hydrogeological investigations should include:

- Deep hole tests (with infiltration studies)
- Installation of groundwater monitoring wells
- Groundwater level measurements
- Testing to evaluate hydraulic conductivity; perform soils sieve analysis
- Infiltration measurements
- Basin flooding study
- Mounding estimates
- Time of travel (tracers) to any sensitive environmental receptors (public wells, lakes, streams)
- Particle tracking analysis using MODFLOW (modular three-dimensional finite-difference groundwater flow model) or similar predictive model
- Estimates of each site’s total wastewater dispersal capacity and treatment requirements
- Evaluation of potential impact to environmentally sensitive areas

The planner should perform modeling and field testing to validate that proposed wastewater dispersal sites can accommodate planned wastewater quantity and quality. The planner should perform water quality impact analysis to confirm that the proposed cluster system plan is acceptable. Many states, including New Jersey, Massachusetts, Connecticut, and Pennsylvania, require a program as described previously as a condition for consideration of a groundwater discharge permit (NJDEP 2002).

Preferred Solution Plan

Once the planner has completed draft solution alternatives and implementation options and the detailed hydrogeological investigations, the community will have the information necessary to select the preferred cluster system solution alternatives based on economic, environmental, and other criteria (for example, political or aesthetic). The solution alternatives should be presented to the community and key stakeholders in an objective, factual manner to allow the community to decide on a preferred plan.

There is no single path to developing a preferred cluster solution plan that will attract widespread public support. Developing a preferred solution plan is a highly dynamic, political process that requires skill, flexibility, and determination. Presenting the most promising alternatives factually during the cluster plan development and extensive, proactive public participation are two essential ingredients to building consensus around a preferred cluster plan.

Additionally, an open and inclusive process will identify important features that the successful cluster plan should address. The plan should include financial and management and institutional/ownership elements.

Financial Elements

The important financial elements of the plan are the preparation of capital and annual O&M cost estimates for the project. A simple spreadsheet/financial model to evaluate project financing and user charge options can be helpful to planners and the public.

Management and Institutional/Ownership Elements

The institutional ownership structure for a cluster wastewater management plan needs to be specified. The planner needs to specify a new or existing entity to be responsible for:

- Financial and administrative management
- O&M

For Type II systems in particular, preliminary estimates for staffing requirements should be determined.

The community and/or developer and key stakeholders will then have the information necessary to determine the preferred solution alternative based on economic, environmental, and other (for example, political or aesthetic) criteria. Once the community or developer, and stakeholders have decided upon a preferred solution plan, the planner should validate the preferred plan through public review and feedback.

Regulatory Process

Regulatory requirements will vary considerably among jurisdictions. Some common elements and requirements of the regulatory process are outlined in this section. (More in-depth information on the regulatory process and key regulatory issues are discussed in Chapter 3.)

Common state regulatory requirements include:

- Approval of wastewater management plan by state regulators
- Environmental impact assessment for larger Type II cluster systems
- Review and approval of cluster system construction plans

Regulatory agencies should be involved from the outset. This process includes keeping regulators informed of progress in the planning process to insure that they support and approve of the plan that is being developed. Regulators can also sensitize the planner to the opportunities and constraints associated with developing an acceptable cluster system plan. Soliciting recommendations and comments from regulators helps to insure that the planning process achieves a viable plan that can be implemented without requiring any time-consuming and costly revisions.

Implementation Plan

The implementation plan serves as the executive template of the scope and schedule for financing, engineering design and construction, startup, and operation of physical and institutional elements of the cluster wastewater management plan. As such, the implementation plan must specify:

- Service areas
- Collection, treatment and dispersal/reuse facility technologies and sites
- Capital and O&M cost estimates over the life of the system
- Financial plan (grants, user charges, connection fees, property taxes, fee structure, and other financial considerations)
- Financing requirements (sources of capital funds, amount of funding to be borrowed)
- Institutional (primarily ownership) and management structure
- Implementation schedule
- Regulatory (permit) requirements

Public Participation

Public participation is vital to the cluster system wastewater management planning process, especially for the community-wide context. Wastewater management is typically the second largest expenditure at the local level (after education), and it is often subject to heated controversy and not-in-my-back-yard attitudes. Moreover, much of the opposition to cluster development plans can stem from the perception, real or not, that the public is being deceived.

In new parcel development, legally required public participation activities are limited, especially for Type I size cluster systems, although the information is often available for public access. Plans for larger Type II cluster systems are often subject to public comment periods before permits are granted. Specific requirements, however, will vary with each jurisdiction and are affected by cluster system size and characteristics. Particularly for this reason, it is important that a preliminary regulatory roadmap be developed at the initial planning stages. Often, it is advantageous to engage in more than the minimum required public participation.

Public participation in existing communities for wastewater management planning may consist of the following:

- Homeowner questionnaires soliciting information about their existing onsite wastewater systems and their opinions on wastewater management.
- In-depth and detailed public meetings for specific neighborhoods or areas of the community with unique wastewater needs or issues.
- Homeowner notification forms focusing on individual wastewater needs and proposed wastewater solutions
- Public meetings presenting project findings at key milestones:
  - **Kick-off—**Describe the scope, objectives, and schedule of the project; inform the public of opportunities for involvement.
  - **Preliminary results—**Present survey results, methodology to be used in needs definition analysis, and pilot study area application results.
  - **Town-wide or community-wide needs definition results—**Present the complete results of the wastewater needs definition analysis and the wastewater dispersal needs for the study areas.
  - **Neighborhood needs definition results—**Additional meetings should discuss the needs definition methodology, defined wastewater needs, and wastewater dispersal needs for specific areas of the community. These meetings should be tailored to the specific neighborhoods or sub-groups of the study area and should address issues and concerns unique to each neighborhood.

    In some locales, it may be necessary to educate the public on the value of alternative systems, as there may be a socioeconomic stigma associated with anything but a conventional system.

  - **Draft solution alternatives—**Present the complete results of the solution alternative analysis.
  - **Preferred solution—**Present solution alternatives to the community and key stakeholders in an objective manner to enable the stakeholders to decide on a preferred solution plan.
- Periodic meetings with project stakeholders to discuss project status in greater detail.
- Web sites and Internet access to documents, data, meeting materials, reports, and other relevant information from the planning process.

Public involvement and education are essential elements in any planning for cluster systems. Cluster systems require mechanisms for funding, compliance with regulations, management, and regular operation and maintenance. Unlike paying a fee for wastewater services provided by a municipality or authority, operating a cluster system can require a neighborhood or development to establish legal, financial, management, and repair structures. Failing systems can cause public health problems and environmental damage and can be expensive to repair. How communities develop a response to these problems can vary: it may be more difficult, for example, for a group of neighbors to work together to install a cluster system for existing homes than it is for a developer of a new group of homes to permit, install and hand over the system to the homeowners.

In each of these situations, education and the tools of public participation can play an important role in achieving the community's goals. Several steps can ease the startup of a project by making sure that the stakeholders have a common understanding of the problem and potential solutions. Community and neighborhood groups may also need to explore legal options for building and operating a system, such as a conservancy group or private utility.

The *Public Involvement Program* section lists a number of steps that groups can take to organize and educate themselves as they consider a cluster system. There are also web sites, listed as follows, for more case studies or advice on moving forward and developing support for a community wastewater project.

Web Sites

www.nesc.wvu.edu/nsfc
***National Small Flows Clearinghouse*—**This site offers information for smaller communities working on wastewater problems and solutions. Included are publications, such as *Small Flows Quarterly* and *Pipeline*, a newsletter that focuses on single topics each issue in easy-to-read formats for municipal officials and their customers.

www.epa.gov/owm
***EPA Office of Wastewater Management*—**This web site offers useful information on regulations, publications, and other topics connected with onsite and clustered wastewater treatment systems. Links to US EPA's practical and useful fact sheets for public information are provided.

www.ces.purdue.edu/extmedia/ID/ID-265.pdf
Small Community Wastewater Cluster Systems/Purdue University Cooperative Extension Service**—**This site presents a case study on rural solutions to wastewater problems.

www.gdrc.org/ngo/media/index.html
Global Development Research Center**—**This site offers excellent advice on how to deal with the media, from practical information on writing press releases to finding reporters who will cover environmental projects.

www.ocwagis.org/Website/downloads/Decentralized/decentralized.htm
Orange County Water Authority**—**This web site lists a number of useful US EPA publications related to cluster systems and alternative technologies. Users can download and print easy-to-read fact sheets on technologies for community information and meetings.

Public Involvement Program

Many elements of a good public involvement program will apply to the three contexts of cluster development. The following suggestions can help projects move forward in a cooperative and timely manner:

- **Document and develop an understanding of the need for a system**. Talk with the local or state health department about options for community-based systems.
- **Share information about needs and options with all of the stakeholders**. If all or most of the residents of the study area do not agree that a remedy is needed, it will be difficult for the group to move through later steps, such as financing and O&M. Invite the local public health official to a neighborhood meeting. Back up this information with independent information from web sites, such as the Small Flows Clearinghouse (www.nesc.wvu.edu/nsfc), which publish fact sheets on health risks of failing systems and options for remediation.
- **Establish a volunteer advisory committee**. This group, composed of people who live in the study area and are respected or recognized as leaders, will help organize and present information throughout the project. The group members should not be perceived as having pre-existing agendas, and they should, if possible, represent a range of interest groups.
- **Conduct public/neighborhood meetings to keep everyone up to date as the project moves forward**. As the advisory committee completes looking at key issues—regulatory requirements, financial structures, technical options—the members have to keep their neighbors apprised of the information and get consensus on options as they move forward.
- **Use available resources, such as the media, to gather and spread information or to facilitate discussions.** Local or regional media can help inform a wider group of people about options, progress, and community views on needs, costs, and O&M. If the process is stalled by disagreement on technology or siting options, for example, a public involvement consultant might help to facilitate discussions or develop consensus.
- **Interview and choose a consultant in an open and appropriate manner**. The advisory group should establish a scope of services and evaluation criteria for the project before advertising for or seeking consultants. Again, the other stakeholders should be informed

about this process. (One web site with good advice on this process is offered by the Purdue University Cooperative Extension Service at www.agcom.purdue.edu/AgCom/Pubs/menu.htm.) Make sure that meeting with the stakeholders, explaining options, and helping the group to find funding are part of the consultants' scope of work.

- **Be aware that this is a long-term process**. Cluster systems require long-term O&M, sometimes requiring access to individual homes, but always carrying cost and perhaps part- or full-time staff. Training property owners is an important component of O&M as well as having a financial structure that guarantees that the funds will be available to maintain public health with a safe and reliable system. When residents have been part of the solution—involved in the planning and discussions—they are better informed and better prepared to be partners over the long term.

Case Study: Wastewater Needs and Public Participation in Concord, MA

As part of the public participation component of its wastewater management planning, Concord sent notifications in the mail to homeowners in the town informing them of their wastewater needs designation (onsite or off-site required) and soliciting their feedback. The notification effort was coordinated with a series of localized neighborhood meetings that presented the lot-by-lot methodology, needs definition results, draft solution alternatives, and likely implications for each neighborhood in an impartial, factual, and interactive format.

The effort resulted in an overwhelming agreement between the wastewater needs definition and property owners' comments.

Out of 619 owners town-wide who received notices that they were designated as requiring an off-site solution, 35 (6 percent) responded that they disagreed with the designation. All of these disputes were successfully resolved by clarification of the information on their parcel:

- 27 parcels (77 percent) were located in wetlands, wetlands buffers, or floodplains.
- 8 parcels (23 percent) were too small to accommodate a septic system.

Out of 2,257 owners town-wide who received notices that they were designated as **not** requiring an off-site solution, 20 (<1 percent) responded that they disagreed with the designation. All of these parcels fell into one of the following categories:

- 16 (80 percent) prefer sewers for their neighborhood or the town in general, or had surface drainage problems that could be corrected on site.
- 4 (20 percent) incorrectly believed that they had inadequate space for a system.

This public notification process was successful because it gave the public the opportunity to scrutinize the wastewater needs definition process and data inputs in great detail and provide their individualized feedback, while building consensus for the solutions.

Case Study: Assabet River Consortium—A Collaborative Watershed Approach to Wastewater Management Planning in Massachusetts Communities

In some cases, it may make sense for communities to join together in a regional approach to wastewater planning, especially when they share a natural resource such as a river and its watershed where treated effluent is discharged. Six Central Massachusetts communities—Hudson, Marlborough, Maynard, Northborough, Shrewsbury, and Westborough—discharge treated effluent from four treatment plants into the Assabet River. When the treatment plants' NPDES permits were due to be renewed, the Massachusetts Department of Environmental Protection (DEP) required each community served by the plants to study regional wastewater treatment issues. The communities joined together as a consortium to leverage resources and share information and expertise as they worked on a watershed-based plan to meet the anticipated future needs of each community and protect the Assabet River watershed.

Regulators are now encouraging alternatives to sewering and centralized treatment, including cluster systems and groundwater discharge within the source watershed. The consortium study is looking at existing conditions and future needs and evaluating alternatives to arrive at a recommended plan for each community. A coordinated approach is helpful as the communities work with state and federal officials to identify potential partnerships to accomplish the goals of this ambitious project.

The public participation program for the study includes community citizen advisory committees, public and small group meetings, a survey, periodic newsletter, press outreach, and local cable television. While consortium communities maintain their independence, this collaborative, regional, watershed-based approach has expanded the universe of possibilities for each community's wastewater treatment plans.

Political Issues

The political issues around cluster wastewater systems are usually associated with:

- Land Use
- User-Charge System

Land-use impact concerns are associated with the perception of increased development that can occur with cluster systems. Cluster systems can present the land-use/development impacts associated with sewering, albeit on a smaller scale. Restrictions on the increased development can be implemented as discussed in Chapter 3; however, these restrictions usually require a vote of the governing body and can be subject to potential legal suits if a "taking" of property rights is perceived or actually does occur.

The user-charge system for cluster systems consists of apportionment of the capital and annual O&M costs in the following manners:

- Solely to the users of the cluster system
- To other property owners

- Other techniques such as
  - Dedication of a portion of a special tax (such as a motel room tax) to the wastewater fund as is performed in Provincetown, MA
  - Increasing costs in an existing sewer system

The “fairness” of any proposed user-charge system will be a matter of political debate.

The land-use and user-charge system issues are political because they reflect the values of the community and require consensus to be implemented. The user-charge system is particularly important, since the inclusion of property owners other than users entitles those other property owners to vote in the establishment of the cluster system. In many cases, these voters will be against the establishment of the cluster system because they will not receive direct benefits, and negative sentiments about subsidizing others will tend to prevail. Having only the users pay the capital and annual O&M costs increases their costs, but it can eliminate significant negative political sentiment over the establishment of a cluster plan.

Affordability of wastewater fees is a sensitive matter. US EPA guidelines on these issues are presented in Chapter 4.

As previously discussed in the community-wide context, cluster service areas are defined as follows:

- Lots requiring off-site solutions
- A grouping of “needs” lots into a cluster system service area

As such, the grouping of needs lots results in inclusion (sewering) of lots without needs (in other words, can be solved on site). These lots without off-site needs may be developed or undeveloped. The inclusion of these lots in the cluster sewering plan can be a contentious issue because:

- Property owners may want to remain with onsite systems, usually because they anticipate lower operational costs and salvageable capital costs. Also, some properties may have just installed a new onsite system and will likely resist connection to a cluster system.
- The public may not desire to enable development of the previously undevelopable land or allow higher development densities that sewers can support. Many land-use codes allow higher development densities when sewers exist.

The legal rights of property owners can sometimes override local sentiments. As an example, in Massachusetts, property owners are entitled by law to connect to the sewer if the sewer passes their property. Property owners can give up this right if the community petitions the state legislature to do so. The town of Provincetown, MA, established a wastewater management district in which property owners who could install a code-compliant, onsite wastewater system could elect out of the wastewater management district (that is, give up their right to connect to the sewer). With this option in place, the district consisted of a “checkerboard” (non-contiguous) of properties. The high density of development in the Provincetown District allowed this checkerboarding to occur while permitting the cluster system to remain economically feasible. Potential users of this approach need to recognize that significant legal and administrative costs are incurred in the planning process to enable checkerboarding to occur.

Restrictions on increased development associated with sewers can be accomplished, as discussed in Chapter 3; however, developing a solution that is agreeable to the community and is legally defensible can be challenging. Projects that have successfully addressed this issue provide:

- A clear definition of the future development potential enabled by existing laws and regulations
- Open discussion of desired development constraints
- Development of legal mechanisms to implement the desired constraints

Case Study: Cluster Wastewater Systems Development in Mayo Peninsula, MD

The development of the Mayo, MD, cluster wastewater systems required addressing the land use impacts of sewers. One reason for this cluster system's success was that it developed a local solution. The plan provided a limited capacity to serve existing and build-out growth only versus a connection to the Annapolis, MD, wastewater treatment plant with perceived unlimited capacity. The public remained concerned about the community impacts of cluster sewering, which would enable development of the numerous very small (approximately 4,000 square feet) lots.

To address these issues, the cluster plan first quantified the build-out potential in the study area. Maps and property lists were presented to the public including the precise location and quantity of buildable lots when the cluster system was implemented. This process enabled the public to see where build-out could occur, and it addressed an extremely volatile issue factually. Second, the county legislature passed an ordinance requiring the combining of lots with common ownership, thereby reducing the total number of build-out lots.

Case Study: Cluster System in Hall County, GA

Harbour Point is a John Wieland Homes & Neighborhoods residential community on the shores of Lake Sidney Lanier located in Hall County, GA. To develop the steep sloped areas bordering the lake, 9,900 gpd community septic systems were designed in more desirable locations within the development. Reduced lot sizes were allowed in these areas by including the dispersal field acreage in the density calculations.

Each residential unit is responsible for installation and maintenance of a 1,500-gallon septic tank and wastewater filter. The septic tanks tie into a gravity collection system that flows to a pumping station. Effluent pumps were selected as an additional safety factor to protect the dispersal field. The control panel includes non-resetting type elapsed-time meters and an audible alarm with provisions for a remote alarm.

The dispersal field is an equal distribution system using high-capacity infiltrator chambers. The linear feet of absorption line was determined based on the percolation rate provided in a level 3 soil investigation performed by a certified soil scientist. A pressure distribution valve was used to rotate pump cycles to multiple zones and discharging into distribution boxes. Washed stone was placed along the sides of the chambers to maximize lateral water infiltration.

The developer formalized a multiple-year prepaid maintenance agreement with a company to provide monthly monitoring of the system. Monthly reports must be submitted to the local Environmental Health Department, which inspects the site twice annually. Monthly fees and renewal clauses are stated in the homeowner's restrictive covenants. These fees collectively pay for any maintenance and inspections associated with the system. The homeowner association documents contain a provision that if the maintenance program is not maintained, the county commissioners have the authority to tax the properties for the O&M costs, in a manner similar to a special assessment district.

Courtesy of:

Bud Haynes	*Patricia Lacey*
Rochester & Associates, Inc.	*Hall County Health Department*
Gainesville, GA	*Gainesville, GA*

3 TYPICAL CHALLENGES AND EMERGING ISSUES FOR CLUSTER WASTEWATER MANAGEMENT

A number of challenges and issues are emerging for the planning and implementation of cluster wastewater systems. This section addresses the following topics:

- Soils Functions
- Soils Issues
- Hydrogeological Issues
- Soil and Hydrogeological Site Evaluation
- Growth Management and Land-Use Planning
- Public Participation
- Regulatory Issues
- Indirect Water Reuse and Nutrient Impacts

The goal of this section is to help planners and communities understand these emerging issues and consider proven techniques for addressing them in a positive, proactive manner. New technology issues are discussed in Chapter 5.

Soil Functions

Soils have a significant role in cluster wastewater systems planning that uses subsurface dispersal. Soils filter, disinfect, and help return purified wastewater to the environment. Soil functions can be categorized as follows:

- Advanced Level Wastewater Treatment
- Wastewater Nutrient Removal: Nitrogen
- Wastewater Nutrient Removal: Phosphorus
- Wastewater Disinfection
- Purified Wastewater Dispersal

Advanced Level Wastewater Treatment

Soils have a varying role in wastewater treatment. For Type I cluster systems that are receiving septic tank effluent (STE), soils provide wastewater treatment in the form of BOD and TSS removal (organic matter degradation) and ammonia (NH_4) nitrification to nitrate. In certain situations, phosphorus removal can occur. When sufficient depth of unsaturated soil to a limiting layer is provided, wastewater disinfection occurs. This treatment activity occurs in a primarily aerobic biomat that is formed just below the STE distribution system. The ability of the biomat to remain viable and purify STE by BOD, TSS, and NH_4 removal is referred to as the soil's long-term acceptance rate (LTAR), specified in gallons per day per square foot (gpd/sf).

Generally, STE applications below established LTAR design values will maintain aerobic conditions, and loadings above the LTAR design value will create anaerobic conditions and result in treatment-dispersal system failure—usually manifested by surface ponding of untreated wastewater. In other words, when the biomat becomes anaerobic, its hydraulic permeability decreases below the wastewater application rate, resulting in ponding of untreated wastewater.

Typical values for wastewater below the biomat and unsaturated soil zone are (US EPA 2000):

BOD	<1 mg/l
TSS	<1 mg/l
NH_4	<2 mg/l

These wastewater treatment levels are generally referred to as advanced secondary treatment levels.

Permanent phosphorus removal can occur

- In non-calcareous soils by aluminum dissolution and aluminum-phosphorus mineralization as varisite
- By reductive dissolution of iron and iron-phosphorus mineralization as vivianite and strengite, which is reversible if anaerobic conditions develop in the aerobic unsaturated zone

Temporary phosphorus removal occurs by sorption to soils. However, desorption may occur and result in future phosphorus contributions to water bodies. This phenomena is referred to as the retardation factor (Lombardo 2004).

Subsurface dispersal systems contribute purified wastewater to groundwater in a watershed. Groundwater can supply a significant amount of nitrogen and phosphorus to surface water bodies, streams, and lakes, in a watershed (USGS 2003; McCobb *et al*. 2003) and is therefore an important pathway for nutrient contributions. USGS (2003) found that an average of 48 percent of the nitrogen load in streams in the Chesapeake Bay watershed was transported through groundwater. McCobb *et al*. (2003) and USGS (1999) determined that phosphorous in the plume from a subsurface dispersal of now abandoned treatment plant effluent will likely contribute phosphorus to Ashumet Pond for decades due to the desorption of treatment plant effluent phosphorus from aquifer sediments. For these reasons, understanding the ultimate fate and impact of nutrients from cluster systems is important as discussed in Chapter 2, the *Surface Water Discharge Considerations* section.

There will be a lag time between nutrient (or other water quality constituents) additions (or removals) and receiving surface water body water quality changes that will be specific to the watershed and situation under consideration.

Wastewater Nutrient Removal: Nitrogen

Wastewater nitrogen removal occurs primarily by heterotrophic denitrification of nitrate-nitrogen to nitrogen gas by the biological process shown in Equation 3-1:

$$4NO_3^- \text{ (nitrate)} + 5CH_2O \text{ (organic matter)}$$
$$\downarrow$$
$$2N_2 \text{ (nitrogen gas)} + 5CO_2 \text{ (carbon dioxide)} + 3H_2O \text{ (water)} + 4OH \text{ (hydroxide)} \qquad \textbf{(Eq. 3-1)}$$

For soil heterotrophic denitrification to occur, labile (that is, biologically available carbon) must be available for the denitrification bacteria (see Equation 3-1). Because most of the wastewater carbon has been removed in the biomat for denitrification to occur, there must be a source of labile carbon in the subsurface environment, which does not exist at most sites. Denitrification will occur when the subsurface plume of the dispersal system comes in contact with the labile carbon in the soils, including the hyporheic zone where the plume emerges into a surface water body. These areas are critically important for nitrogen, and to some extent phosphorus, removal from dispersed wastewater. The lack of labile carbon, such as in sandy soils of coastal areas or in sand/gravel areas in water supply recharge zones, is the primary reason why wastewater dispersal systems in these areas remove little nitrogen.

Wastewater Nutrient Removal: Phosphorus

Phosphorus removal by soils occurs by complex physical and geochemical mechanisms that are fully described in a companion NDWRCDP document due to be published in 2005, entitled *Micro-Scale Evaluation of Phosphorus Removal: Part II – Alternative Wastewater Systems Evaluation*. Simply stated, phosphorus removal by soils occurs by:

- Sorption
- Mineralization/precipitation with aluminum, iron, and calcium
- Crystallization

Numerous techniques have been used for estimating phosphorus removal by soils (US EPA 2000) and all have limitations. Many practitioners have assumed that soils have a virtually infinite capacity to remove phosphorus. Recent USGS investigations, however, have determined that phosphorus sorption removal by soils is reversible.

To best estimate the phosphorus subsurface dispersal ability of a system, the investigator should:

- Understand the mechanisms for phosphorus removal
- Understand the geology, especially surficial, of the study area
- Estimate dispersal system flow paths to understand the soils with which the dispersal plume will be in contact, including the hyporheic zone

A cautious approach to subsurface phosphorus soils removal should be used, especially for areas with sandy/gravel soils. Also, pretreatment may prevent the conditions to develop that enable the aluminum- or iron-phosphorus mineralization.

If vegetation is low, nitrogen and phosphorus removal can also occur by plant uptake with drip distribution systems. US EPA wastewater land application manuals should be consulted for this issue (US EPA 1981), as well as the *Wastewater Subsurface Drip Distribution Report* (EPRI 2004).

Due to the slow speed of groundwater movement, manifestations of nutrient over-enrichment may not be observed for many years. Unfortunately, when manifestations occur, corrective actions may not produce visual improvements, as the groundwater aquifer needs to flush itself of the nutrient-enriched water. Strategically located groundwater monitoring provides an early warning system.

Wastewater Disinfection

One of the purposes of subsurface soil dispersal systems is for removal of pathogenic organisms. Although many pathogenic organisms are removed in the biomat zone, generally a minimum depth of unsaturated soils is necessary for pathogen removal. The minimum amount of unsaturated soil depth for acceptable pathogen removal is debatable and a function of soil type; however, for planning purposes and in compliance with many state codes, a minimum of two to four feet should be provided for disinfection of STE. This unsaturated zone requirement is reduced to one to two feet in some states when the wastewater is pretreated prior to the dispersal system. With disinfection prior to discharge, some states reduce the unsaturated requirement even further.

In certain states (such as Massachusetts, New Jersey, and California) a separate analysis is necessary when cluster dispersal systems are in water supply recharge areas, where a minimum six-month travel time is required.

Purified Wastewater Dispersal

A major reason for using subsurface dispersal systems is to return the purified wastewater to the environment. With subsurface dispersal systems, groundwater aquifer recharge occurs. The location of the dispersal system in relation to other groundwater flow patterns should be judiciously chosen, as groundwater recharge may result in indirect water reuse. This issue is further discussed later in this chapter.

Water moves by preferential flow in macropores (Gachter 1998) and may not be in contact with the entire soil matrix within the dispersal plume. In designing dispersal areas, most states require reserve areas (typically 50 to 100 percent of the primary area) be identified and set aside for use should the primary dispersal area fail.

Soils Issues

The importance of soils and understanding how soils purify wastewater and how water is transmitted through soils cannot be understated for subsurface dispersal cluster wastewater systems.

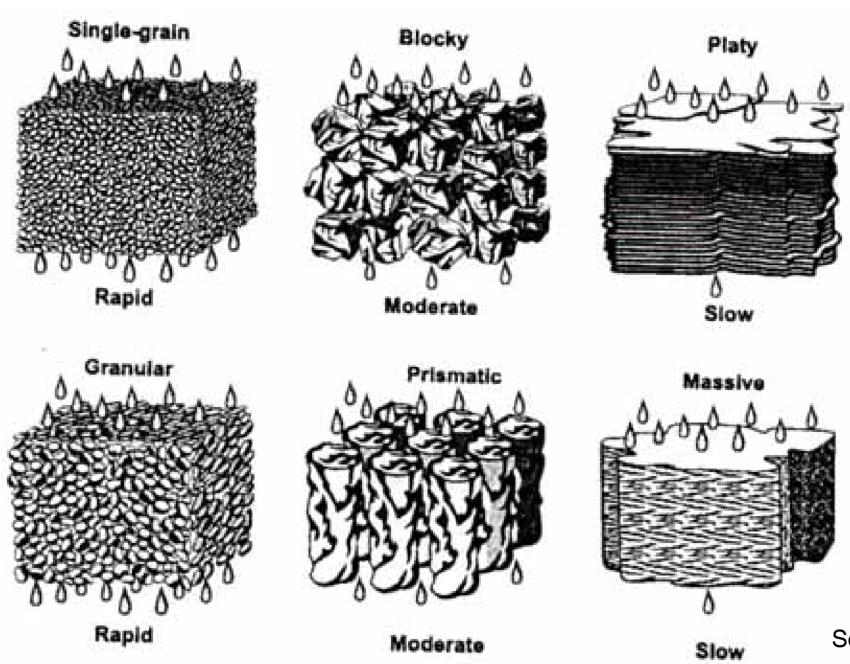
There are many US EPA documents, most notably the *Onsite Wastewater Treatment Systems Manual* (US EPA 2002a), which address this issue in great detail, as well as professional papers (White and West 2003). Many states have upgraded their requirements for site soils evaluation in light of the extensive research, US EPA advocacy, and lessons learned during the past decades, and they now require site analysis by a certified soils specialist.

The most important soil characteristics that are used in the design of cluster system dispersal systems are:

- Hydraulic conductivity
- Vertical profile variation
- Depth to groundwater
- Depth to bedrock or impervious material
- Slope

Soil structure is important, as illustrated in Figure 3-1, for hydraulic conductivity. The American Society for Testing and Materials (ASTM) has produced a range of standards for soil testing related to subsurface dispersal systems (ASTM 1996a, 1996b, 1997, 2000a).

Figure 3-1
Soil Structures



Source US EPA (2000)

Using this information and the design flows and wastewater characteristics of the proposed property use, a professional can design a subsurface dispersal system. Proper siting of the system on the property and engineering details are other important matters that are addressed in US EPA's *Onsite Wastewater Treatment Systems Manual*.

The US Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) has prepared soil surveys of the US that describe soils to a six-foot depth. These studies are often used for planning purposes, especially when site specific data is not available. The NRCS soil surveys delineate soil series and provide physical characteristics and engineering criteria. Soil permeability ranges (usually as a function of depth) for depth to groundwater and depth to bedrock/impermeable layer are typically included. NRCS states that this data is for general planning purposes, and decisions about the suitability of a specific site for an intensive use must be based upon an onsite soil evaluation by a certified soils evaluator.

For wastewater management planning purposes, sole reliance on the NRCS soil surveys results may overestimate the need for sewers (off-site solutions). Public support and credibility are difficult to achieve when the NRCS soil survey-based analysis states that onsite septic systems are not viable in a community that has hundreds of recently permitted septic systems operating in these areas.

Consequently, planners should adjust the NRCS soil surveys when local data are available. Local data are usually available in health department files of septic system designs that include soil characterization data (hydraulic conductivity, depth to groundwater, and depth to bedrock/impermeable layer). The quality of the data needs to be considered and poor-quality data should not be used for adjustment considerations. In addition, groundwater adjustment factors may be needed.

Based upon the work of Dr. Michael Frimpter of the USGS (USGS 1980), the State of Massachusetts allows use of a formula for the estimation of the seasonal-high groundwater level at a site. If the hydrogeologic conditions at the site are similar with an off-site observation well, use of this formula for estimation is acceptable. As a result, some Massachusetts town health departments publish weekly adjustment factors for use with groundwater measurements made in specific communities. This information enables estimates of seasonal-high groundwater levels to be made at virtually any time during the year. Soil mottling observations are used to identify seasonal-high groundwater levels.

The NRCS soils series characteristics adjustment process consists of the following process:

1. Digitize soils information from recently permitted septic systems where the data is reliable

2. Assign the NRCS soil series for the properties with the recent data

3. Analyze each NRCS soil series using recent septic system data

4. Compare NRCS soils design characteristics to measured septic design data

5. Assign revised soils design characteristics using the correlation data

The planner can then determine the suitability of sites for dispersal locations based upon the locally-adjusted NRCS soils surveys. These surveys are useful for planning Type I-size cluster systems and drip distribution systems. Surficial geology information (below six feet of the soil surveys) is usually necessary when planning subsurface dispersal systems for Type II-size cluster systems using the higher application rates associated with trenches or beds.

When these techniques were applied to the town of Acton, MA (Lombardo Associates, Inc. 2002), the following results occurred:

- Based on the existing NRCS information, more than 50 percent of the 5,714 properties with septic systems would have been sewered. The potential total capital cost to address the town's wastewater needs on this basis was estimated to be $74 to $120 million.
- After adjustments to the NRCS data using actual field measurements, 13 percent of the 5,714 properties with septic systems were proposed to be sewered. The potential total capital cost to address the town's wastewater needs, based upon the revised soils characteristics, was an estimated $37 to $60 million.
- The sole use of the NRCS data would have led planners to a proposed $37 to $60 million of unnecessary expense in this community alone.

Based upon measured values of hydraulic conductivity, state codes provide dispersal system sizing design criteria. This criteria is usually calculated by the percolation rate for Type I cluster systems and permeability testing for Type II cluster systems, or in some states, such as Georgia, by an assignment of hydraulic conductivity to the identified soil type. For Type II cluster systems, most states require hydrogeologic testing and analysis, as described in the following section.

Hydrogeological Issues

For prospective dispersal areas, the Type I cluster system feasibility screening process consists of the following steps:

1. Desktop screen potential sites for suitability based on readily available soils and hydrogeological information, including well logs, hazmat, and remediation studies and aquifer studies. The USGS usually has a wealth of hydrogeology and surficial geology studies that can provide significant insights.

2. Further evaluation of sites that remain viable after the initial desktop screening in the field with simple and inexpensive techniques (site walkover and test pit excavations). For smaller systems, test pit excavations and hydraulic conductivity measurements may be the only evaluations needed.

3. If the field soils and hydrogeological assessment find the site is suitable, perform simplified mounding analysis and fate and transport modeling as described in Healy and May (1997), Finnemore (1993), Finnemore (1994), and Amoozegar and Martin (1997).

For Type II cluster systems, two additional confirmation steps are needed:

4. Perform detailed site tests for hydraulic conductivity; install groundwater monitoring wells.
5. Perform mounding and fate and transport analyses with sophisticated techniques such as MODFLOW and particle tracking analysis.

Whether one or all of the steps need to be followed depends on the system size, as outlined in Table 3-1.

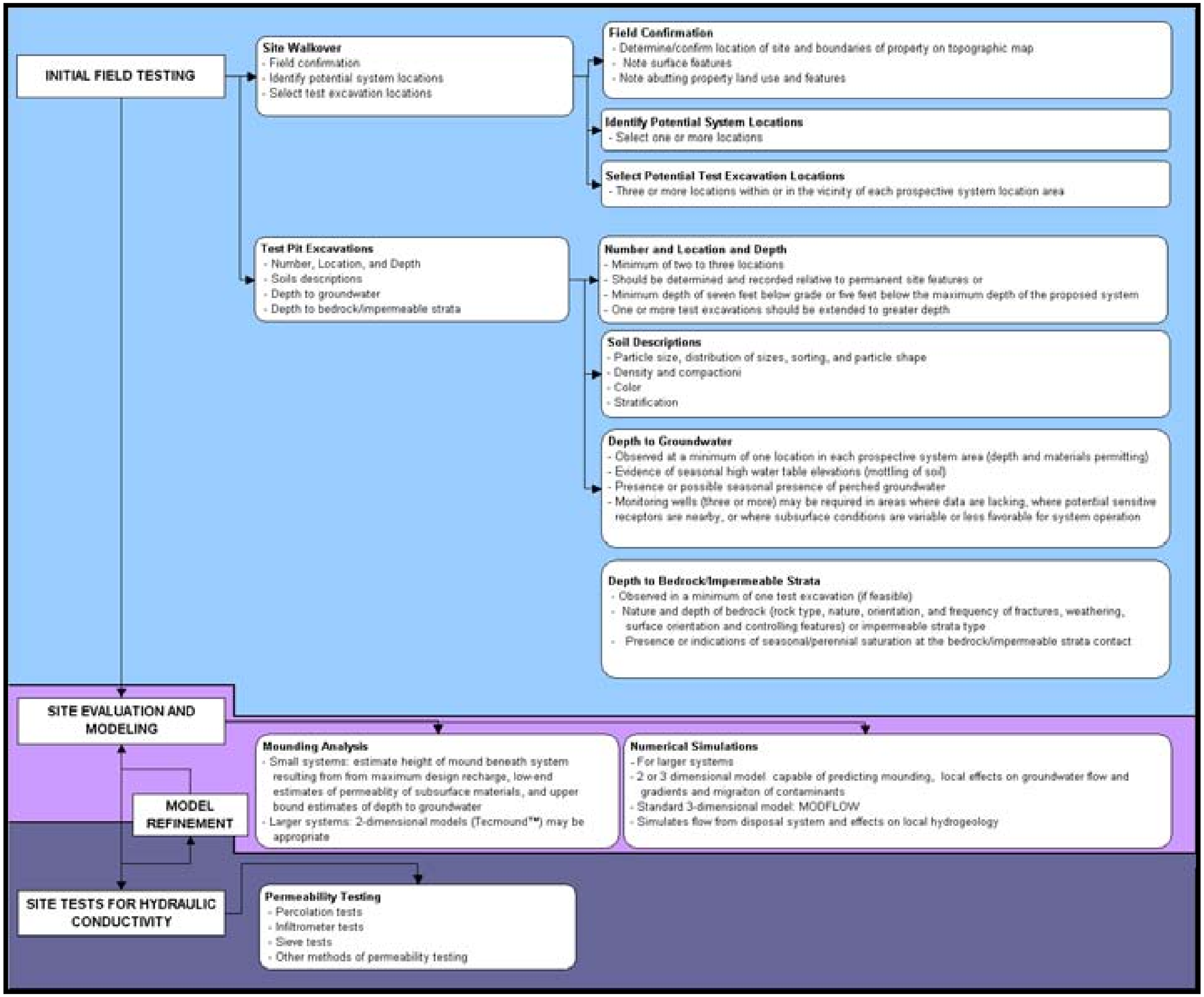
Table 3-1
Level of Soils and Hydrogeological Evaluation Needed by System Size for Planning Subsurface Dispersal Systems

Cluster System Type	Size of System	Range of Flows (gpd)	Level of Soils and Hydrogeological Evaluation
I	Small	<2,000	Initial desktop site screening and simple field evaluation may be sufficient
	Medium	2,000 to 10,000	
II	Medium-Large	10,000 to 25,000	Second-phase field evaluation and variable level of modeling
	Large	10,000 to 50,000	Long-term monitoring and comprehensive modeling analysis required
	Very Large	>50,000	

The site screening process is illustrated in Figure 3-2.

Figure 3-2
Process Flow for Hydrogeological Evaluation of Subsurface Dispersal Sites

Figure 3-2
Process Flow for Hydrogeological Evaluation of Subsurface Dispersal Sites (Cont.)



For small (Type I) systems, there are two primary soil suitability considerations for subsurface wastewater dispersal:

- Hydraulic conductivity
- Depth to groundwater/limiting layer

Many state codes usually require that percolation rates be less than 60 minutes per inch (mpi), and in some states less than 120 mpi, for a site to be used as a dispersal location. Depth to groundwater is measured from the bottom of the dispersal distribution system (that is, the bottom of the trench), and must generally be at least four feet, although as little as one-half foot is allowed in some states for specific applications.

For Type II cluster systems, additional issues usually require the preparation of a detailed hydrogeological assessment. Additional issues that must be evaluated include:

- **Groundwater mounding—**The volume of water being discharged may cause the groundwater below the dispersal area to mound, or increase in elevation. This mounding can cause local flooding (as has occurred in Barnstable, MA) and flooding at the dispersal area as well. Flooding of the dispersal system will cause it to malfunction as previously discussed. This process is illustrated in Figure 3-3.
- **Surface breakout/emergent groundwater—**Depending on local topography, hydrogeology, surficial geology, and other factors, effluent dispersed into the subsurface may eventually emerge at the surface downgradient from the dispersal area. This emergence may or may not be acceptable, and must be evaluated as part of the site evaluation process.
- **Fate and transport—**Depending on the size of the cluster system, fate and transport analysis may be required to identify the flow path and ultimate discharge location of the dispersed wastewater effluent. This analysis is necessary to evaluate any impacts from the system on downgradient receptors. Figure 3-4 illustrates particle tracking analysis using MODFLOW to demonstrate the flow paths of a proposed wastewater dispersal system and the flow paths of water to a water supply well.
- **Indirect reuse—**Many communities disperse treated wastewater into aquifers that are also used for water supply. This practice is termed “indirect reuse,” and can be acceptable if performed within certain guidelines (as discussed in the following *Regulatory Issues* section). To protect public health and public water supplies, subsurface dispersal into indirect reuse aquifers should be evaluated to determine the cumulative impacts to the aquifer and public water supply. Time of travel to water supply wells and percent contribution analyses should be performed.

Figure 3-3
Schematic of Groundwater Mounding and Emergent Groundwater

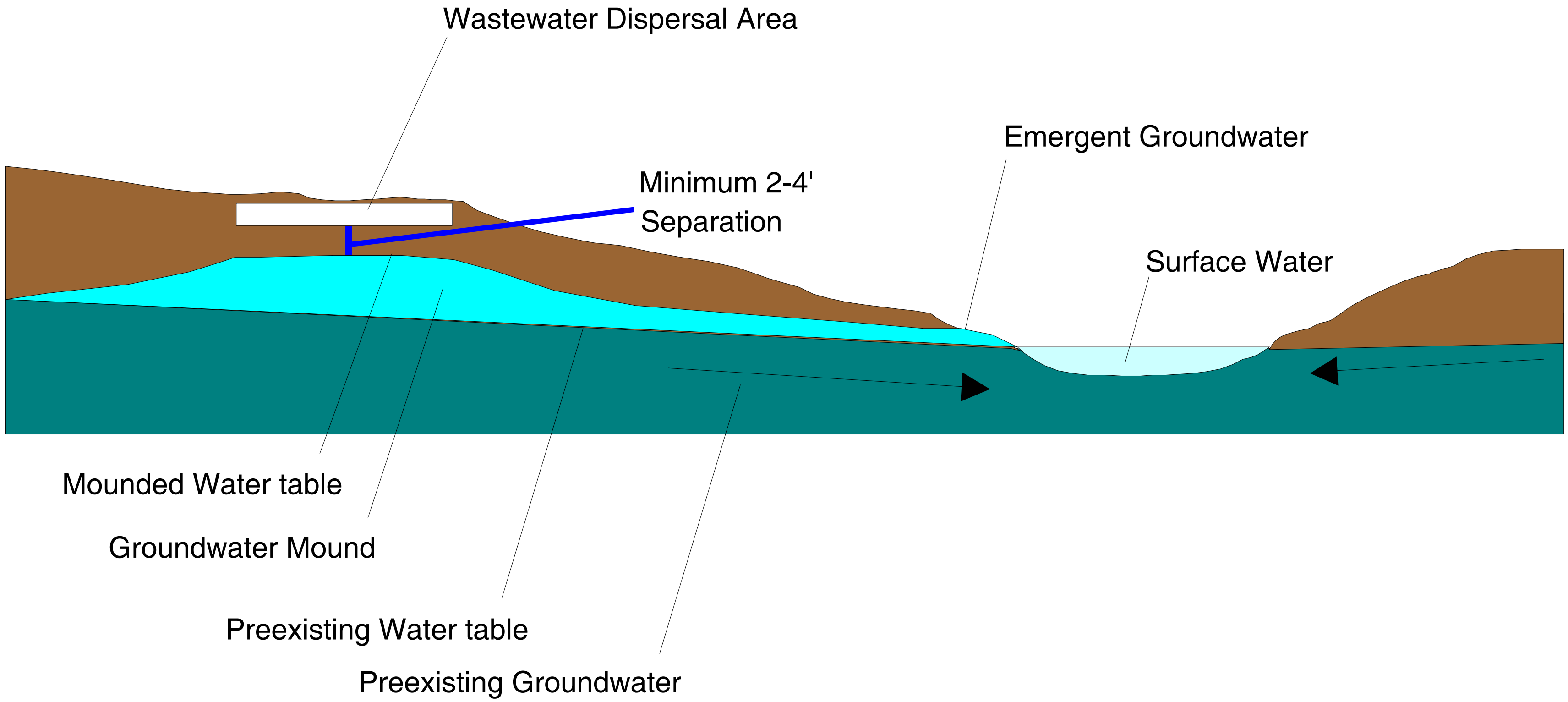
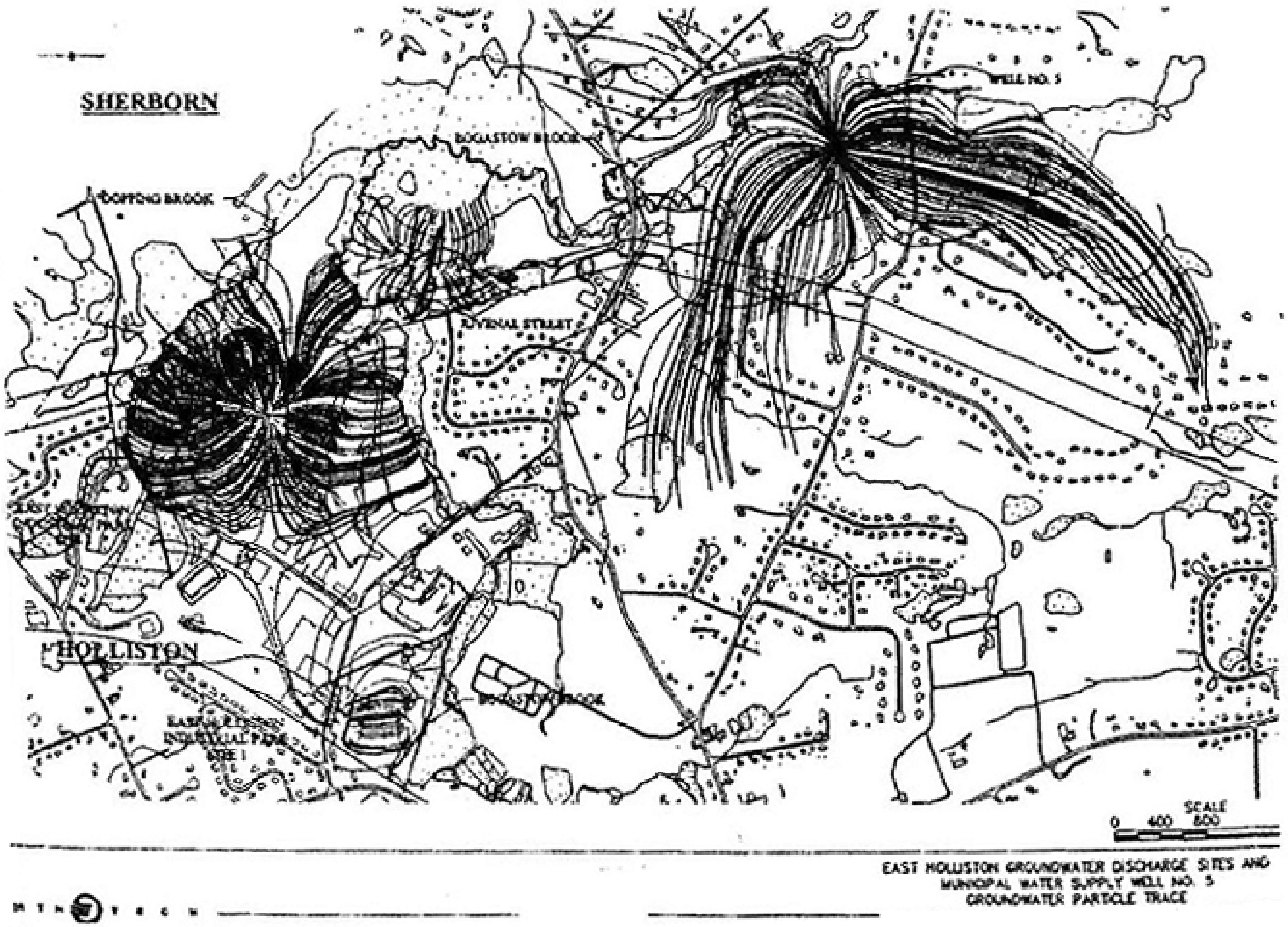


Figure 3-4
Particle Tracking of Wastewater Discharge and Nearby Water Supply Well Intake



Source: (EarthTech 1999)

The Connecticut Department of Environmental Protection, for example, has two requirements: (1) that there be no breakout/emergent groundwater for a minimum of 21 days, and preferably 42 days, of subsurface travel time or during travel to the property line or receiving wetlands; and (2) that total nitrogen at the property line or receiving wetland be 10 mg/l or less (Healy and May 1997).

Demonstration of compliance with these requirements involves a detailed hydrogeological site assessment, including groundwater modeling. Although such assessments can be expensive, failing to perform appropriate testing is often far more costly.

The NDWRCDP is implementing the following studies to provide further information on these issues:

- Hydrogeological evaluations for larger cluster and high-density wastewater soil absorption systems
- Field evaluations for large cluster wastewater soil absorption systems

For larger projects or for projects in environmentally sensitive areas, groundwater tracers (Davis *et al*. 1996) should be used to field-validate modeling projections.

Soil and Hydrogeological Site Evaluation

The entire site evaluation process, including methods for evaluating the concerns and issues associated with large-capacity cluster systems, is described in the following section and shown in Figure 3-2.

Desktop Site Screening

The objective of the initial screening-level evaluation of lands that are or may be available for wastewater dispersal systems is to gather all pertinent, easily accessible information concerning the prospective sites so that subsequent field investigations focus resources in locations that have real potential. The information may include:

- Soil information
  - Types
  - Verical profile variations
  - Permeabilities
  - Drainage characteristics
- Hydrogeological information

- Previous surficial geology and hydrogeology studies performed by public entities (especially USGS) as well as hazardous waste characteristics and remediation studies
  - Test pit and percolation test data
  - Well logs
  - Groundwater elevation
  - Groundwater flow direction and velocity
  - Hydraulic conductivity
- Location and design of current septic systems
- Location of public and private water wells
- Potential sensitive receptor information
- Current and future development of the site and nearby areas
- Topography
- Land uses

Sources of information for the initial screening-level evaluation include local agencies and sources. State, regional, and federal agencies are listed in Figure 3-2.

Field Site Screening

If the site appears to be potentially feasible for subsurface wastewater dispersal based on the results of the desktop hydrogeological evaluation, it can be considered for detailed hydrogeological assessment and field testing. The field site screening consists of a:

- Site walkover
- Test pit excavation

Site Walkover

The information collected during a site walkover includes:

- Location and boundaries of site
- Surface features on site and in the vicinity (topography, surface soil type and moisture, vegetation and changes in vegetation type and density bedrock outcrops)
- Abutting property land use and features (surface water drainage concentrations and groundwater discharge points, well and septic locations, potential contaminant sources, topography)

The site walkover should also identify three or more possible locations for test excavations.

Test Pit Excavations

The purpose of the test pit excavations is to:

- Permit detailed evaluation of subsurface soils
- Obtain information, if possible, on
  - Depth to groundwater
  - Depth to bedrock or impermeable/relatively impermeable strata
  - Horizontal and vertical changes in soil types over the site area
- Provide valid and significant locations for permeability tests

A minimum of two or three test pit excavations should be performed in areas being considered for Type I cluster systems, while a larger number of deep test pits should be excavated in areas considered for Type II systems or in areas where considerable variation (vertically or horizontally) in soil characteristics exist. The locations of test excavations should be determined relative to permanent site markers and plotted on a plan of the site. Test pit excavations should extend to a minimum of 10 feet below the maximum depth of the potential dispersal system. Ideally, test excavations should be extended to bedrock. Test excavations are preferable to soil borings for the initial evaluation of a site because soil horizons exposed in the sides of a test excavation provide a more graphic and accurate view of subsurface conditions. Hollow stem auger borings may be desirable to characterize the full depth of aquifer materials and as a supplement to deep test pits where they are not feasible.

The soil encountered during the test pit excavation should be recorded in detail on a log of the excavation and described as precisely as possible. Nomenclature used by the NRCS is commonly employed. The important soil characteristics to note are as follows:

- **Boundaries of horizons—**Layers of soil that exhibit similar properties
- **Texture—**The distribution of particle size among sand, silt, and clay separates; the average particle size should be recorded for each strata according to standard soil descriptors used by the engineering community (Table 3-2)
- **Structure—**The nature of the aggregation of soil particles
- **Color—**The hue (color quality), value (lightness or darkness of color), and chroma (purity of spectral color) of the soil
- **Redoximorphic features—**Presence/absence of mottles
- **Consistence—**Degree of cohesion or adhesion of soil

Table 3-2
Soil Descriptions Used

Descriptor	Particle Size		Typical Surrogate Description	Standard Sieve Size
	Inches	Millimeters		
Gravel	3.0–0.19	76–4.75	Lemons to peas	3" to #4
Coarse sand	0.19–0.08	4.75–2.0	Rock salt	#4 to #10
Medium sand	0.08–0.02	2.0–0.425	Granulated sugar	#10 to #40
Fine sand	0.02–0.003	0.425–0.075	Powdered sugar	#40 to #200
Silt	Less than 0.003	0.075–0.002	Talcum powder	Passing #200
Clay		Less than 0.002		Passing #200

During the test pit excavation, determining depth to groundwater might be possible by simply observing soil mottling and measuring the depth at which groundwater flows into the excavation and using adjustment factors for seasonal issues (as discussed in the *Dispersal Soils* section). In other cases, the installation and monitoring of observation wells might be required. For Type II cluster systems, observation wells will generally be necessary.

Site Evaluation and Modeling

The level of effort required to predict the effects of operation of the proposed system depends on several factors:

- Size of the proposed system
- Preliminary estimates of the capacity of the proposed site(s)
- Complexity of the site
- Nature and location of potential sensitive receptors

Groundwater models may be used to evaluate or predict the effects of the application or dispersal of wastewater on local or regional groundwater flow in porous media and on local or regional groundwater quality. A model is simply an approximation or simulation of conditions, which have existed, may exist in the future, or currently exist.

For large cluster systems (Type II), detailed modeling may be required by regulation to predict mounding of the groundwater table in the vicinity of the system site and the potential water quality effects on downgradient sensitive receptors. For Type I systems, estimates of the effect of system operation on the local water table and potential effects on nearby sensitive receptors may be required or recommended to provide increased assurance of site suitability.

Mounding

The water table rises beneath an area (see Figure 3-3) where recharge occurs through natural or artificial means, creating a groundwater mound. The groundwater mound changes the local groundwater flow pattern, resulting in the dispersal of the recharged water up-, across-, and down-gradient with respect to the regional groundwater flow direction. In areas where the groundwater table is shallow, where soils are moderately or poorly permeable, or where the effective thickness of the permeable aquifer is limited, the mound may approach and submerge the dispersal system or even breakout on the surface. This could result in failure of the system. For Type I cluster system installations under favorable conditions, it may be sufficient to estimate the height of the mound beneath the system resulting from the maximum design recharge, low-end estimates of the permeability of subsurface materials and upper bound estimates of the depth to groundwater. Any of a number of public-domain or commercially available models, employing solutions developed by Hantush (1967), Glover (1964), or Finnemore (1993), may be used to estimate the theoretical mound height under these assumed conditions. For larger installations, or where potential sensitive receptors are nearby, slightly more complex two-dimensional models may be appropriate (for example, Tecsoft's Tecmound™ is a two-dimensional model that employs the Hantush (1967) or Glover (1964) analysis).

Numerical Simulations

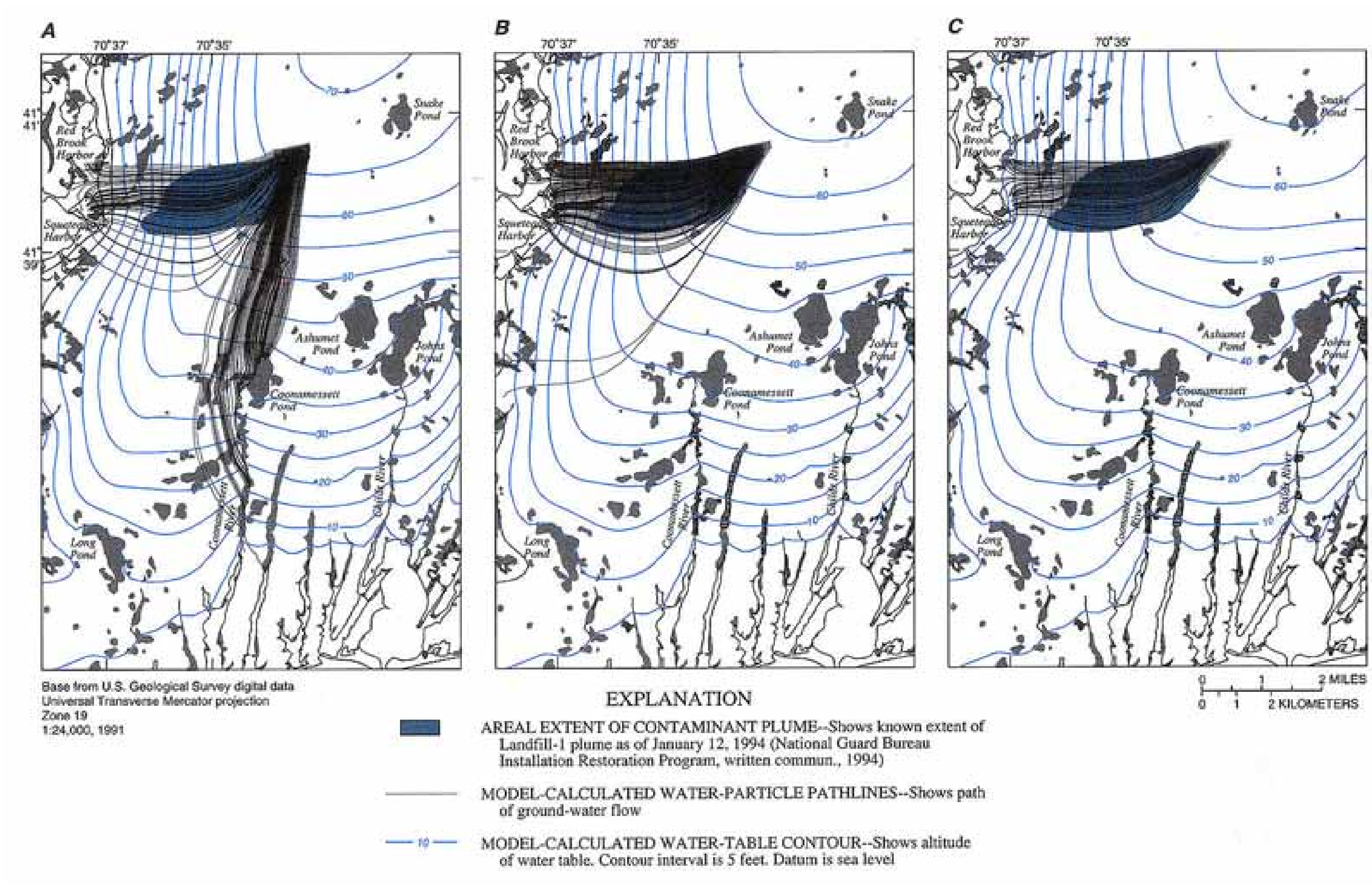
The application of a two- or three-dimensional model may be justified for large systems, systems in marginal areas, or where subsurface conditions are variable or near potential sensitive receptors. This kind of model is capable of predicting mounding, local effects on groundwater flow and gradients, and migration of contaminants. The standard three-dimensional modeling software is the USGS Modular Three-Dimensional, Finite-Difference Groundwater Flow Model (MODFLOW). This is a publicly available FORTRAN program first devised in the 1970s and modified on numerous occasions. There are a number of software modules that may be used in conjunction with MODFLOW to perform calculations such as particle tracking and contaminant transport. Many graphical user interfaces, such as Visual MODFLOW™, Groundwater Vistas™, or Groundwater Modeling System™, are commercially available today to ease model preparation and graphical output. These are easily operated from a personal computer.

Three-dimensional groundwater models enable the user to simulate flow from a dispersal system and its effect on the local hydrogeology accurately. The user can make the model as detailed or as simple as possible. Three-dimensional models enable variation of subsurface parameters such as hydraulic conductivity, storage coefficients, and recharge to depict site-specific conditions more accurately. Water table elevation information from the site provides a means of comparison in model calibration. Proper calibration of the model to match ambient conditions is an important aspect of any three-dimensional modeling effort (Anderson and Woessner 1992). Particle tracking may be used to improve numerical model calibration (Barlow 1997 and Masterson *et al*. 1996).

Although modeling can provide critical insights on subsurface flow patterns and therefore potential impacts on downgradient receptors, models should be field-verified to ensure model parameters are accurate. A sensitivity analysis of model parameters will provide guidance in the importance and parameters that need to be field-verified. Figure 3-5 illustrates particle tracking flow paths from a contaminant plume on the Otis Air Force Base in Cape Cod, MA (Barlow 1997). Depending on the horizontal hydraulic conductivity used (varied from 50 to 150 to 200 feet per day), the model predicts ultimate discharge to different areas, which would have significant implications for treatment requirements.

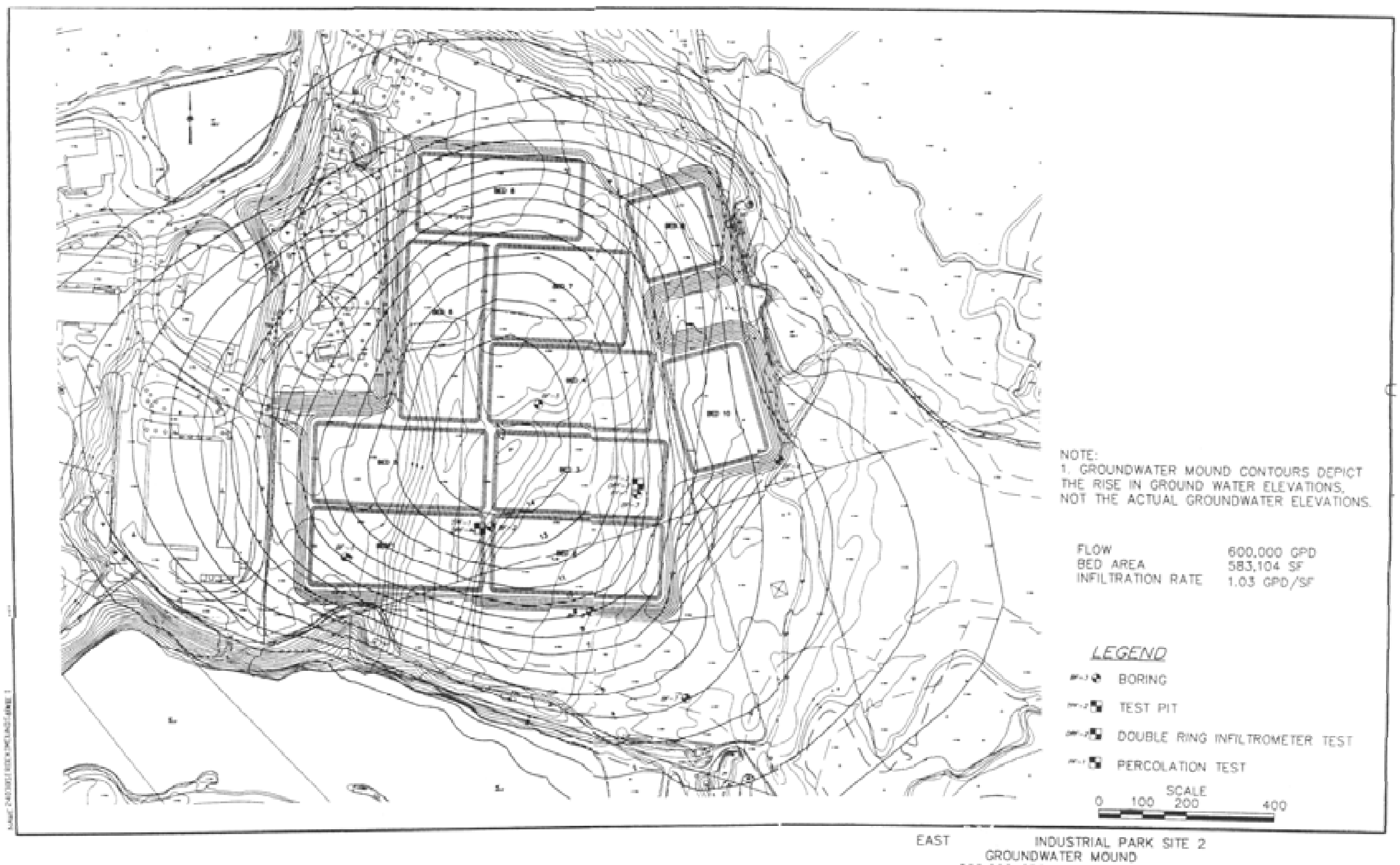
Once a model is properly calibrated, it may be used to simulate the artificial recharge of a dispersal system. This simulation enables the user to predict mounding effects and predict travel times for effluent to migrate a given distance. This prediction is especially important in determining potential impacts on nearby receptors. The model may be used to predict the hydrogeologic effects of a dispersal system far into the future and under varying natural conditions, such as periods of drought or above-average precipitation. Figure 3-6 and Figure 3-7 show example outputs from mounding of a large subsurface cluster dispersal system and water supply well zones of contribution analyses, respectively.

Figure 3-5
Use of Particle Tracking Analysis to Improve Numerical Model Calibration



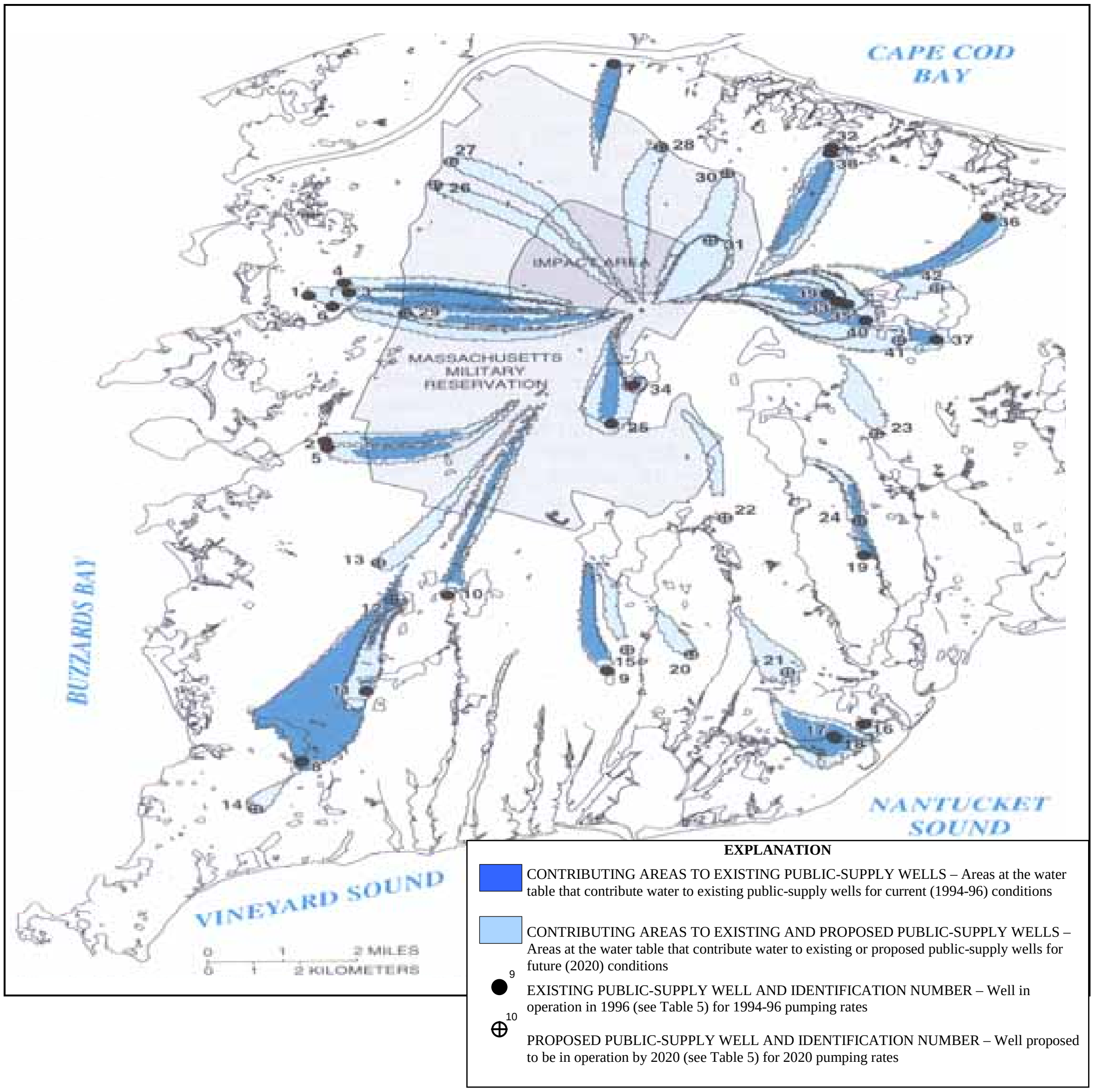
Effects of increasing horizontal hydraulic conductivity are shown on model-calculated water-particle path lines and water-table configurations.
A = 50 feet per day; B = 150 feet per day; C = 200 feet per day

Figure 3-6
Example Output from Mounding Analysis



Source: EarthTech 1999.

Figure 3-7
Example Output from Water Supply Wells Zone of Contribution



Site Tests for Hydraulic Conductivity

If the desktop and field site screenings demonstrate the feasibility of using the site for wastewater dispersal, the planning team should confirm site suitability with additional field tests, as described in the following section, to determine hydraulic conductivity.

Permeability Tests

A variety of testing procedures can be used to determine the permeability of subsurface materials on a prospective site to supplement office work. A percolation test and an infiltrometer test are typically performed as part of the preliminary evaluation of a prospective site for a cluster system.

Percolation test—This test involves excavating a small hole in the surface or subsurface soils (at depth in a test excavation), filling the hole with water, and measuring the rate at which the water level in the hole drops. The results are expressed as inches of decrease in hydraulic head of water in the hole per minute (Carroll County, MD 2000; Driscoll 1986; Fetter 1994; Robertson Geoconsultants, Inc. 2003; State of Connecticut 1998; State of Pennsylvania 1983; State of Utah 2000; Tri-County [Utah] Health Dept. 2001; US EPA 2002a). In practice, percolation tests are performed by placing a tube in a hand-dug hole, saturating the soil in the vicinity of the hole for a specified time period, filling the hole with water to a specified depth and measuring the rate at which the water drops. This test is losing favor in many jurisdictions since it fails to provide direct information on hydraulic properties.

Infiltrometer tests—Infiltrometer tests are similar to percolation tests, with the exception that the tester drives the tube into the soils to be tested, pre-saturates the system for a specified time period, and measures the infiltration rate of water through the tube (ASTM 1994; Robertson Geoconsultants, Inc. 2003; State of Connecticut 1998; US EPA 2002a).

Other methods for estimating soil permeability include:

In situ observation of shallow groundwater flow—This method is most appropriate for uniform, moderately permeable soil present as a thin layer above a relatively impermeable, sloping surface (bedrock or hardpan). The thickness of saturated materials above the relatively impermeable lower boundary layer is measured in a test excavation or appropriately located boring (State of Connecticut 1998; US EPA 2002a).

Observation of differences in groundwater level—This method consists of making observations of groundwater elevation at two locations on a sloping surface and attributing the difference in observed groundwater elevation to the average daily infiltration (average daily precipitation less evaporation, evapotranspiration, and runoff) on the slope between the two locations (State of Connecticut 1998; US EPA 2002a).

Pit bailing tests—These tests can be performed either by measuring the rate at which groundwater flows into a deep test excavation, or by pumping groundwater out of a test excavation and measuring the rate of recharge. The rate at which water enters or re-enters the excavation, adjusted for the area of the excavation below the water table, is proportional to the permeability of saturated soils intersected by the excavation (State of Connecticut 1998; US EPA 2002a).

Undisturbed tube samples—In this method, a sharp-edged, thin-walled tube is pushed smoothly into the soil horizon to be tested in a horizontal or vertical orientation. The sample enclosed in the tube is withdrawn and handled with care to avoid disruption. The sample tube is placed vertically in a bed of testing sand in a shallow pan and a small amount of testing sand is placed on the surface of the soil sample to prevent erosion when water is added. The sample and the testing sand are saturated, taking care to avoid the introduction of air bubbles into the soil, then a falling head hydraulic test (where the rate at which the water level above the samples falls is monitored) or constant head hydraulic test (where a known amount of water is added over a known time interval to maintain a constant water elevation above the sample) is performed to estimate the permeability of the sample (Freeze and Cherry 1979; Robertson Geoconsultants, Inc. 2003; State of Connecticut (1998).

Sieve testing—This method involves sieving a sample of material collected from a known depth and location within the test excavation and using the resulting data on the distribution of grain sizes and various empirical formulae to arrive at an estimate of permeability. Estimates of permeability may be derived from the Hazen relationship ($K = Ad_{10}^2$), where K is the permeability, A is a constant dependent on the units used and material tested, and d_{10} is the grain size diameter at which 10 percent by weight of the soil is finer grained and 90 percent are coarser (ASTM 1998; ASTM 2000b; Hazen 1911).

Soil identification—This method consists of making an estimate of permeability based on visual observation of soil type. It may be used to confirm or support estimates of permeability made by other means (State of Connecticut 1998).

In Situ Hydraulic Conductivity

In cases where the installation of groundwater monitoring wells is required, or where groundwater monitoring wells are available, rising or falling head hydraulic conductivity tests can be performed to provide an estimate of the horizontal hydraulic conductivity of saturated materials. These tests are most commonly performed by quickly adding or withdrawing a slug of water to or from a well and recording the subsequent return to static conditions. The resulting data may be analyzed by a variety of methods to arrive at an estimate of hydraulic conductivity (Binkhorst and Robbins 1994; Bouwer and Rice 1976; Bouwer 1989; Cooper *et al*. 1967; Freeze and Cherry 1979; Hvorslev 1951; US EPA 2002a).

Pumping Tests

Pumping tests may be required where the proposed system capacity is large, or where heterogeneity or other limitations necessitate a more definitive evaluation of horizontal hydraulic conductivity. Pumping tests consist of withdrawing water at a known rate from a well and recording the resulting drawdown in the well and/or in the aquifer. Withdrawal of water from an aquifer creates a zone of depression in the water table around the withdrawal point. Care must be taken to discharge the pumped water at a location remote from the zone of depression. In relatively homogeneous aquifer materials, the zone of depression may take the form of a cone centered on the pumping well. In heterogeneous materials, or where other recharge or discharge points are present, the shape of the zone of depression around the pumping well may vary. Pumping tests typically require the installation of a pumping well and a number of observation wells at different distances from the pumping well within an area likely to be affected by the pumping (Driscoll 1986; Fetter 1994; Freeze and Cherry 1979).

Notes on Permeability, Hydraulic Conductivity, and Transmissivity

Specific or intrinsic permeability (k) of a granular porous medium is defined as the product of the square of the mean diameter (d) of the constituent particles and a constant, which represents a number of other factors, including the distribution of grain sizes, the sphericity and roundness of the grains, and the nature of the packing ($k = Cd^2$). The specific or intrinsic permeability is a property of the porous medium and is independent of fluid properties. Specific permeability is expressed in generic units of area (l^2).

Hydraulic conductivity, or coefficient of permeability, is a proportionality constant that expresses the relationship between the hydraulic gradient in a material and the velocity of fluid flow through it:

$$v = -K\, i$$

where v = velocity, K = the hydraulic conductivity or coefficient of permeability, and i = the gradient. Hydraulic conductivity is expressed in units of volume per area per time (l^3/l^2t), which is commonly abbreviated to length per time (l/t).

Transmissivity, T, is a function of hydraulic conductivity, and is expressed as a flux per unit width under a unit hydraulic head:

$$T = K\, b$$

where T = transmissivity, K = hydraulic conductivity, and b = saturated thickness. Transmissivity is therefore dependent on the saturated thickness and may vary in unconfined conditions when the thickness changes, whereas hydraulic conductivity is a function of the properties of the porous media and the fluid. Transmissivity is expressed in units of volume per width of the aquifer per time, which is abbreviated to area per time (l^2/t).

The term “permeability,” as used in wastewater engineering, is a shortening of “coefficient of permeability” and actually refers to hydraulic conductivity.

Refinement of Models

Based on the additional information collected in the site tests for hydraulic conductivity, the mounding models and fate and transport models described in the previous section can be further refined. This refinement usually applies to large or very large cluster systems.

Hydrogeologic Investigation Example

This section provides an example of the hydrogeologic investigation portion of cluster system design.

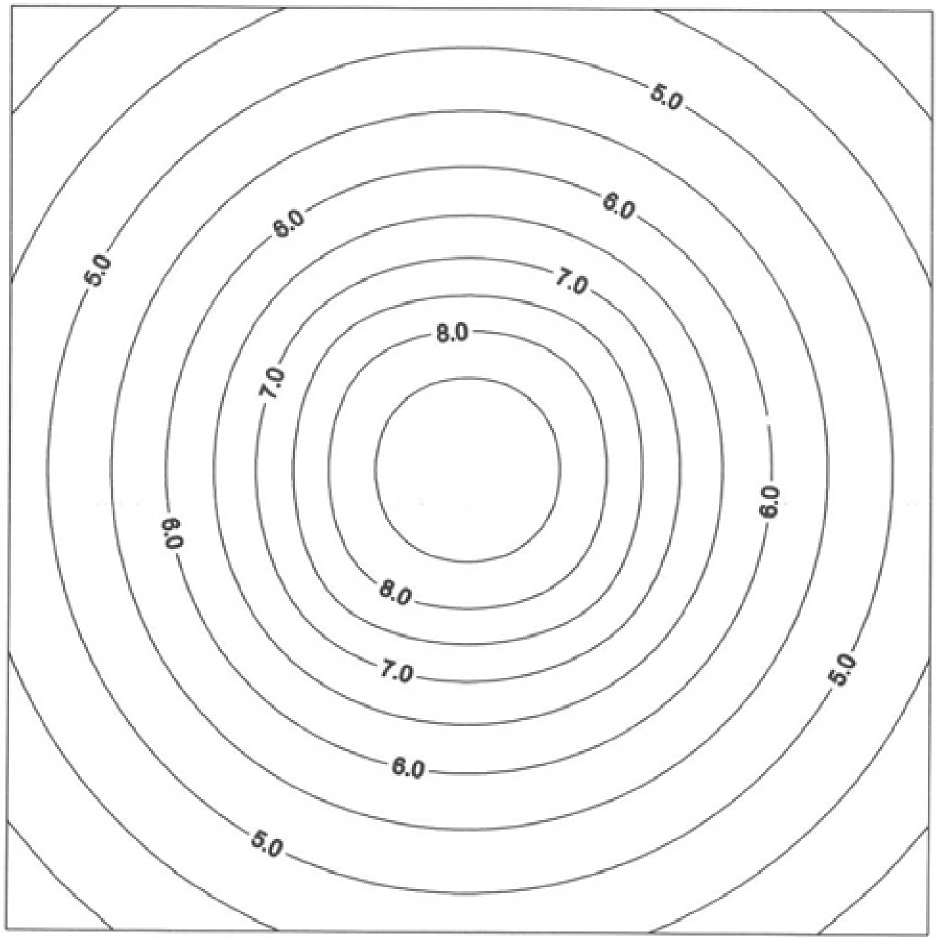
A developer wanted to install a subsurface wastewater dispersal system to treat wastewater from construction of 20 new single-family homes. Subsurface conditions were not conducive to placement of individual septic systems due to the clay-rich soil underlying most of the property. Conditions appeared to be suitable for a cluster treatment and dispersal system location in a portion of the property. The developer hired a consultant to determine the suitability of this portion of the property for cluster system placement.

The consultant conducted limited subsurface investigation activities at the site, including excavating three test pits and permeability testing. Permeability testing consisted of infiltrometer tests performed just below ground surface and within the test pit at a depth of eight feet. The soil at the site appeared to be uniformly sandy and conducive to system placement. The consultant also installed three monitoring wells at the site to determine depth to groundwater and flow direction. Average depth to groundwater was 17 feet below ground surface, and the consultant observed water to be at this depth during well placement. The consultant also performed slug tests on each well to confirm the hydraulic conductivity measurements taken from the infiltrometers. Infiltrometer and slug testing returned average hydraulic conductivities of 22 feet per day.

Local health codes dictated system effluent must pass through a minimum of five feet of unsaturated soil before reaching the water table. The infiltration trenches would be installed at a depth of three feet below ground surface. Since mounding from system infiltration would affect the groundwater levels underneath the system, the consultant needed to balance system output requirements with site hydrogeology to determine if the amount of expected mounding was acceptable. Thus with the average water table at a depth of 17 feet, and with the system requiring unsaturated soil to a depth of at least eight feet from ground surface, the maximum allowable mound height was nine feet above the average water table.

The consultant decided to model system mounding using Tecsoft's Tecmound with an infiltration area of approximately 40,000 square feet (200 feet wide by 200 feet long), which is a little less than an acre. The developer had approximately eight acres of property suitable to cluster system placement. The consultant input the hydraulic conductivity into a grid 600 feet wide and 600 feet long, generally representing the area suitable for system placement, and placed the system infiltration area in the center. After running the model for different capacities, the consultant determined the system would create a mound approximately nine feet above the average water table with a system outflow of approximately 6,200 gallons per day (spread over the 40,000 square foot infiltration area). Figure 3-8 is a contour map, prepared using Golden Software's Surfer™ contouring software, based on a Tecmound model run output. The consultant used an average wastewater generation of 200 gallons per home per day, or 4,000 gallons total per day for 20 homes. This amount was within the capacity of the site to accept wastewater and the design flow methodology was accepted by the regulatory agency.

Figure 3-8
Contour Map Prepared with Golden Software's Surfer Software Based on Tecmound Model Output



Growth Management and Land-Use Planning

The relationship between growth and wastewater management evolves in many communities. Because growth is often a politically volatile issue between pro- and anti-development interests, proactively addressing growth implications and wastewater management options helps to develop practical wastewater management plans.

Historically, wastewater management has tended to drive growth management. While growth management and wastewater management are linked by necessity, communities can use tools to develop a balanced relationship, with growth and wastewater considerations having an equal voice in the planning process.

How Wastewater Management Is Used as a Growth Management Tool

This section is intended to provide the tools needed to integrate growth and wastewater management. First, it discusses the conventional methods of growth management. Second, it presents more innovative techniques for mitigating the impacts of cluster systems on growth. Third, it provides some model bylaws that can be used to manage growth. Finally, the conservation development growth management approach—a composite of innovative land-use planning techniques—is discussed as a possible technique for managing growth in unsewered areas.

Conventional Methods of Growth Management

Over the last 40 years an increasing number of jurisdictions in unsewered areas have experienced rising growth pressures. These communities have attempted to limit new residential development by adopting large-lot zoning. Without a doubt, this technique is by far the most common response to limiting development. Unfortunately, these policies have had the unintended effect of producing sprawling development patterns that have consumed far more farmland acreage and woodland habitat. In addition, the atomized development patterns that have resulted from large-lot requirements made any real sense of community impossible. The legal justification for large-lot zoning has principally been the poor quality of native soils to filter and purify septic sewage effluent. The success of newer technologies in small-scale wastewater treatment breaks the linkage between soil maps and land-use planning. These options have significantly weakened, if not eliminated, this rationale.

Innovative Techniques for Mitigating the Impacts of Cluster Systems on Growth

As previously discussed, a major side effect of nearly all off-site wastewater solutions is the development potential that the new cluster or centralized wastewater system generates. In many states, all parcels that front the wastewater collection system have a legal right to connect to the system. Often, a significant portion of these parcels has not been developable because they could not accommodate an onsite wastewater system. The new cluster or centralized wastewater system makes these parcels developable.

This development potential is often a politically volatile issue and, if not properly addressed, it can derail the wastewater management plan. Several innovative approaches can help communities address this new growth potential including:

- Regulatory techniques
  - Land acquisition
  - Purchase of development rights
  - Transfer of development rights
  - Checkerboard wastewater service districts
  - Urban growth boundaries

- Rate-of-growth programs
- Phased growth programs
- Adequate public facilities requirements
- Natural features conservation standards zoning
- Density zoning

- Private, conservation-based techniques
  - Easements
  - Limited development
  - Landowner compacts

Regulatory Techniques

Approaches involving regulatory techniques include:

Land Acquisition—An increasing number of municipalities and counties in high-growth areas have approved local bond issues providing funds to purchase specific parcels of land lying in the path of development. Although this is an excellent technique to protect entire parcels, its extremely high public cost limits use to a select few communities.

Purchase of Development Rights (PDR)—This approach involves the purchase of development rights by local governments, and the subsequent dedication of the land for conservation easements, protecting it as open space or agricultural areas. PDRs provide an excellent but expensive way for a municipality to conserve an entire parcel on an occasional basis; for this reason, they can become an important element in protecting individual properties of great local significance.

Transfer of Development Rights (TDR)—TDR ordinances are a market-based technique that encourages the protection of strategic and/or vulnerable lands (referred to as “sending areas”) through the transfer of their development rights as development credits to designated growth areas (or “receiving areas”). Experience in Maryland suggests that TDRs work best at a county-wide level. They also succeed where rural zoning densities are typically much lower than those in suburban areas (commonly five to ten acres per dwelling).

Checkerboard Wastewater Service Districts—These districts allow property owners within a proposed sewered area the opportunity to connect to the sewer or to install a code-compliant onsite system. For example, the town of Provincetown, MA, has implemented a checkerboard district for its central business district.

Urban Growth Boundaries—Development in unsewered rural and semi-rural locations could be decisively controlled by limiting new development to areas within Urban Growth Boundaries (UGBs) drawn around existing centers with utility infrastructure. Because of this technique’s dramatic impacts on rural landowners, few jurisdictions in the country have adopted UGBs.

Notable exceptions include the State of Oregon, various townships in Lancaster County, PA, and the Bluegrass Country around Lexington, KY. Typically, this technique restricts use of cluster systems as well as central sewer systems outside these boundaries.

Rate-of-Growth Programs—Such programs typically ration permits to build new dwellings to a limited number per year. Such permits are often issued on a first-come basis, with a maximum number per subdivision in any calendar year.

Phased-Growth Programs—These programs permit development to occur in phases that could be coincidental with wastewater treatment plant expansion.

Adequate Public Facilities Requirements—This approach restricts development until the public facilities needed to serve it have been provided. Typical facilities included are water supply, sewage dispersal, road capacity, and classroom space.

Natural Features Conservation Standards Zoning—This zoning technique typically excludes certain environmentally sensitive lands from development activities. Depending upon the fragility of the resource, restrictions can prohibit construction, grading, and even vegetative clearing.

Density Zoning—A variation on natural features conservation standards, density zoning permits a variation in the intensity of development in direct relation to the ability of the site to safely accommodate the development. This approach, frequently referred to as "performance zoning," was first promoted actively in Bucks County, PA during the early 1970s.

Development Impact Fees—Development impact fees are one-time charges applied to new developments. Such fees are designed to raise revenue for the construction or expansion of capital facilities located outside the boundaries of the new development, but that benefit the contributing development. Impact fees are usually dedicated to the provision of additional water and sewer systems and other public services, but not for the operation, maintenance, repair, alteration, or replacement of capital facilities.

Private, Conservation-Based Techniques

Approaches involving private, conservation-based techniques include:

Easements—Tax benefits are available to landowners for placing conservation easements on all or part of their properties. The easement approach can help preserve all or part of specific properties owned by individuals with strong conservation interests or substantial wealth.

Limited Development—Under limited development, landowners voluntarily restrict the number of new homes to a fraction of the legally permitted maximum. This technique requires that market demand for upscale country properties for which purchasers are wiling to pay premium prices.

Landowner Compacts—A landowner compact is a voluntary agreement among two or more adjoining landowners to essentially dissolve their common internal lot lines and to plan their separate but contiguous landholdings in an integrated comprehensive manner. Areas for development and conservation could be located so that they would produce the greatest benefit, enabling development to be distributed in ways that would preserve the best parts of the combined properties.

Model Bylaws

Many bylaws can be used to manage the growth effects of cluster wastewater systems. Example bylaws are briefly listed as follows. These examples were developed by the Cape Cod Commission (Barnstable County, MA) to assist its member towns (15 towns) with these issues. For more information see www.capecodcommission.org/bylaws/.

- **Model Development Rate Limitation Bylaw**—This bylaw sets a model approach for towns seeking to limit building permits issued to a defined annual amount. The bylaw ties annual building permits to capital facilities planning so that new growth and development will not outstrip the town's ability to pay for support services for such growth.
- **Model Development Agreement Bylaw**—This bylaw enables towns with a certified comprehensive plan to enter into legally binding agreements—contracts—with landowners, developers and the commission. These contracts protect the landowner from regulatory changes that may occur during a project's life. They benefit the community and Cape Cod in general, by acquiring public benefits from the project proponent through legal means.
- **Model Village Style Development Bylaw**—This zoning bylaw establishes a template for Cape Cod towns seeking to protect their historic villages through the use of site planning and traditional zoning dimensional controls. When coupled with architectural review guidelines, this bylaw should prove useful in establishing and maintaining a vision of a town's downtown centers.
- **Model Transfer of Development Rights Bylaw**—This zoning bylaw provides an innovative method for protecting a town's—and Cape Cod's—natural and built resources. The bylaw sets up a procedure for designating portions of the community that residents want protected and allows for the transfer of the rights to build in those areas to other, less sensitive and more urban locations within the town or Cape Cod.
- **Open Space Residential Development Bylaw (cluster bylaw)**—This model is an in-depth zoning bylaw that enables towns to permit cluster-type subdivisions. The bylaw incorporates provisions common to typical cluster regulations (for example, lot configuration and open space set-aside), but it also includes several provisions not present in many Cape Cod cluster regulations, including mandatory cluster requirements, site design considerations, and restrictions on re-use of common open space.
- **Model Aquifer Protection Overlay District Bylaw**—This bylaw provides a comprehensive overlay district for the protection of groundwater used for drinking water on Cape Cod. The bylaw focuses on groundwater protection by incorporation of state standards as well as emphasizing minimization of stormwater contamination and nitrogen loading.

Conservation Development Growth Management

The final growth-management technique is actually both an extension and a composite of various other innovative approaches. This design ties together in the three major land-use documents (tools) already existing in most communities:

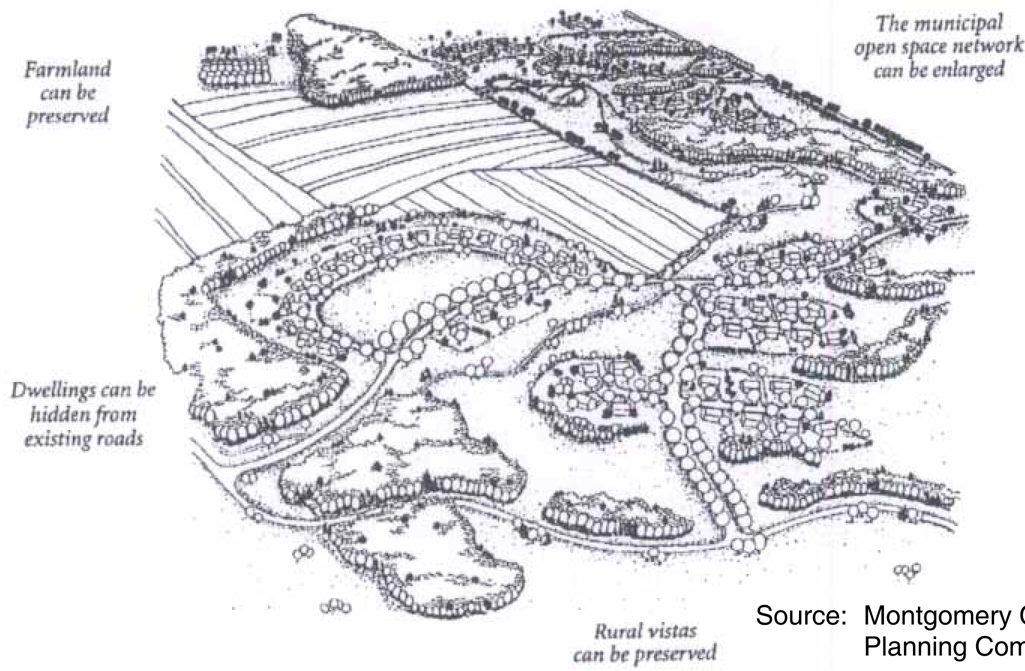
- The comprehensive plan
- The zoning ordinance
- Subdivision regulations

The goal of this form of design is to work in synergy to produce the greatest possible impact. These three tools have been integrated to a high degree in a statewide conservation planning education program for local officials in Pennsylvania, known as "Conservation Development." Table 3-3 lists the additions required to the land-use documents for this holistic approach. Figure 3-9 illustrates how to apply the techniques described to set aside open space.

Table 3-3
Additions Required to Major Land-Use Documents for the Conservation Development Approach

Land-Use Document	Additions Required
Comprehensive Plan	• Community-wide map of potential conservation lands • Detailed list of recommended changes to zoning and subdivision ordinances
Subdivision Ordinance	• Context map • Existing resources/site analysis map • Site visit • Sketch plan (or conceptual preliminary plan) • Four-step conservation design process
Zoning Ordinance	• By-right designation for conservation design • Density determination alternatives through yield plans and net-outs • Menu of options for density levels, with density incentives and disincentives • Design standards for conservation lands • Density bonuses for public access and endowments • Management plans for open space maintenance • Ownership options for the conservation lands

Figure 3-9
Preservation of Open Space with the Conservation Development Approach



Source: Montgomery County Planning Commission

Conservation development is a strategy that is extremely well suited for use in conjunction with small-scale wastewater treatment and dispersal systems. This strategy can also be used with conventional, individual septic systems, located either on-lot or within common open space. This technique succeeds in part because it does not depend on large-scale public expenditures or landowner generosity. For example, Pennsylvania townships such as Lower Makefield, London Grove, and West Vincent have protected hundreds of acres of developable land within the first several years of adopting this technique, at no cost to taxpayers, no equity loss for landowners, and no reduction in the developers' legal entitlement to build the units permitted under existing zoning densities.

The conservation subdivision design is a key component of the conservation development approach. This term describes a relatively new breed of residential development that protects the majority of flat or rolling, dry, and otherwise buildable land from clearing, grading, and construction by reducing lot sizes in order to achieve full-yield density. Conservation design is seen as a potentially useful tool for augmenting the land protection efforts possible through state and county funding programs, which may be quite limited in scope. This design approach avoids the issue of "taking property" because developers can—as-of-right—achieve the full density allowed on their properties under the zoning ordinance. The land not converted to suburban house lots remains privately owned, typically by homeowner associations.

Comprehensive Plan Components

The main comprehensive plan component is a community-wide map of potential conservation lands. The principal purpose of this map is to establish an overall structure for the open space network. This map also shows how the open space in any particular, individual subdivision would fit into this broader framework. The map should outline areas that are recommended for development and areas recommended for conservation on each parcel of land. Ideally, nine kinds of special features should be shown on a base map of existing roads and parcel ownership lines:

- Wetlands and their buffers
- Floodways and floodplains
- Moderate and steep slopes
- Groundwater resources and their recharge areas
- Woodlands
- Productive farmland
- Significant wildlife habitat
- Historic, archaeological, and cultural features
- Scenic viewsheds from public roads

This draft map should render a variety of resource lands in various colors based on conservation categories. Possible mapping categories might include:

- **Primary Conservation Areas—**Flood prone, steep, wet
- **Secondary Conservation Areas—**Stream corridors; moderately steep slopes; woodlands and hedgerows; fields, meadows, and pastures with soils rated prime or of statewide importance; fields, meadows, and pastures in the public viewshed as seen from existing roads; historic structures and archaeological sites
- **Existing Protected Areas—**Eased land, public parks, conservancy properties

Dividing these resources into three broad categories acknowledges major differences between them. Primary conservation areas are deemed to be inherently unbuildable due to extremely severe environmental constraints. Secondary conservation areas contain resources that are either significant at some level or are at least notable and worthy of consideration for conservation wherever possible. This map should be drawn on (or overlain by) another map showing tax parcel boundaries, to ensure that no more than half of the buildable area in any single ownership is shown as potential conservation land. Existing Protected Lands form the core areas around which the community's future open space network would grow.

This kind of map, which is best prepared using computer-based Geographic Information Systems (GIS), should be supplemented by several pages of text describing its function and significance. Several additional pages should be added to augment the existing text, providing further observations and recommendations about certain zoning and subdivision ordinance changes needed to make the conservation subdivision design process operational. Such wording would create the legal foundation for the specific kinds of zoning and subdivision ordinance modifications required.

Subdivision Ordinance Components

Subdivision ordinance components include:

- **Context Map—**This map expands on the “Location Maps” provided for in most ordinances and shows the location of natural features and development patterns on adjacent properties and also within one-half mile of the development site. To make this information easy to provide and to minimize the cost, such data can easily be traced from existing published sources such as aerial photographs (from the USDA NRCS) for patterns of vegetation and development, USGS topo sheets, Federal Emergency Management Agency (FEMA) floodplain maps, and US Fish and Wildlife Service (FWS) wetlands maps. These maps and photos should then be reproduced to the same scale (1 inch = 400 feet). Such an enhanced context map helps reviewers understand the relationship of resources on the subject property to natural and cultural features and to possible development patterns on adjacent and nearby lands within 2,000 feet.
- **Existing Resources/Site Analysis Map and Site Visit—**Because understanding a site completely by examining only a paper document is impossible, it is essential for the interested parties to walk the property with a comprehensive map that analyzes all relevant site conditions and identifies both the significant and noteworthy historic and cultural resources. In addition to basic data (such as topography, wetlands, and floodplains), at this stage the map should include locations of the healthiest woodlands and trees larger than a selected diameter, significant wildlife habitat (such as vernal pools, essential in the life-cycle of salamanders and other woodland amphibians), historic or cultural features (in addition to cemeteries and stone walls) and public viewsheds. Soil data is a key factor at this point in the inventory process, specifically the location of the best soil available on the entire property. In the absence of sewers, and not considering the stream-discharge option, suitable soils are a basic necessity.
- **Sketch Plans—**Sketch plans are simple and inexpensive drawings that illustrate conceptual layouts of house lots, streets, and conservation areas. They are ideally based upon the existing resources/site analysis map and comments received from local officials during the site visit. The sketch plan helps all parties avoid the extremely common situation where developers first pay to engineer expensive preliminary plans, then understandably refuse to modify their layouts in any substantial manner.
- **Four-Step Design Approach—**Local subdivision ordinances should be updated to describe the specific steps involved in designing conservation subdivisions. A suitable four-step approach is:

1. Identify primary and secondary conservation areas. This task should be a relatively easy once the existing resources/site analysis map is prepared.
2. Locate house sites to enable enjoyment of views and often direct access to the protected open space. Siting the homes in this manner provides developers with a strong marketing advantage, compared with layouts where homes are boxed in on all sides by other house lots.
3. Align streets and trails, which should simply be a matter of connecting the dots for vehicular and pedestrian access.

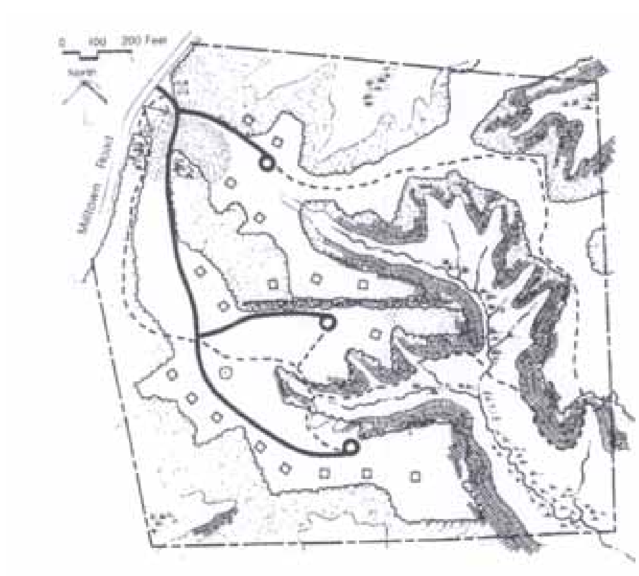
4. Draw in the lot lines, which should involve little more than marking boundaries midway between house locations.

This approach is illustrated in Figure 3-10.

Figure 3-10
Four-Step Conservation Subdivision Design Process

Step one: Identify conservation areas and potential development areas

Step two: Locate housing sites



Step three: Align streets and trails

Step four: Draw in lot lines

Zoning Ordinance Components

Zoning ordinance components include:

- **By-Right Designation for Conservation Design—**Under the conservation development approach, conservation design is classified as a permitted use, available as-of-right in designated zoning districts. Many existing ordinances that allow these flexible design approaches also designate them as "conditional uses." This condition typically discourages applicants from opting for the flexible design approach that communities actually want to encourage. Local officials must be persuaded that they can control as much, if not more, with detailed standards in the subdivision ordinance than they can by running an application through zoning requirements for conditional uses. Such flexible approaches can be adopted for developments executed at rural or suburban densities and with lots smaller than those typical in conventional developments. Conservation subdivisions can be made to perform well through a set of detailed and strict performance standards relating to the quantity, quality, and configuration of the protected open space.
- **Density Determination Alternatives—Yield Plans and Net-Outs—**Under this zoning component, applicants are provided with two alternative methods for determining density, one that is basically graphic, the other essentially arithmetic. Yield plans are un-engineered layouts showing the maximum number of lots served by septic systems that would be feasible under standard large-lot zoning requirements. These plans must be realistic. In unsewered areas, for example, applicants may be required to submit deep-hole test pits to demonstrate septic suitability on a 10 percent sample of lots selected by the local government. If any of the sample lots fail, the yield number is reduced and the applicant waits four weeks to submit a second 10 percent sample. This process continues until all the lots in a given sample pass the test for septic suitability. Net-outs require calculating the acreages of various soil types, slopes, and other physical constraints to development and subtracting certain percentages of each area of constrained land from the gross tract acreage. This process produces a net buildable acreage figure, which is then divided by the number of square feet or acres required per dwelling unit under the density standards of the zoning ordinance.
- **Menu of Options for Density Levels, with Density Incentives and Disincentives—**The full conservation development approach provides landowners with a menu of five density options to encourage land-conserving subdivision designs and to discourage land-consumptive layouts that needlessly divide all the acreage into suburban house lots and streets. The five options are:

1. **Density-Neutral—**Yields the same number of lots attainable under the preexisting zoning. To attain full density, developers have to submit a conservation design in which lots are reduced in area in order to permanently conserve half the **unconstrained** land.

2. **Highest-Density—**Involves a significant density bonus, doubling the pre-existing yield to produce well-designed village layouts in a neo-traditional manner, including architectural standards for all new construction, tree-lined avenues, village greens, parks, playgrounds, and broad perimeter greenbelts or conservancy areas in which mini-farms could be situated.

3. **High-Density—**Involves a density bonus for leaving a large percentage of the unconstrained land as undivided open space.

4. **Lowest-Density—**Encourages landowners to consider creating rural estates, for example, at one principal dwelling per 10 acres. Several incentives are offered for those who choose this alternative, including special street standards for gravel-surfaced country lanes, and the ability to add two accessory dwellings per lot (subject to certain size limits and design requirements for harmonizing with the rural landscape).

5. **Low-Density—**Halves the lot count and is provided for developers who feel that there is a strong local market for executive homes on large lots.

- **Design Standards for Conservation Lands—**Detailed standards exist in the conservation Development model ordinances. They specify not only the minimum percentage of open space (typically 50 to 75 percent in unsewered areas with base densities of one to three acres per dwelling), but also the quality and configuration of that land. This specification is to ensure that the conservation areas contain much more than simply unbuildable lands. The standards also guarantee that a network of open space will be preserved across the community as a whole.
- **Density Bonuses for Public Access and Endowments**—To encourage certain desirable results where there is no clear legislative authority to require them, conservation development enables communities to offer targeted density incentives. Possible incentives include:
  - The creation of endowment funds to finance perpetual maintenance of conservation lands within a new subdivision that are donated to a land trust
  - Public access to trail corridors within new subdivisions where officials would at least be likely to reserve the right to include this segment in a longer community-wide trail network.
- **Management Plans for Conservation Lands—**Land not divided into house lots should be managed comprehensively (usually by a homeowners' association) to maintain or enhance the ecological health of the habitat.
- **Ownership Options for the Conservation Lands—**Four ownership options exist:

1. A **homeowner association** (HOA) that works well when membership is automatic upon purchase of a lot or house. Association bylaws give the association legal authority to place a lien on the property of any member who does not pay his or her dues, and the facilities are kept simple.

2. **Non-common ownership** involves third-party ownership and maintenance of the open space land under the terms of a conservation easement and management plan. Such arrangements relieve HOAs of the responsibility for maintaining that acreage, while enjoying the visual benefits of open land.

3. **Land trusts** respond to the need for endowments accompanying land gifts (to pay for maintenance, property taxes, and liability insurance premiums). Conservation development ordinances offer density bonuses to encourage developers to fund such endowment needs.

4. The **local government** might need land for recreational purposes or trail connections. Density bonuses are provided as well to encourage land donations or bargain sales by developers.

Regulatory Issues

Regulatory agencies should be involved in the planning process from the beginning in order to understand any boundaries that might constrain possible solutions and to evaluate the acceptability of new ideas. In some states (such as New Jersey), a pre-application meeting is held to involve all regulatory stakeholders and identify the lead agency. Continued involvement with the regulatory community is recommended to maximize the probability of project success.

Regulatory requirements for cluster systems typically depend on system size and, in some states, jurisdiction where the system is to be located. Small systems (Type I), below 2,000 to 10,000 gpd (depending on the state), are typically governed by state health departments, which issue onsite septic-system-type codes with minimum standards. In some states, the county or local municipality may have jurisdiction over issuance of Type I cluster wastewater permits.

Larger systems (Type II) are typically governed by state environmental protection agencies that issue groundwater discharge or surface discharge permits. Type II systems are also governed by state or federal restrictions according to underground injection control (UIC) programs.

Regulatory requirements, including minimum system design standards, apply to the cluster wastewater collection, treatment, and dispersal systems. Many states maintain a list of pre-approved technologies for Type I small flows, with an assumed rate of performance based on historical records. For Type II applications the systems are engineered and performance to permit specifications is required. Monitoring requirements for permit compliance will vary from bi-weekly to monthly to quarterly, as well as requiring minimum frequency of system operator onsite visits. For smaller Type II systems, operator and monitoring requirements can each represent approximately 33 percent of annual operations cost. Consequently, automating these processes and Internet use can be cost-effective techniques.

Location and Design Requirements

Typically, the most important and most constraining requirement of a cluster system is the dispersal system. Planners need to focus first on this issue to determine the capacity of the dispersal area at the outset. This analysis will define the location and quantity of water that may be applied in an area. The dispersal area must adhere to minimum prescribed standards, such as unsaturated depth of soil below the dispersal area and maintenance of the water below grade, typically for a minimum length of time and or distance. Fate and transport analysis of the dispersed effluent also needs to be performed to determine any potential impacts on downgradient receptors. Such impacts may dictate higher treatment levels or different dispersal techniques.

Soil permeability is the most critical dispersal site parameter for Type I cluster systems. In addition, the following information is needed to determine whether an elevated (mound) system is needed:

- Depth to seasonal high groundwater
- Depth to bedrock or other impervious layer

Table 3-4 presents Georgia regulations specifying the minimum dispersal field area as a function of soil type for STE. Some states do not rely on a percolation (perc) test, which measures the absorption rate of the soil, but on soil type to size the dispersal area.

Table 3-4
State of Georgia Absorption Rates Based on Soil Series

(**) = exact depths can be determined onsite by qualified Soil Classifier.

SOIL SERIES *SEE SUITABILITY CODES DEFINITIONS*	MLRA	SLOPE % ranges *of the soil type*	DEPTH TO BEDROCK (ranges) (**)	BEDROCK HARDNESS	DEPTH TO SEASONAL HIGH H20 TABLE *(inches) ranges(**)*	ABSORPTION RATE AT RECOMMENDED TRENCH DEPTH MIN/ IN. *predicted range(s)*	RECOMMENDED TRENCH DEPTH (ranges) (**)	SUITABILITY CODE
BODINE	RIDGES AND VALLEYS	5-70%	>60"		>72"	20 - 40	24 - 30"	A
NOTES	make sure no restrictive layers are present, heavy equipment may be necessary to observe soils during dry periods. (see code G if slopes > 35%)							
CAPSHAW	RIDGES AND VALLEYS	0-12%	40-80"	HARD	24-42"	> 120	SEE CODES	F
NOTES								
CARTECAY	RIDGES AND VALLEYS	0-5%	>60"		6-18"	SEE CODES	SEE CODES	C
NOTES	FLOODING IS COMMON							
CEDARBLUFF	RIDGES AND VALLEYS	0-2%	>60"		6-12"	SEE CODES	SEE CODES	C
NOTES	FLOODING IS COMMON							
CHENNEBY	RIDGES AND VALLEYS	0-2%	>60"		12-30"	SEE CODES	SEE CODES	C
NOTES	FLOODING IS COMMON							
CHEWACLA	RIDGES AND VALLEYS	0-2%	>60"		6-24"	SEE CODES	SEE CODES	C
NOTES	FLOODING RANGES FROM NONE TO FREQUENT							
CONASAUGA	RIDGES AND VALLEYS	0-45%	20-40"	SOFT	>72"	> 120	SEE CODES	F
NOTES								
CRAIGSVILLE	RIDGES AND VALLEYS	0 - 5%	> 60"		> 72"	20 - 30	24"	D
NOTES	FLOODING IS FREQUENT							
CRAIGSVILLE (GRAVELLY)	RIDGES AND VALLEYS	0-5%	>60"		>72"	20 - 30	24"	D
NOTES	FLOODING IS FREQUENT							
CUNNINGHAM	RIDGES AND VALLEYS	2-25%	40-60"	SOFT	>72"	90 - 120	24"	J
NOTES								
DECATUR	RIDGES AND VALLEYS	1-25%	>60"		>72"	45 - 75	24 - 30"	A
NOTES								
DEKALB	RIDGES AND VALLEYS	0-80%	20-40"	HARD	>72"	20 - 30	24"	I
NOTES	see code G if slopes are greater than 35%							
DEWEY	RIDGES AND VALLEYS	2-40%	>60"		>72"	45 - 75	24 - 30"	A
NOTES								
DOCENA	RIDGES AND VALLEYS	0-6%	>60"		18-36"	45 - 60	SEE CODES	C
NOTES								
DOWELLTON	RIDGES AND VALLEYS	0-8%	40-60"	HARD	6-12"	> 120	SEE CODES	F
NOTES								
EMORY	RIDGES AND VALLEYS	0-5%	>60"		60-72"	30 - 40	24 - 30"	D
NOTES	FLOODING RANGES FROM NONE TO OCCASIONAL							
ENDERS	RIDGES AND VALLEYS	1-65%	40 - > 60"	SOFT	>72"	75 - 90	24"	J
NOTES								

Table 3-4
State of Georgia Absorption Rates Based on Soil Series (Cont.)

(**) = exact depths can be determined onsite by qualified Soil Classifier.

SOIL SERIES *SEE SUITABILITY CODES DEFINITIONS*	MLRA	SLOPE % ranges of the soil type	DEPTH TO BEDROCK (ranges) (**)	BEDROCK HARDNESS	DEPTH TO SEASONAL HIGH H2O TABLE (inches) ranges(**)	ABSORPTION RATE AT RECOMMENDED TRENCH DEPTH MIN/IN. predicted range(s)	RECOMMENDED TRENCH DEPTH (ranges) (**)	SUITABILITY CODE
HAMBLEN	SAND MOUNTAIN	0-3%	>62"		24-36"	30	SEE CODES	C
NOTES	FLOODING RANGES FROM NONE TO COMMON							
HARTSELLS	SAND MOUNTAIN	2-45%	20-40"	HARD	>72"	30 - 40	24"	I
NOTES								
HECTOR	SAND MOUNTAIN	1-60%	10-20"	HARD	>72"	20	SEE CODES	E
NOTES								
HECTOR (STONY)	SAND MOUNTAIN	2 - 60%	10-20"	HARD	>72"	20	SEE CODES	E
NOTES								
LINKER	SAND MOUNTAIN	1-40%	20-40"	HARD	>72"	30 - 40	24"	I
NOTES								
NAUVOO	SAND MOUNTAIN	2-35%	40-60"	SOFT	>72"	30 - 40	24"	A
NOTES								
ALBERTVILLE	RIDGES AND VALLEYS	2-25%	40-60"	SOFT	>72"	90 - 120	24"	J
NOTES								
ALLEN	RIDGES AND VALLEYS	2-40%	>60"		>72"	30 - 45	24 - 30"	A
NOTES								
APISON	RIDGES AND VALLEYS	2-25%	20-40"	SOFT	>72"	30 - 45	24"	I
NOTES								
ARAGON	RIDGES AND VALLEYS	2-25%	>60"		>72"	> 120	SEE CODES	J
NOTES								
ARKABUTLA	RIDGES AND VALLEYS	0-2%	>60"		12-18"	SEE CODES	SEE CODES	C
NOTES	FLOODING IS COMMON							
ARMUCHEE	RIDGES AND VALLEYS	5-60%	20-36"	SOFT	>72"	> 120	SEE CODES	H
NOTES								
BARFIELD	RIDGES AND VALLEYS	3-50%	8 - 20"	HARD	> 72"	SEE CODES	SEE CODES	H
NOTES								
BELLAMY	RIDGES AND VALLEYS	0 - 6%	> 62"		18 - 30"	SEE CODES	SEE CODES	C
NOTES								
BIGFORK	RIDGES AND VALLEYS		40 - 60"	HARD	> 72"	30 - 40	24"	A
NOTES	make sure no restrictive layers are present, heavy equipment may be necessary to observe soils during dry periods. (see code G if slopes > 35%)							

Design flows that are to be used for a specific situation are usually stated by code, with the allowance in some situations to vary the design flows if the applicant has water use records for a minimum length of time that substantiate alternate design criteria.

With code-required hydraulic application rate design criteria and design flows, the consultant can determine minimum dispersal field footprint requirements. Many states allow increased hydraulic application rates when wastewater is pretreated to secondary effluent quality or better prior to discharge to a dispersal system.

For the larger Type II flow applications, groundwater mounding analysis will typically dictate (that is, restrict) a site's capacity, rather than soils permeability.

Design and construction requirements for small systems are typically the same as the on-site code for Type I systems and the same as large sewerage systems for larger Type II cluster systems. Each state may employ a different daily wastewater flow maximum (typically 4,000 to 10,000 gpd) above which sewerage system regulations (from an environmental protection-type agency or department) take precedence.

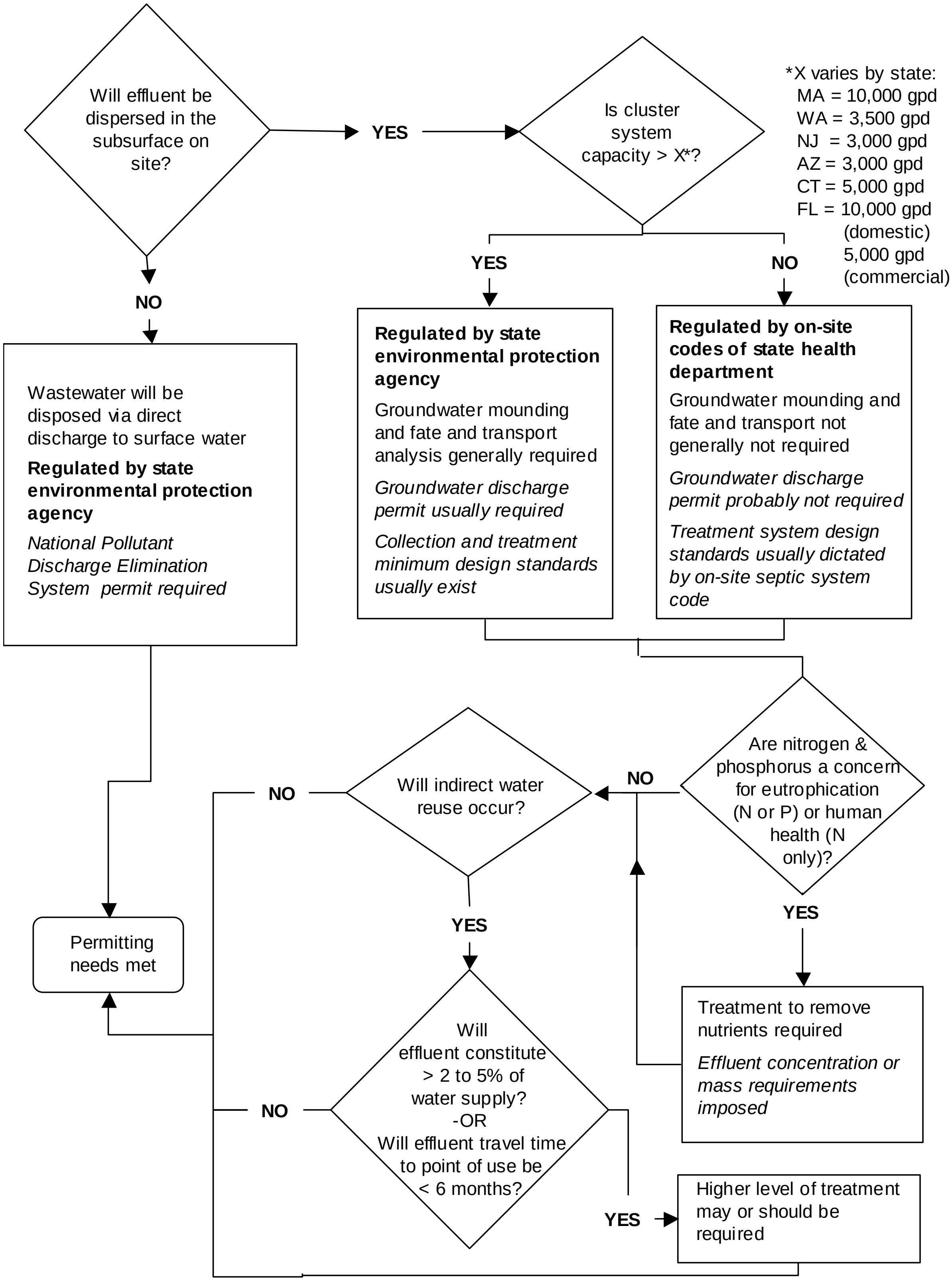
Effluent Dispersal Requirements

The primary factor that determines which effluent requirements govern a given cluster system is the system's mode of effluent dispersal. A cluster system can be designed to disperse effluent by:

- Direct discharge to surface waters
- Soil dispersal
- Reuse
- A combination of these options

Figure 3-11 shows a flow chart of the key issues in the regulatory process, as it relates to effluent requirements. These issues are discussed in detail in the following section.

Figure 3-11
Flow Chart for Regulatory Requirements



Direct Discharge

Direct discharge to surface waters is not commonly allowed for new cluster systems. In cases where it is, an NPDES permit is required. NPDES permits are issued by a state's environmental protection agency or, in states that do not have delegation responsibility, by the US EPA. The permit specifies the maximum flow allowed and a concentration and/or mass limit for specific water quality constituents. BOD, TSS, and fecal coliform are usually regulated in NPDES permits. Typical minimum requirements are provided in Chapter 2, the *Surface Water Discharge Considerations* section, Table 2-8.

In addition, nitrogen and phosphorus, as well as certain specific metals, may be regulated under an NPDES permit. Small flow systems (Type I) may be regulated under a general statewide NPDES permit.

Soil Dispersal

The most common dispersal mechanism for cluster systems is subsurface dispersal. In subsurface dispersal systems, groundwater discharge permits are usually required for Type II systems. The cutoff system capacity at which groundwater permits generally become required varies by state. In Massachusetts, for example, systems with a capacity greater than 10,000 gpd are required to obtain a groundwater discharge permit, whereas in New Jersey the cut-off is 3,000 gpd. If the system is large enough to require a groundwater permit, then groundwater mounding and fate and transport analysis of water quality constituents of concern will generally also be required. The groundwater discharge permit will set flow limits and concentration and/or mass limits for specific water quality constituents. These water quality constituents can include nitrogen and phosphorus.

Underground Injection Control Program

Cluster systems utilizing soil dispersal may also be regulated as Class V wells under the Underground Injection Control (UIC) program (US EPA 1999). Under Federal law, cluster systems that have the capacity to serve 20 or more persons per day **or** receive any commercial or industrial waste are treated as Class V wells. State laws may be based on broader definitions of Class V wells. Owners or operators of Class V wells must meet the following minimum federal requirements, as well as any additional state requirements that may apply (see www.epa.gov/safewater/uic/pdfs/fact_class5_septicsystems.pdf):

- Prohibit injection that allows the movement of fluids containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation or adversely affect public health.
- Provide inventory information (facility name and location, legal contact name and address, ownership information, nature and type of injection wells, and operating status of the injection wells) to the state or US EPA regional UIC program.

State Class V UIC regulations and state requirements for large capacity septic systems may be complimentary, or one regulatory framework may predominate (US EPA 1999). The planner should check with the state UIC program to determine the requirements, as well as www.epa.gov/safewater/uic.htm.

US EPA has delegated primacy to 34 states, shares responsibility in 6 states, and implements the program in 10 states.

Water Reuse

If the treated effluent is dispersed in the subsurface and mixes with groundwater used as a public water supply, then indirect water reuse of the effluent will occur. Although some states have developed criteria to regulate indirect water reuse, these criteria are constantly evolving. One common requirement is that the time of travel in the subsurface from point of discharge to point of use be greater than six months (Crook 2001; MADEP 2001). This travel time is thought to be the minimum time required for suitable attenuation of viruses. In addition, there may be total organic carbon (TOC) discharge limits imposed on the system if its effluent comprises a large portion of the total groundwater flow that is used for a water supply. In California, for example, the effluent from systems that discharge into groundwater used as a public water supply is required to have:

$$\text{TOC} \leq \frac{1\text{ mg/l}}{\text{RWC}}$$

where RWC is equal to the percent of reclaimed water contribution in groundwater extracted by drinking water wells (Crook *et al.* 2001). In other words, if the wastewater treatment system effluent contributes 50 percent to the total groundwater flow, then the TOC in the system's effluent is required to be less than 2 mg/l. Tertiary or higher treatment will be required to meet this limit. Epidemiological studies have suggested that TOC is a good surrogate for emerging contaminants of concern (Crook 2001).

Water reuse guidelines and requirements exist (State of Georgia 2002) for the various types of water reuse, such as:

- Subsurface (drip) irrigation
- Surface (spray) irrigation
- Toilet flushing
- Commercial and industrial reuse

Reuse guidelines from the state of Massachusetts are shown in Table 3-5.

Table 3-5
Massachusetts Reclaimed Water Standards

Type of Reuse	pH (SU)	BOD (mg/l)	Turbidity NTU	Fecal Coliform	TSS (mg/l)	TN (mg/l)	Permit Standards	Comments
Golf Courses	6–9	≤ 10	≤ 2	Median of no detectable colonies/100 ml over continuous running 7-day sampling periods, not to exceed 14/100 ml	5	<10	Class I Groundwater	a, b, c, d
Toilet Flushing	6–9	≤ 30	≤ 5	Not to exceed 100 colonies/100 ml	10	<10	Class I Groundwater	a, b, c, d
Indirect Aquifer Recharge	6–9	≤ 10 or ≤ 30	≤ 2 or ≤ 5	Median of no detectable colonies/100 ml over continuous running 7-day sampling periods, not to exceed 14/100 ml or 200 colonies/100 ml	5 or 10	<10	Class I Groundwater	e, f, g, h

Code	Comment
a	Reclaimed water must be clear, odorless, and virtually pathogen and contaminant free
b	Reclaimed water delivered from treatment plants for a reuse must undergo a full chemical and microbiological characterization and pilot or performance test prior to implementation of reuse program
c	All reclaimed water projects must include appropriate public awareness techniques including but not limited to: • Fact sheet/brochures • Color coding of all plumbing • Signage (multilingual and pictorial)
d	Treatment plants providing reclaimed water for reuse projects must have immediate, permitted discharge alternatives
e	New treatment plants located in approved Zone IIs with less than a two-year groundwater travel time to the public water supply well must treat to the more rigorous standards

Table 3-5
Massachusetts Reclaimed Water Standards (Cont.)

Code	Comment
f	Existing treatment plants that can demonstrate the four- or five-feet of separation and where the well has not shown any evidence of water quality degradation may maintain the lesser standard
g	Massachusetts Drinking Water Program waivers reducing the required sampling of public water supply wells will not be issued if there are permitted groundwater discharges in the Zone II
h	Treatment plants that meet the criteria listed above are considered to be improvements over unsewered Title 5 systems as it pertains to Safe Drinking Water Act (SDWA) susceptibility assessments

4 CLUSTER WASTEWATER SYSTEM MANAGEMENT APPROACHES

The term management is used to represent many activities in this handbook. A detailed definition of cluster wastewater system management as used in this handbook is provided in the *Ownership and Management Options* section in Chapter 2.

The cluster wastewater system management requirements can be minimal, such as for a small Type I cluster system, or complex, as with a wastewater RME for Type II cluster systems serving many customers with a large collection system.

Cluster wastewater system management functions include:

- Ownership Options
- Administration
- Operations Management

Ownership Options

Ownership describes the entity that has legal responsibility, liability, and authority regarding all aspects of a cluster wastewater system. Ownership is sometimes referred to as the institutional structure of a cluster wastewater system, and generally falls into three categories: public, private for-profit, and private non-profit.

The ownership options in a state are usually defined by existing enabling legislation that defines the responsibilities, authorities, composition, and functioning of the ownership entity. A community, especially in home-rule states, can petition the state legislature to establish a wastewater management district with unique features. Naturally, these desired features must be constitutional and endorsed by a vote of the community.

Traditionally, centralized wastewater systems have been owned and managed publicly, while onsite and cluster systems have been owned and managed privately with public oversight. Today, these are not the only options, and cluster systems have successfully been implemented using other innovative ownership structures. Table 4-1 describes the range of possible ownership structures.

Table 4-1
Matrix of Cluster Ownership Options

Ownership Institution	Infrastructure	Centralized	Cluster	Onsite
Public	• Health department • Department of Public Works • Independent public entity	Traditional	**Innovative**	**Innovative**
Combination Public/Private	• Combinations	**Innovative**	**Innovative**	**Innovative**
Private	• Private individuals • Special purpose entities • For-profit corporation • Non-profit corporation	**Innovative**	**Innovative**	Traditional

The ownership of a wastewater system may constrain the available financial and institutional management system options available. For example, privately owned systems have traditionally been unable to obtain public funding in the form of grants. Recent legislation and programs in some states enable septic system loan programs to be used for private systems. Presumably, they could be used for Type I cluster systems. Planners should review the current program requirements in their state to explore the availability of this funding source.

The administration and monitoring, maintenance, and repair (MMR) options are discussed in the following sections. An owner can either perform some or all of these activities internally or have them performed by others (outsourced).

Administration

Administrative functions include:

- Ownership Management
- Program Management for Capital Improvements
- Use Regulation
- Regulatory Compliance Reporting
- Customer Service, Billing, and Collections
- User-Charge System
- Financial

Ownership Management

The ownership management function can consist simply of oversight of the activities of others to whom all activities have been outsourced, the performance of all activities by the owner's manager directly or within an RME, or a wide variety of combinations. At a minimum, ownership management maintains records on the cluster system and submits required compliance performance reports (as the owner's agent) to regulatory agencies, and educates system users.

Type II systems require an RME in the form of an existing or specific-purpose entity with powers to make and enforce rules that provide oversight regulators assurance of sustainable compliance.

Idaho provides for non-profit corporations to own and manage Type I cluster systems (Idaho DEQ 2000).

Ownership administration management costs include:

- General administration
- Professional services for engineering, legal, and accounting
- Insurance
- Office space and other overhead
- Customer service, billing, and collection, as described further in this section

Program Management for Capital Improvements

During cluster system creation and during major expenditures, there is a significant need for management of the proposed system's capital facilities implementation. This activity is usually outsourced to an experienced engineering or program management-type firm.

Use Regulation

All cluster wastewater systems are regulated regarding authorized use. Use regulations are typically included in the state and/or local code for Type I cluster systems. Adoption of special regulations on prohibited use and practices may be necessary. For example, certain disinfecting chemicals and floor cleaning products are toxic to wastewater treatment systems and cause them to malfunction. Prohibiting the discharge of certain chemicals to the cluster system is necessary, because the lower flow of cluster systems does not provide the dilution that would mitigate the toxic effects of certain waste discharges. Pretreatment requirements on high-strength wastewater generators may also be necessary to protect the wastewater collection and treatment systems.

Regulatory Compliance Reporting

As cluster systems increase in size and proximity to environmentally sensitive areas, their regulatory reporting requirements generally increase. Owners must provide for gathering and transmission of the required regulatory compliance reporting information.

Customer Service, Billing, and Collections

Cluster systems are mini-sewer systems, so customer service is a required activity. Customer service issues range from responding to odor complaints to change of use, including service termination and the addition of new service connections.

Billing and collections are vital functions of any RME. Many utility organizations and private and public entities provide outsourcing services for this activity. A key issue is the ability of the cluster RME to take enforcement action for non-payment of fees.

Typical enforcement options include:

- Property liens
- Water shut-off
- Civil actions (small claims court)

Owners must ensure that all stakeholders understand the legal mechanisms and proper notification procedures as well as the impact of non-payments of fees on the financial viability of the cluster system. Owners can contract with private organizations that guarantee user-charge payments. These organizations provide the revenue cash flow and will place liens (or use other legal instruments) on the property of non-paying users.

User-Charges System

According to a 1995 survey (Beecher *et al*. 1995), Public Utilities Commissions (PUCs) regulate investor-owned wastewater utilities in 28 states, municipal systems in six states, sewer districts in five states, and non-profits in four states. Typically these are the larger wastewater systems.

Private ownership option user rates are:

- Regulated by a PUC-type agency
- Overseen by an US EPA-type department (usually for adequacy)
- Unregulated

Each state defines whether the private ownership's user rates are regulated and the terms of those regulations. The user-charges of publicly owned cluster wastewater systems are not usually regulated.

The primary cost categories for user-charges associated with cluster wastewater systems are:

- Capital Costs
- Administration
- Operation and Maintenance Costs
- Repair Funds
- Replacement-Depreciation Funds

Capital Costs

Capital costs are the total installed costs of the wastewater system(s), including engineering (design and construction management), land, financing and capital improvement program, administration, and construction costs. Capital costs for cluster systems have been generated in one or more of the following ways:

- Federal or state grants and loans
- User-charges, in which a portion or all of the capital costs are amortized over a fixed term (such as 20 years)
- Connection charges, in which users pay a fee when the cluster system is constructed or when they connect
- Property taxes in which all property owners in an entire community, regardless of whether the property owners are served by the cluster system or a special tax district, finance some or all of the wastewater system
- Unique taxing mechanisms, in which revenues are restricted for payment of capital and/or O&M costs
- Private entity building the cluster system, as in a new parcel development
- Private entity in a design, build, own, and operate situation

A key determinant of which financing options will be available is the ownership of the system, as many public funding sources are restricted from being used for private property.

Administration

Administration costs were described previously in the *Administration* section.

Operation and Maintenance Costs

O&M costs include the annual cost of operating and maintaining the system arising from:

- Electricity use
- Labor
- Chemicals
- Equipment servicing
- Residuals removal and ultimate disposal
- Routine repair/parts replacement
- Equipment and major component replacement

Repair Fund

A repair fund should be established for equipment with a useful life of less than 10 years. This fund is used to pay for small equipment repair/replacement when it fails or on a scheduled basis (to avoid damaging impacts). Establishing an annual repair fund contribution ensures that funds are available when needed. A repair fund also levels impacts on the user-charge rates.

Replacement-Depreciation Fund

A major challenge with cluster systems and wastewater systems in general is the funding of future replacements of major capital equipment. This funding is sometimes referred to as a depreciation fund.

User-charge systems need to be established to cover:

- Amortization of capital costs, if any
- Annual actual O&M costs
- Repairs, when needed
- Replacement, when needed

Typically, funding of future major equipment replacement has been a challenge for RMEs. Inclusion of replacement-depreciation fund contributions in user-charge systems is strongly recommended so that funds are available when major repairs are required. An affordability challenge exists when the user-charge includes some capital amortization. When this occurs, replacement-depreciation fund contributions can be programmed to occur in later years, say after year 10, and fully funded when the initial capital is fully paid (for example, after year 20).

Some states require that privately owned cluster systems maintain the replacement-depreciation fund (sometimes referred to as the reserve fund) with the regulatory authority having access to those funds, should the private entity not replace the system when necessary to maintain permit compliance. In addition to actual fund contributions, numerous financial instruments (such as bonds or letters of credit) provide equivalent financial assurances.

GASB 34 (Government Accounting Standards Board 2000) requires replacement-depreciation funding of municipal systems. Replacement-depreciation funding and asset management are intertwined issues. US EPA (2002b) provides a *Fact Sheet on Asset Management for Sewer Collection Systems* at: www.epa.gov/npdes/pubs/assetmanagement.pdf.

The NDWRCDP is completing a study entitled *Decentralized Wastewater System Reliability Analysis* (Project Number WU-HT-03-57) that should provide some guidance on this issue.

Financial

The financial issues associated with cluster systems are:

- Budgeting, accounts payable, and accounts receivable, as with any business operations
- Capital resources procurement

The owner will need to establish a budget for any cluster system (in particular for user-charge determination), and revenues and expenses will need to match the budget parameters. Cash-flow difficulties arise when the timing of expenses outpaces revenue receipts. In part for this reason, capitalizing the first year or two of operating expenses may be wise.

The procurement of capital resources for cluster systems is a significant issue and the options are discussed in the following section.

Government Financing Options

Grants and loans for wastewater projects are available under several state and federal programs. Major programs that are generally available on a national basis include:

- Federal Sources
  - US EPA Nonpoint Source Section 319 Grant Program
  - USDA Rural Utilities Service
  - HUD Community Development Block Grants
  - Department of Commerce Economic Development Administration
  - US EPA Hardship Grants Program for Rural Communities
- Tribal Sources
  - US EPA Colonias Set-Aside Program
  - US EPA Clean Water Indian Set-Aside Grant Program
  - US EPA American Indian Environmental Office Tribal Grants
  - HUD (Resources for Native Americans)
  - Indian Health Service Sanitation Facilitation Construction Program
  - US Department of Health and Human Services Administration for Native Americans Environmental Regulatory Enhancement

- State Sources
  - State Revolving Funds
  - Other specific state programs include:
    - Massachusetts Community Septic Management Program
    - Pennsylvania Community Septic Management Program (PENNVEST)
    - Texas Supplemental Environmental Project
    - Washington Centennial Clean Water Fund

The major federal programs, along with the state revolving funds, are briefly described as follows:

Clean Water Act Section 319 Non-Point Source Management Program—This program provides grants through state governments. The goal of the program is to support projects nationwide that work to restore water adversely affected by non-point source pollution and to protect waters endangered by such pollution. Most states allow the use of Section 319 funds for decentralized wastewater system projects. The program has provided money to small communities and state agencies to construct decentralized wastewater systems in areas where these systems are more cost effective than centralized systems. Funds have also been used for the repair of existing decentralized wastewater systems and for decentralized system technology demonstration projects. Projects must meet a minimum set of project planning, implementation, monitoring, and evaluation requirements designed to lead to successful documentation of project effectiveness with respect to water quality protection or improvement.

USDA Rural Utility Service (RUS)—Communities may be able to fund projects through RUS, formerly Farmers Home Administration (FmHA). RUS offers low interest loans at 4.5 percent or higher depending on the criteria set by RUS for award. The RUS grant/loan program is a grant in conjunction with a low-interest loan. The population and the median income are two important factors used to determine pre-qualifiers for the RUS grant and low interest loan.

The final eligibility for RUS funding depends upon the available funding in the program, the number of projects submitted, and the rankings for each project. The grant/loan combination for any particular community may be limited to a maximum of $2.5 million dollars for any fiscal year. The projects can be phased to spread the cost over a number of years to maximize funding. To receive funding a community must show that it:

- Cannot obtain funding from commercial lenders at reasonable rates
- Has the capacity to borrow and repay loans and pledge security
- Can operate and maintain the affected facilities

The maximum grant funding level is 75 percent of a project's total cost.

Nationwide, RUS (and FmHA) has provided $16 billion in loans and grants since 1940, including $3.7 billion between 1992 and 1998.

For more information contact:

USDA RUS
Water & Environmental Programs
1400 independence Avenue SW
Washington, DC 20250
(202) 720-9583
www.usda.gov/rus/water

HUD Community Development Block Grant (CDBG) Program—HUD provides block grants to participating states, which allocate funds to local governments that perform development activities, principally for people with low to moderate incomes. HUD requires that 70 percent of grant funds be used to benefit low- and moderate-income people. Detailed eligibility requirements vary by state. Funded activities include wastewater, drinking water, and economic development projects. As of 1999, 48 states and Puerto Rico participate in the HUD CDBG program. Hawaii and New York do not administer the CDBG program. CDBGs are available directly from HUD for communities in these states.

For more information contact:

US Department of Housing & Urban Development
Office of Block Grant Assistance
State and Small Cities Division
451 7th Street SW
Washington, DC 20410
(202) 708-1322
www.hud.gov/cpd/cdbg.html

Department of Commerce Economic Development Administration (EDA) Funding—EDA grants are intended to help distressed communities attract new industry, encourage business expansion, diversify local economies, and generate long-term jobs. Water and wastewater facilities designed primarily to serve industry and commerce are among the many projects that can be funded under this program.

For more information contact:

US Department of Commerce
Economic Development Administration
Public Works Division
Herbert C. Hoover Building, Room H7326
Washington, DC 20230
(202) 482-5265
www.doc.gov/eda/html/pwprog.htm

US EPA Hardship Grants Program for Rural Communities—This program applies to communities that meet the following criteria:

- Fewer than 3,000 residents
- No access to centralized wastewater treatment or collection systems or need improvements to onsite wastewater treatment or collection systems
- Proposed project will improve public health or reduce environmental risk
- Per capita income of less than 80 percent of the national average
- Unemployment rate exceeding the national average by 1 percent or more

For communities that meet these criteria, grants can be issued for the planning, design, and construction of publicly owned treatment works or alternative wastewater services, such as onsite treatment systems (including septic systems). States may also use hardship assistance to provide training, technical assistance, and educational programs on the operation and maintenance of wastewater treatment systems.

For more information contact:

US Environmental Protection Agency
Clean Water State Revolving Fund Branch
(Mail Code 4204)
401 M Street, SW
Washington, D.C. 20460
(202) 260-2268
www.epa.gov/OWM

US EPA Colonias Program—Native American communities located in Texas, New Mexico, or within 62 miles of the Mexican border may be eligible for funding assistance under the Colonias Program. Program criteria are set at the state level, and include:

- Economic/income criteria
- Communities must be unincorporated
- Communities must pre-date the Colonias program
- Communities must lack basic services such as water and sanitation

Through October 2001, approximately $27 million has been budgeted for water and wastewater projects on tribal lands, and some 25 projects have been identified for funding.

For more information contact:

Colonias Program
Office of Waste Management
401 M Street SW
Washington, DC 20460
(202) 260-5841
www.epa.gov/owm/smallc.htm

State Revolving Fund (SRF) Loans—Capital for state SRF programs is provided 20 percent by the state and 80 percent by US EPA. States have broad discretion to establish program priorities and project eligibility criteria. There are two SRF programs for which communities may be eligible:

- Drinking Water State Revolving Fund Program (DWSRF), created as part of the 1996 Clean Water Act. As of 2000, approximately $2.3 billion has been awarded to states under this program.
- Clean Water State Revolving Fund (CWSRF), created in 1988, all 50 states and Puerto Rico currently participate in the program. As of 2000, CWSRF programs nation-wide have total assets of approximately $30 billion.

These loan programs are mainly designated for communities with water quality problems.

Local Financing Options

Local financing options for cluster systems include community-wide charges and those based on the service area:

- Community-Wide
  - Taxes (property or through local assessment districts)
  - Sales tax
- Service-Area-Wide
  - User-charges
  - Connection fees

Community-Wide

Local community-wide financing options include all financing options that are derived from the community at large through public means. Under these structures, everyone in the community supports the wastewater system financially even though the system may not provide service to all of the property owners. The primary community-wide financing structure is the property tax. Property taxes have historically been used to pay for infrastructure work such as wastewater systems. This is normally done by increasing the property tax rate (the mil rate) for the entire community. Alternative structures are also possible, such as establishing special tax rate districts. The tax burden is based on the relative value of each property and is independent of the wastewater capacity or generation from a property. The property tax is normally used to finance all or a portion of a wastewater system.

An innovative means of community-wide financing is the use of a specialty tax. The town of Provincetown, MA, for example, which hosts many tourists, dedicates a portion of its room tax to its wastewater fund.

Service-Area-Wide

Local service-area financing options include revenues that are derived only from the property owners served by the wastewater system. These financing options can be implemented through public or private entities. They can take the following forms:

- **User-charges** are periodic (monthly, quarterly, or semiannual) fees paid by all property owners in the wastewater system. User charges can be structured as a fixed fee per connection, a fee based on actual wastewater flows (flat rate or a usage based multi-step rate structure with a minimum monthly fee), or a fee based on allocated capacity (regardless of actual usage). User-charges can be implemented to raise revenues for capital, O&M, or both.
- **Connection fees** are typically a one-time payment or assessment made at the time the wastewater system is built or when the property connects to the system. The fee is the proportionate share of the capital costs. Connection fees are assessed based on the principal that the property is being improved by the wastewater system. Connection fees can be assessed based on lot size, street frontage, water demand/wastewater generation capacity, or as a fixed amount per equivalent dwelling unit (EDU), with non-residential properties assessed based upon similar capacity criteria.

A combination of property taxes, user fees, and connection fees is frequently used to finance projects. The relative distribution of revenue from property tax, connection fee, and user fee varies widely by community.

Communities can also fund wastewater projects through municipal (or county or other locality) bonds. Municipal bond interest rates will depend on the community’s bond rating. An innovative financing technique is through the use of tax increment financing, described as follows.

Tax increment financing captures the projected increase in property tax revenue created by developing an area and uses that projected increase to obtain a bond to pay for the wastewater projects. Tax increment financing is possible because the wastewater project is expected to increase the aggregate assessed value of property in the project area. A guarantor of the tax increment bonds is usually needed to mitigate the financing risk.

Upon creation of a project (or district), the local assessor establishes the base-assessed value of the properties in that area. During subsequent years, the assessor certifies the current assessed value of the property in the project area or district. The tax increment is the difference between the amount of regular levy property taxes on the current assessed value and the amount of regular levy property taxes on the base-assessed value. Regular levy property taxes on the base-assessed value of the property continue to be allocated to the appropriate local taxing bodies, while the tax increment is deposited in a tax increment financing fund used to pay the project bonds.

There are two ways to fund projects using tax increment financing:

- **Pay-as-you-go—**In some cases, the municipality may be able to use the tax increment to pay for projects as they are constructed. Small wastewater improvement projects might be suitable for the pay-as-you-go method.

- **Issuing Tax Increment Financing Bonds or Notes**—In other cases, such as with larger wastewater projects, there may be substantial up-front capital costs. Thus, the county or municipality can issue tax increment financing bonds or notes to help finance the project. These obligations will provide money to pay for a portion or all of the project's capital costs. They can then be paid back by the tax increment over a period of up to 30 years.

Affordability Guidelines

The US EPA (1995) has developed guidelines to assess the affordability of wastewater fees. Simple assessment guidelines are the annual cost as a percentage of median household income with the following benchmarks for comparison:

- Little Impact Less than 1 percent
- Mid-Range Impact 1 to 2 percent
- Large Impact Greater than 2 percent

For situations of large impacts, secondary indicators should be examined and include:

- Bond rating
- Overall net debt as a percentage of full market value of taxable property
- Unemployment
- Median household income—as a percentage of state median income
- Property tax revenues as a percentage of full market value of taxable property
- Property tax collection rate

Grants are available for connection and assessment fees for low-income families and the elderly. Developing fee deferral programs for the elderly and low-income households in which the fees accumulate and are paid when the property is sold may also be advantageous. Obviously, cash-flow financing will need to be provided to the ownership agency.

Operations Management—Monitoring, Maintenance, and Repair

The maintenance, monitoring, and repair (MMR) activities required for cluster wastewater systems are heavily influenced by system capacity, with Type II systems having more requirements than Type I systems. Maintenance and repair activities are dictated by the equipment, while monitoring requirements are dictated by permits.

Table 4-2 presents typical MMR responsibilities for the range of cluster wastewater system sizes. Table 4-3 shows the State of Florida Required Monitoring Schedule for a wastewater treatment plant discharging to surface waters with an NPDES permit.

Table 4-2
Typical MMR Responsibilities for the Range of Cluster Systems

MMR Activity	Onsite Systems	Small Systems *<2,000 gpd*	Medium Systems *2,000–10,000 gpd*	Large Systems *10,000–50,000 gpd*	Very Large Systems *50,000+ gpd*	Centralized Systems
Maintenance	Periodic residuals removal		Treatment, collection system maintenance	Treatment, collection, dispersal system maintenance activities	On-going treatment, collection, dispersal system maintenance activities	
Monitoring	Periodic Inspections	Periodic Inspections Remote monitoring systems may be appropriate	Regular inspections Regular sampling On-call personnel Remote monitoring systems	Regular inspections Regular sampling On-call personnel SCADA system	Regular inspections Regular sampling Full time personnel SCADA system	
Repair	Component repair as needed		Component repair as needed On-call personnel	Preventative repair and replacement program On-call personnel	Preventative repair and replacement program Full time personnel Redundant systems	
Administration	Varies by degree of oversight (Education, Permit Applications, Inspections, etc.) System use regulation		Discharge permit Compliance reporting System use regulation	Discharge permit Compliance reporting Minimal customer service System use regulation	Discharge permit Compliance reporting Full customer service System use regulation	

Table 4-3
Sample Schedule for Minimum Sampling and Testing Domestic Wastewater Treatment Plant Discharging to Surface Water with NPDES Permit, State of Florida

Parameters	Permitted Capacity						
	2,000 gpd up to, but not including 5,000 gpd	5,000 gpd up to, but not including 50,000 gpd	50,000 gpd up to, but not including 500,000 gpd	0.5 mgd up to, but not including 1 mgd	1 mgd up to, but not including, 5 mgd	5 mgd up to, but not including, 15 mgd	15 mgd and above
Flow, pH[1] Chlorine Residual[2]	Daily (5/wk)	Daily (5/wk)	Daily (5/wk)	Daily (5/wk)	Continuous	Continuous	Continuous
Dissolved Oxygen	Daily (5/wk)	Daily (5/wk)	Daily (5/wk)	Daily (5/wk)	Daily (7/wk)	Daily (7/wk)	Daily (7/wk)
Suspended Solids[4] $CBOD_5$, Nutrients	Monthly	Monthly	Every two weeks[3]	Weekly	Weekly	Daily (5/wk)	Daily (7/wk)
Chlorine Residual[5]	Monthly	Monthly	Every two weeks[3]	Weekly	Daily (7/wk)	Daily (7/wk)	Daily (7/wk)
Fecal Coliform[4]	Monthly	Monthly	Every two weeks[3]	Weekly	Weekly	Daily (5/wk)	Daily (7/wk)

[1] Hourly measurements during the period of required operator attendance may be substituted for continuous measurement.

[2] Total chlorine residual measured for disinfection effectiveness (after chlorine contact). Hourly measurements during the period for required operator attendance may be substituted for continuous measurement except for systems permitted under Part III of Chapter 62-610, F.A.C. Continuous measurement shall be provided for all systems permitted under Part III of Chapter 62-610, F.A.C.

[3] Reuse and land application facilities (which include rapid-rate, slow-rate, absorption fields, and other systems pursuant to Chapter 62-610, F.A.C.) less than 100,000 gpd, may sample monthly. (This reduction does not apply to injection wells pursuant to Chapter 62-28, F.A.C., and reuse systems requiring high-level disinfection.)

[4] For reuse systems requiring high-level disinfection, samples shall be obtained and reported daily, 7 days per week for systems of 0.5 mgd and greater, 4 days per week for systems 50,000 gpd but less than 0.5 mgd, and 3 days per week for systems less than 50,000 gpd; or daily during the period required for operator attendance, whichever is less. At permit renewal, reduction to 4 days per week for systems of 0.5 mgd and greater or to 3 days per week for systems of at least 50,000 gpd but less than 0.5 mgd may be requested if no violations for these parameters have occurred in the last 12 months. For systems requiring high-level disinfection, the reduction allowed by note 3 does not apply.

[5] Total chlorine residual measured for dechlorination effectiveness.

5 DECENTRALIZED WASTEWATER TECHNOLOGIES

In the past two decades, numerous innovative technologies and systems have entered the market for wastewater collection, wastewater treatment, dispersal, and reuse that can be used in cluster systems. Community planners, engineers, regulators, and homeowners have more options for advanced wastewater management systems than ever before. These possibilities enable greater flexibility in wastewater planning and management and protecting water quality.

Technological feasibility no longer needs to be the deciding factor for a cluster system, because cluster wastewater systems can perform as well as centralized wastewater systems. This fact should not suggest that there is no need for technology improvements. On the contrary, technology improvements are needed in the areas of:

- Development of improved cost-competitive technologies
- Removal of nitrogen and phosphorus to low levels
- Treatment of emerging contaminants

The nutrient removal requirements in environmentally sensitive areas generally remain the most challenging treatment technical issue, as well as treatment of emerging contaminants. Dispersal challenges are typically associated with the site subsurface conditions.

The key considerations of technologies are:

- **Capital, operating, and maintenance costs optimization**—Innovative technologies for small flow systems avoid the need for extensive collection infrastructure, which is usually the most significant portion of capital costs. Monitoring or operating costs may be higher for certain technologies, however, due to their size and decentralized nature. Use of passive treatment technologies and the Internet for monitoring can achieve significant cost savings and maintain the positive economic competitiveness of cluster systems.
- **System monitoring and maintenance issues**—Most advanced cluster wastewater treatment units have greater maintenance needs or energy requirements than conventional septic systems. Neglecting maintenance, as has occurred in the past, will reduce or eliminate their effectiveness. Low-cost system monitoring and maintenance are critical.
- **Management requirements**—Even the simplest of systems require some management oversight. Establishing basic management systems will enable identification and resolution of operational issues before they become catastrophic and costly to address. An overview of the wastewater management technologies available for collection, treatment, dispersal, and reuse for cluster system applications is presented in Table 5-1 and Figure 5-1.

Table 5-1
Wastewater Treatment Technology Options

Pretreatment Needed	Technology+	Design Flows (gpd)			
		<2,000	2,000–10,000	10,000–20,000	20,000–50,000+
	Pretreatment				
	Septic Tank++	✓	✓	✓	✓
✓	Anaerobic Upflow Filter	✓	✓	✓	✓
	Secondary Treatment				
	Fixed Film Growth				
	Rotating Biological Contactor		✓	✓	✓
	Trickling Filter +++	✓	✓	✓	✓
✓	Subsuface Wetlands—Vegetated Submerged Beds	✓	✓	✓	✓
✓	Constructed Wetlands (FWS)			✓	✓
✓	Recirculating Media Filters	✓	✓	✓	✓
✓	Intermittent Media Filters	✓	✓	✓	
	Suspended Film Growth				
	Oxidation Ditch				✓
	Activated Sludge Systems	✓	✓	✓	✓
	Sequencing Batch Reactor	✓	✓	✓	✓
	Membrane Bioreactor			✓	✓
	Integrated Fixed Film-Suspended Growth	✓	✓	✓	✓
	Advanced Treatment				
✓	Nitrogen Removal	✓	✓	✓	✓
✓	Phosphorus Removal	✓	✓	✓	✓

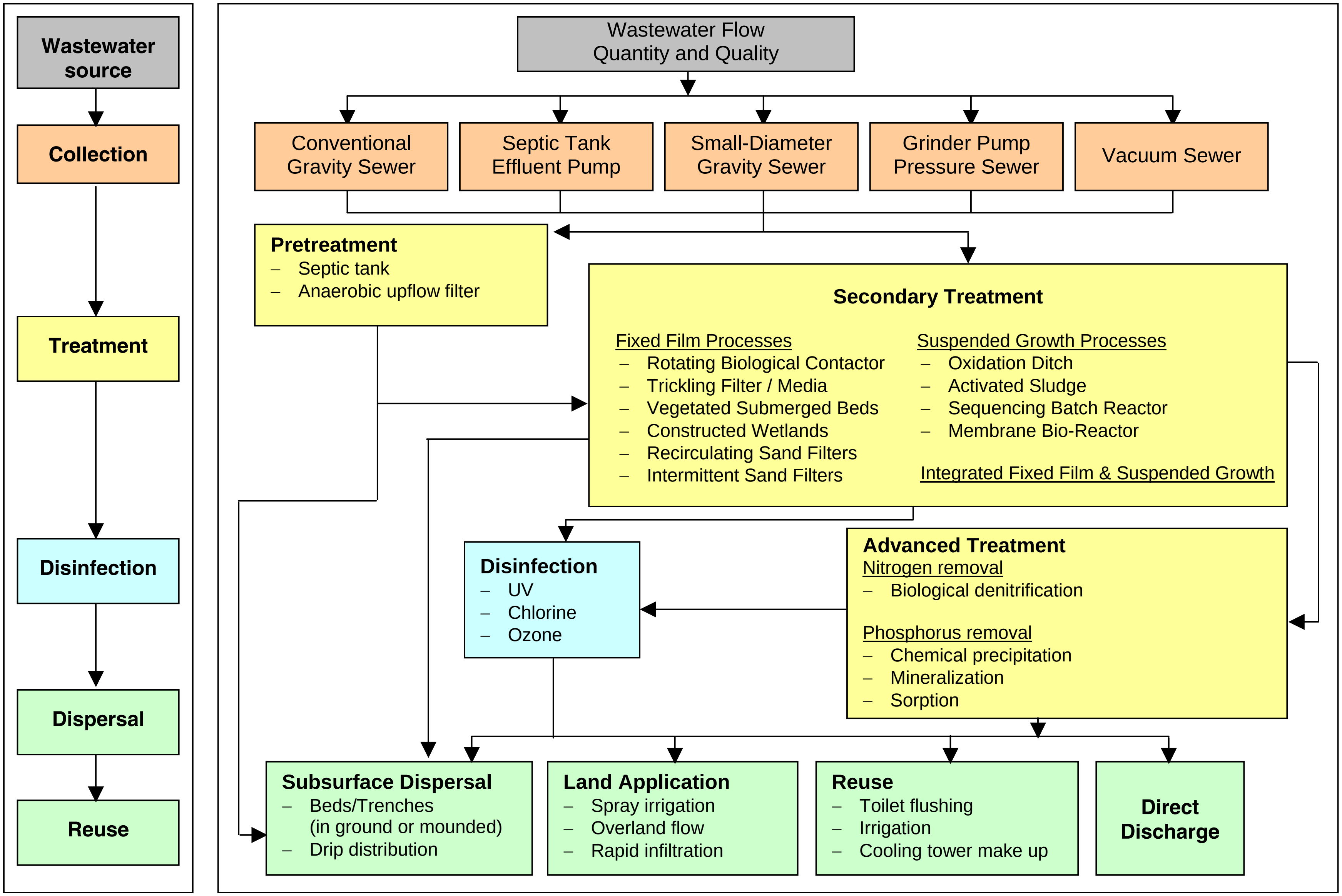
Notes:

+ Depending on method of dispersal, disinfection systems may or may not be required.

++ Tank may be part of collection system or located at treatment site.

+++ Various media, usually with recirculation.

Figure 5-1
Overview of Collection, Treatment, and Dispersal Technologies Suitable for Cluster Wastewater Systems



Wastewater generation rates for cluster systems are defined by code in Type I systems and by either code or sewer system design standards for Type II systems. For the smaller Type II systems, wastewater flows may be determined as for the Type I systems. For the large Type II system, state and sewer design standards are used. Typical sewer design standards are 200 to 250 gpd/Equivalent Dwelling Unit (EDU), and non-residential connections are converted to EDU. As an example, a restaurant may be assigned six EDUs. An assignment technique is to compute the number of EDUs for a connection using the Type I design code and using the Type I design code flow of a three-bedroom house as one EDU.

Wastewater Collection

Because wastewater conveyance systems often represent the major portion of the total capital cost associated with cluster wastewater management (up to 70 percent), communities should place considerable importance on developing the least-cost collection system.

The various technologies that can be implemented as a cluster system range in scale from a communal septic tank and dispersal system to a large alternative sewer system connected to a treatment plant that can treat large wastewater flows with a variety of wastewater treatment technologies with a surface discharge or a subsurface dispersal system. Each alternative technology must be evaluated for a given site in terms of its appropriateness in solving the problem, project costs, and environmental impact of the project.

Planners must consider many additional factors in the selection of an appropriate site specific wastewater collection system, including:

- Housing density and road frontage
- Size of the project and wastewater volume to be conveyed
- Topography and sensitive natural resources
- Depth to bedrock or groundwater
- Distance to the cluster treatment and dispersal site

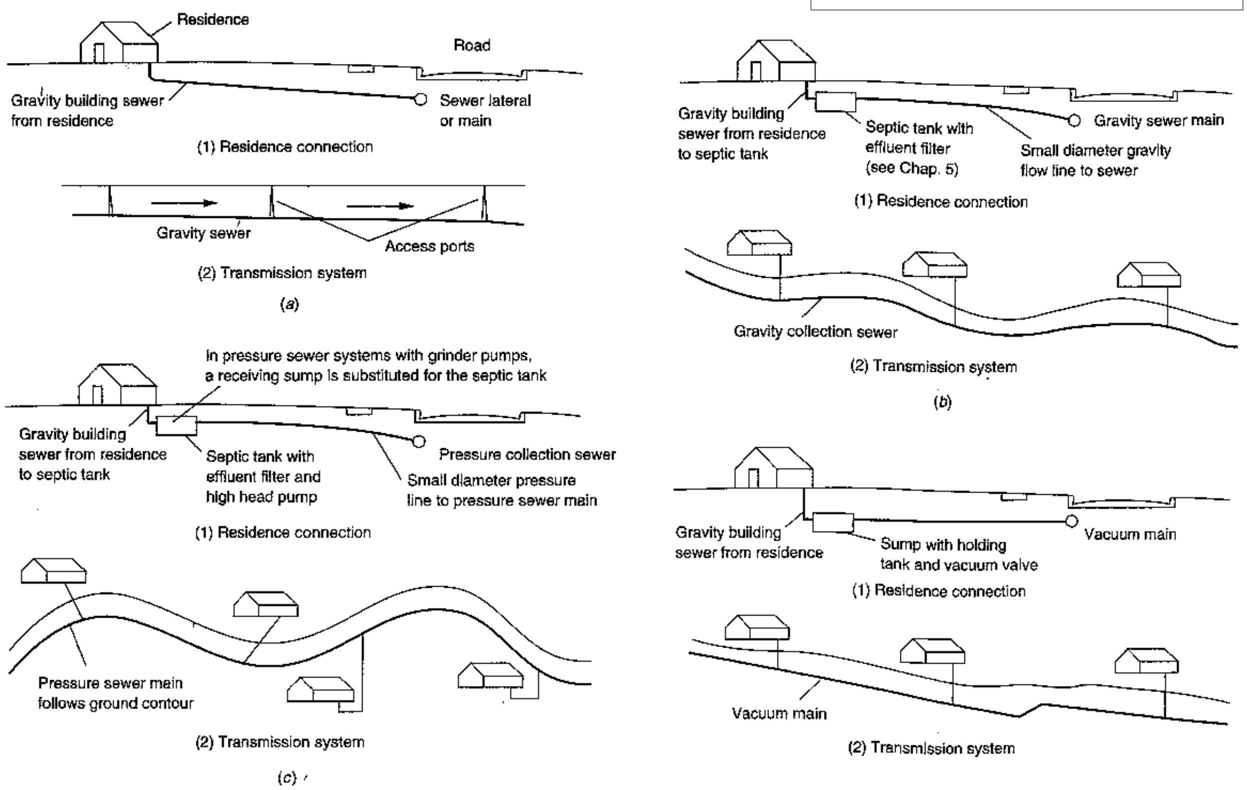
The basic collection system technology alternatives for a cluster system are:

- Conventional gravity systems (with lift stations as needed)
- Septic Tank Effluent Gravity (STEG) system (or small-diameter gravity sewers)
- Septic Tank Effluent Pump (STEP) pressure system
- Grinder pump pressure sewer system
- Vacuum systems

These systems are generally defined in Figure 5-2.

Figure 5-2
Sketch of Sewer Systems

KEY
(a) Conventional gravity
(b) Septic tank effluent gravity
(c) Septic tank effluent pump and pressure sewer with grinder pumps
(d) Vacuum sewer



Source: Crites and Tchobanoglous (1998)

In the past 30 years several alternate collection systems have been successfully implemented in areas where such collection systems provide compelling technical and economic advantages. This success has resulted in wider acceptance of alternate collection systems nationwide. These alternative technologies are more cost-effective than conventional sewers in conditions where there is shallow depth-to-groundwater and/or in bedrock areas.

To determine the appropriate collection system technology for a cluster system application, communities need to prepare preliminary collection system layouts along with cost analyses to determine the least costly option. STEP/STEG systems also provide some treatment, so the investigation should incorporate the value of this function in the cost analyses. Also, since alternative collection systems generally include some on-property components, these costs should be included for conventional sewers to perform a fair comparison.

Wastewater Treatment

The treatment technologies for Type I cluster systems can be the same as onsite systems, although increased in size. For Type II cluster systems, the technologies will tend to be those used in large centralized wastewater treatment plants. As cluster systems get larger, more sophisticated systems may become preferable to land-intensive systems due to site constraints. A list of potential treatment systems is shown in Figure 5-1. The generic options are:

- Septic tank
- Anaerobic upflow filter
- Aerobic treatment using:
  - Fixed film processes
  - Suspended growth
  - Integrated fixed film and suspended growth

To learn more about treatment technologies, refer to (Crites and Tchobanoglous 1998):

- US EPA guidelines, reports, and web sites
- National Small Flows Clearing House at West Virginia University
- Water Environment Federation (WEF)
- Water Environment Research Foundation (WERF)
- American Society of Civil Engineers (ASCE) publications
- National Water Resource Association (NWRA)
- The Internet can provide numerous links to information
- Any of the organizations discussed in this handbook

Wastewater Disinfection

The disinfection options for cluster systems are:

- Chlorine
- Ultraviolet (UV)
- Ozone

Chlorine

The use of chlorine for wastewater disinfection has been practiced for the past century. A variety of technologies are used including tablets, gas, and chlorine dioxide. Due to its harmful environmental effects, dechlorination may be required. Since chlorine addition creates carcinogenic compounds, its use in environmentally sensitive areas is discouraged.

Ultraviolet (UV)

UV disinfection operates by exposing the wastewater to a UV light source of sufficient intensity and time to kill infectious organisms in the wastewater.

Ozone

Ozone disinfection operates by bubbling ozone through the wastewater. Ozone (O_3) is a strong oxidant and is highly toxic to organisms.

Water Reuse

Water reuse for cluster systems generally consist of:

- Irrigation
- Toilet flushing in commercial buildings
- Indirect water reuse

Compare annual and daily reuse demand and supply to determine reuse system requirements and if supply and demand closely match. Some amount of storage may be required to balance supply and demand.

Water reuse for onsite systems consists of treatment of total or solely greywater for non-potable purposes, such as subsurface irrigation and/or toilet flushing. Greywater reuse requires dual piping and is generally only practical for new construction. Technology has successfully provided onsite reuse for toilet flushing. Compost toilets are an effective system for toilet waste treatment. Reclaimed water use for toilet flushing in houses is currently prohibited due to concerns about cross connections.

By recharging groundwater that is used for water supply, subsurface dispersal systems are recharging aquifers and, at times, providing indirect water reuse. Guidelines for indirect water reuse can be used to determine the acceptable limits of this practice.

Water Conservation

Indoor domestic water use generates wastewater from three major sources:

- Toilet (40 percent)
- Bathing (26 percent)
- Laundry (21 percent)

A typical family of four uses approximately 120 ccf (90,000 gallons) of water per year. The use of water conservation techniques can greatly reduce wastewater generation from these uses.

The three categories of water conservation techniques are:

- Flow reduction
- Use of water-conserving fixtures and appliances
- Utility water rates and rate-schedule incentives

Flow Reduction

Flow reduction is generally the least expensive technique to implement. Many commercially available inserts, fixtures, and appliances can conserve water in the shower, toilet, laundry, and sink faucets. Reports show that wastewater quantities have been reduced by 15 to 30 percent when using a toilet tank insert, with the use of water reduced from five to seven gallons down to three and one-half to four gallons per flush.

Use of Water-Conserving Fixtures and Appliances

New types of flush toilets can reduce use to only 1.6 gallons per flush, and are required in new construction. Showerhead flow restrictors reduce water flow from five to seven gallons per minute to about two and one-half gallons per minute, and are also required in new construction. Water-conserving washing machines reduce water use from 45 gallons per load to 30 to 40 gallons per load, and sink faucet aerators reduce the typical two to four gpm flow to one to two gpm.

Utility Water Rates and Rate-Schedule Incentives

Water conservation can be achieved as a result of the economic incentive associated with water and sewer rates and rate structures. A conservation rate structure could have the higher summer demand (usually for irrigation) provided at a higher rate.

Wastewater Dispersal

Wastewater dispersal is either subsurface or surface.

Subsurface Dispersal

Three wastewater dispersal options are available for subsurface dispersal:

- Conventional subsurface dispersal technologies (trenches, leaching beds, and other conventional methods)
- Mounded systems (trenches or beds)
- Subsurface drip distribution systems

Conventional subsurface dispersal methods are also called drainfields. Septic tank effluent or purified wastewater are discharged into a network of buried perforated pipes or chambers from which it enters the soil column and percolates downward until reaching the water table. The purified wastewater then merges with and disperses into the water table.

Mounded subsurface dispersal systems import a select fill to provide the required separation to groundwater or a limiting layer. The purified wastewater then merges with and disperses into the water table.

Subsurface drip distribution systems disperse the purified wastewater within the root zone of vegetation (lawns, landscaping, and other vegetation). These are shallow systems, approximately six to eight inches below the surface. The vegetation absorbs the water and some of the nutrients from the discharge, avoiding or reducing the need for other irrigation/fertilization application. Excess water flows into the soil column with the groundwater system as a conventional subsurface dispersal system.

Surface Dispersal

For surface dispersal, two general options are available:

- Direct discharge
- Created riparian wetland dispersal

A **direct discharge** system includes a discharge pipe/diffuser in a water body to mix the treated effluent with the receiving water body.

A **created riparian wetland dispersal** system is one in which a wetland is created along the shoreline of the receiving water body and purified effluent is discharged into the wetland, as in a subsurface flow wetland, or in saline waters in a submerged aquatic vegetation wetlands.

6 GLOSSARY

Better Assessment Science Integrating Nonpoint Sources (BASINS)—A multi-purpose environmental analysis tool that integrates sate-of-the-art assessment and modeling tools into one convenient package.

Biomat—A layer of anaerobic microorganisms, minerals, and suspended solids from wastewater.

Centralized Sewer—A common system for the collection, conveyance, treatment, and dispersal of municipal wastewater.

Cluster Systems—An option for wastewater management when onsite systems are impractical or connection to centralized systems is not financially or technically feasible. A cluster system collects wastewater from two or more septic tanks and transports, treats, and disperses the wastewater.

Collection—A system of pipes, manholes, and pumping stations to convey wastewater from individual users to a central treatment facility.

Connections—Individual hook-ups from buildings to a sewer collection system.

Cost Effectiveness Analysis (CEA)—The economic technique used to compare various wastewater systems options to determine the least costly option of all technically viable approaches for a particular situation.

Decentralized Wastewater Management—A common strategy to provide oversight for the use of multiple systems and types of systems to collect, treat, and dispose of wastewater. Types of systems include: onsite systems, shared systems, groundwater discharge systems, and direct discharge systems.

Direct Discharge System—A wastewater system that discharges highly treated wastewater into surface waters, such as rivers or streams.

Dispersal System—A system that receives pretreated wastewater and releases it into the air, surface water, or groundwater, or onto or under the land surface.

Effluent—A discharge that flows out, especially from a wastewater system.

Emerging Contaminants—The group of chemicals in personal care products and pharmaceuticals that are found in wastewater and have recently been identified in water resources.

Eutrophication—The process in surface waters in which excessive minerals and organic nutrients promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the death of other organisms, such as fish.

Failed System—A system that fails to protect public health and safety or the environment.

Failure Rate—The number of newly failing septic systems per year divided by the total number of septic systems in a study area.

Geographical Information System (GIS)—Automated systems for the capture, storage, retrieval, analysis, and display of spatial data.

Groundwater Discharge System—A wastewater system that discharges greater than 10,000 gallons per day of highly treated wastewater through the soil and into the ground water.

Hydrologic Simulation Program-Fortran (HSPF)—A comprehensive, conceptual, continuous watershed simulation program designed to simulate all water quantity and quality processes that occur in a watershed.

Hyporheic Zone—the region beneath and adjacent to streams and rivers where surface and ground waters mix.

Indirect Reuse—The practice of discharging treated wastewater into an aquifer or surface water that is also used for public water supply. Indirect reuse is an accepted and safe practice when performed properly; however, improper indirect reuse can threaten public health.

Innovative/Alternative (I/A) System—An onsite system that provides additional treatment prior to dispersal or provides a different means of treatment and/or dispersal of septic tank effluent.

Interim Wellhead Protection Area (IWPA)—The area within a one-half-mile radius for sources whose approved pumping rate is 100,000 gallons per day (gpd) or greater. For smaller sources, the IWPA radius is proportional to the well's approved daily volume.

Long-Term Acceptance Rate (LTAR)—The ability of a biomat to remain viable and purify septic tank effluent.

Method for Assessment, Nutrient-Loading, and Geographic Evaluation (MANAGE)—A watershed risk-assessment tool that uses computer generated maps and other data to evaluate pollution risks of land-use and landscape features.

MODFLOW—Modular three-dimensional finite-difference groundwater flow model used for particle tracking analysis.

National Pollutant Discharge Elimination System (NPDES)—Part of the Clean Water Act requiring municipal and industrial wastewater treatment facilities to obtain permits that specify the types and amounts of pollutants that may be discharged into water bodies.

Needs Assessment—Generally used to describe a broad investigation of the overall limitations and requirements of the wastewater infrastructure in a community (compare to Problem Definition).

Onsite System—An individual wastewater treatment and dispersal system designed to treat and dispose of wastewater beneath the ground on the site where the wastewater is generated.

Pathogens—Disease causing microorganisms, such as bacteria and viruses.

Percolation Test—A test that measures the absorption rate of soil.

Problem Definition—Generally used to describe the specific documentation of the inadequacies of onsite systems in a particular study area (compare to Needs Assessment).

Responsible Management Entities (RMEs)—Public or private entities responsible for proper functioning and certification of water quality protection for a cluster wastewater system.

Reuse—The practice of using purified wastewater for non-potable uses such as irrigation, toilet flushing, or industrial processes.

Septage—The combination of liquid and solid material that is pumped out of a septic tank during routine or emergency maintenance.

Septic Tank—A large underground watertight tank where solid and floating wastes are separated from the liquid before dispersal of the effluent in a soil absorption system.

Sewage—Waterborne sanitary wastes, generally used interchangeably with wastewater.

Shared System—The combination of one or more buildings or parcels sharing a common wastewater system.

Soil Absorption System—A system of pipes, stones, and other structures used to evenly distribute septic tank effluent to the soil.

Soil Mapping Unit—The smallest area with similar soil characteristics delineated on a soil survey map by the US Department of Agriculture Natural Resources Conservation Service.

STE—Septic Tank Effluent

Subsurface Dispersal—The discharge of treated wastewater into the ground by use of exposed infiltration or leaching beds or underground leaching systems.

Surface Dispersal—The discharge of treated (or untreated) wastewater to surface waters such as lakes, ponds, streams, rivers, or marine water bodies.

Total Maximum Daily Load (TMDL)—A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

Type I Cluster Systems—Small (less than 2,000 gpd flows) or medium (2,000 to 10,000 gpd flows) cluster wastewater systems governed by state (or local) health departments, which have prescriptive codes for system design.

Type II Cluster Systems—Medium-large (10,000 to 25,000 gpd flows), large (25,000 to 50,000 gpd flows), and very large (greater than 50,000 gpd flows) cluster wastewater systems governed by state departments such as an US EPA. These systems are typically viewed as small sewers and must comply with state requirements for wastewater collection, treatment, and dispersal/reuse.

Wastewater—Waterborne sanitary wastes; generally used interchangeably with sewage.

Wastewater Treatment System—A system that uses physical, chemical, and biological principles to remove certain constituents from wastewater to make the effluent suitable for dispersal in the environment.

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8 ADDITIONAL RESOURCES

For further information regarding alternative technologies refer to the following resources.

State/Federal/Local/Organizations

www.epa.gov/owm/mtb/decent/technology.htm

www.epa.gov/ne/assistance/ceitts/index.html

Non-Governmental Organizations

www.nesc.wvu.edu/

Type I Cluster Systems

www.deq.state.or.us/wq/onsite/onsite.htm

www.epa.gov/owm/

www.nesc.wvu.edu/nsfc/

www.barnstablecountyhealth.org/AlternativeWebpage/index.htm

www.onsiteconsortium.org/

www.deh.enr.state.nc.us/oww/

www.o2wa.org/

www.ces.purdue.edu/onsite/

www.towtrc.state.tx.us/

www3.extension.umn.edu/water/

www.uri.edu/ce/wq/

www.vdh.state.va.us/onsite/index.htm

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