SEPTIC REGULATIONS AND SUBURBAN DEVELOPMENT PATTERNS:

AN ANALYSIS BASED ON SOIL DATA IN NORFOLK COUNTY, MASSACHUSETTS

by

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ABSTRACT

Urban sanitation systems are fundamental elements of modern urban development. Decentralized, privately operated, on-site wastewater disposal systems have also played an important role in suburban and exurban development over the past fifty years. This research is an attempt to assess the current influence of on-site wastewater disposal technology and regulations on land use patterns in Norfolk County, Massachusetts; to estimate the potential impacts of technological and regulatory change; and to assess the potential role of on-site sanitation policies in managing suburban and exurban development. I grouped soil types into seven interpretive classes based on their limitations for wastewater disposal; and created a Soil Development Index, which represents the relative proportion of soil classes in available and developed land over time.

I found that soils with high groundwater and slow permeability are systematically underrepresented in residential development utilizing on-site wastewater disposal; comparisons to sewer service areas suggest these patterns may be due to regulatory restrictions on the use of septic systems. Slowly permeable soils and shallow bedrock areas are also associated with larger lot sizes in unsewered areas. The land-consumptive patterns of development observed in unsewered suburbs suggest that the current system of on-site sanitation is closely linked to other public policies that promote large-lot single family large-lot development to the exclusion of more diverse development models.

The history of centralized and decentralized sanitation systems in the United States demonstrates that sanitation policies have evolved over time to address a wider variety of social and political concerns, including explicit planning objectives. Additional research is necessary to assess how sanitation policies—including standards for on-site wastewater disposal—might be used as implementation mechanisms for land use and planning policies intended to promote sustainability.

“The growth of population, the multiplication of inventions, the rise of hitherto unknown needs and the employment of uncertain techniques, the acceleration of change itself—all these conditions turned empirical and spontaneous coordination into helpless mockeries. For lack of conscious plan, the empire of muddle arose….”

-Lewis Mumford
The Culture of Cities

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Onward!

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CHAPTER 1: WHY SEPTIC SYSTEMS?

The form of human settlement patterns is a fundamental concern of modern city planning. The arrangement of residential development within the landscape affects natural resources, housing affordability, community character, municipal service provision, and transportation patterns. The massive growth of suburban and exurban development over recent years has brought a new imperative to managing these socioeconomic and environmental impacts, in order to promote a livable and sustainable society.

Communities and planning practitioners engage in diverse strategies to protect resources and manage development; examples include land use controls, open space acquisition, tax and fee structures, municipal service provision policies, and building standards. Because the production of waste is a fundamental aspect of human life, sanitation policies have long been a central concern of public agencies, and have influenced land use patterns. The advent of central sewer systems improved the health and efficiency of dense urban development, and in outlying locations the absence of these systems has acted as a de facto growth control. Over time, health-oriented sanitation policies evolved to encompass a wider array of concerns, including explicit planning objectives such as the containment of urban densities.

Another class of sanitation policies includes public standards for the on-site disposal of wastewater. These regulations have influenced settlement patterns by prohibiting disposal on sites with unsuitable soil conditions. Recently, advancing technologies and changing policies have enabled development on a wider variety of sites. This research is an attempt to assess the current influence of on-site wastewater disposal regulations on land use patterns in Massachusetts, to estimate the potential impacts of technological and regulatory change, and to assess the potential role of on-site sanitation policies in managing suburban and exurban development.

The Percolation Rate Debate

In October 2002, the Massachusetts Department of Environmental Protection (DEP) proposed a change in the regulations for Title 5 of the Massachusetts Environmental Code (310 CMR 15.000), which governs the on-site disposal of sanitary wastewater. The regulations permit construction of wastewater disposal systems only where soils are deep enough to ensure adequate treatment of nutrients and pathogens, and permeable enough to allow adequate drainage of wastewater. The proposed regulatory change relaxed the standard for soil percolation rate (a measure of permeability) from 30 minutes per inch to 60 minutes per inch, permitting construction of septic systems on moderately permeable soils, where they had previously been prohibited.

The proposal generated spirited debate. Proponents of the change stated that the existing standard was unnecessary for the protection of human health and the environment, and that it acted as an artificial barrier to new home construction in a state with a notorious shortage of housing (Flint, 2002; Governor's Commission, 2002; Euchner, 2003). Opponents countered that the change would enable more rapid conversion of marginal, environmentally sensitive lands; and that the likely result would be large houses on large lots that would not increase the supply of moderately priced housing for those who needed it most (Metropolitan Area Planning Council, 2002; Flint, 2002). Planners noted that DEP provided little information on potential land use impacts of the proposed change, information needed to create land use controls that effectively fill the regulatory 'gap' created by the removal of a de facto development control (Metropolitan Area Planning Council, 2002; Albertson, 2002). After public hearings, the DEP approved the change, which is to take effect January 1, 2004.

Are Sanitation Policies Appropriate Planning Policies?

The disagreement about the pending regulatory change exists within a broader debate about whether on site wastewater disposal regulations should be used as a mechanism for planning and growth control. Some land is unsuitable for on site waste disposal due to natural conditions, and the prevailing existing technology has limited capacity for the treatment of wastewater even under the best conditions (Veneman, 1982). Consequently, regulations designed to protect human health and maintain water quality must prohibit the use of conventional treatment technologies in certain unsuitable areas, and must limit overall housing density where the inevitable byproducts of these technologies may affect sensitive resources such as aquifers.

These technical requirements and site limitations effectively prevent the continuous , dense development that is possible where centralized sewer collection and treatment systems exist. Concerned with the aesthetic, environmental, and financial impacts of growth, many towns have decided against the construction of sewer systems in order to take advantage of this *de facto* growth control (Twichell, 1978, Jacobs and Hanson, 1989; Rome, 2001; Goehring and Carr, 1980). Some municipalities have adopted septic regulations more stringent than those promulgated by the state, often in combination with zoning that requires minimum lot sizes of one or two acres.

It is a matter of debate as to whether these municipal restrictions are necessary to protect health and water quality as a result of local conditions, or whether they are intended to provide a further disincentive to development (Governor's Commission, 2002). Whether or not they actually accomplish desirable planning objectives is yet another point of debate. However, if health or environmental justifications act as a 'cover' for planning objectives, the legality and effectiveness of these implicit growth controls may diminish with the growing institutional and popular acceptance of alternative technologies that can provide adequate treatment on a wider variety of site conditions (Hanson and Jacobs, 1989; LaGro, 1996).

Research over the last 25 years (Popper, 1980, 1981; LaGro, 1994) has noted the decreasing influence of physiographic conditions on development. Frank Popper (1980) observed that "many localities and states have in the past used health or sanitary codes in such a way as to inadvertently transform them into indirect devices to control land use or growth…the advent of the alternative [wastewater disposal] technologies may make this approach outmoded, and force some governments to deal with land use directly rather than indirectly for the first time…."

Subsequently, Jacobs and Hanson (1989) researched the application of alternative wastewater technologies in Wisconsin, and found the land use impacts of alternative on-site technologies to be small in comparison to those of development relying on conventional technologies. They concluded that "the policy mechanisms most suited to mitigating settlement impacts are settlement policies, that is, land use policies."

If sanitation policies are confined to the narrow task of preserving health and water quality, then their argument would also apply to the management of development impacts within areas served by centralized sewer systems. Yet researchers and practitioners have developed—and public agencies and courts have adopted—water and sanitation infrastructure policies that function as implementation mechanisms for land-use plans. These policies often use pricing and phasing mechanisms to promote development in designated areas and to discourage haphazard system extensions to outlying areas[1] (Downing, 1972; Binkley et al., 1975). Courts have accepted the legality of these policies, so long as their planning objectives are valid and explicitly stated, and so long as statutory authority for land use planning is properly vested in the implementing agency (Stone, 1982; Herman, 1992; Biggs, 1990).

In contrast, the formulation of septic regulations is generally limited to the narrowly defined environmental concerns of human health and water quality, while ignoring broader issues of land stewardship. This is a result of the institutional and legislative history of on-site wastewater disposal controls.

I agree with Jacobs and Hanson that explicit land use controls are the most appropriate (and most effective) primary mechanisms for the management of settlement patterns. I also find the historical record demonstrates that effective planning demands the coordination of various streams of public policy (e.g., taxation, infrastructure, provision of municipal services, etc.) in order to achieve desired outcomes. In this context, it may be appropriate and effective to create wastewater disposal regulations that explicitly complement land use controls, to the extent possible. Both land use controls and wastewater regulations must account for the environmental, fiscal, and social impacts of different settlement patterns (Burchell, 1995) and promote consideration of these impacts in development decisions.

There is also, admittedly, an important fiscal distinction between publicly owned and operated utilities and privately financed on-site systems, which affect municipal finances and services only secondarily, through the process of growth. Yet the legal justification for planning-oriented sewer policies does not necessarily depend on a utility's fiscal capabilities, but on whether the policies are a rational exercise of the police power to prevent the impacts of development.

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[1] I consider Development Impact Fees to be one such pricing mechanism. Municipalities assess these fees in order to recoup the financial impacts of new housing on municipal expenditures, impacts that vary with the location and density of development (Nelson, 1988; American Planning Association, 1988).

Disposal Standards and Their Role in Development Decisions

Compared to the vast literature on the secondary impacts of centralized sewer systems, there is relatively little research that addresses the influence of septic regulations on land-use decisions. Consequently, the policy debate in Massachusetts is characterized by a striking lack of data on the extent to which septic regulations constrain or guide development (if at all.) This thesis is an attempt to fill the gap, through a theoretical and empirical analysis of how the site requirements of septic regulations (Title 5 in particular) may discourage or promote development under different soil conditions, and a quantitative assessment of this influence on settlement patterns.

The results and methodology of this analysis will lend themselves to policy analysis and formulation. They can be used to estimate the incremental impact of a proposed regulatory change; and they can support the creation of septic regulations that more effectively complement planning efforts and conventional land use controls.

In particular, I am concerned with the extent to which the site requirements of Title 5 influence development on sites characterized by high groundwater, shallow bedrock, or slowly permeable soils. State and local codes may prohibit waste disposal on sites with unsuitable soil conditions; these sites are likely to remain undeveloped. Marginally suitable conditions may require technologies or construction methods that add to the cost of development. In areas of heterogeneous soil conditions, large lots may be necessary to include suitable disposal sites on each property. Conceivably, reduced yield or higher development costs that result from septic requirements could have a deciding influence on the decision to develop.

Prohibitions on development—or standards that affect construction cost or lot yield—should be reflected in land use patterns that show relatively more development on favorable soil conditions and less development on sites with unfavorable soil conditions.

In order to test this hypothesis, I evaluated land use change in four towns in Metropolitan Boston with extremely limited public sewer systems. The goal of this analysis is to determine whether residential development occurs on deep, permeable, well-drained soils relatively more often than on soils characterized by high bedrock, shallow groundwater, or slow permeability. Relying on MassGIS[2] land use data, I identified land developed for residential uses during three periods, 1971-1985 and 1985-1999. I also mapped the distribution of soil types, based on data from the U.S. Department of Agriculture National Resources Conservation Service. I grouped soils types into 7 interpretive classes based on their suitability for septic system construction.

I compared the relative proportion of these interpretive classes within developed areas to their proportion in land available for development[3] at the beginning of each period (1971 and 1985.) I then created a "Soil Development Index" (SDI) that represents the relative proportions of each class in available and developed land.[4] This approach was designed to account for the different soil distributions and amounts of development within each town, as well as the land scarcity problem potentially created by a preference for development on favorable soils. For point of comparison, I also conducted the same analysis on four nearby towns that have extensive public sewer systems.

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[2] MassGIS is the Massachusetts state agency that manages digital geographic data and makes it available to researchers and members of the public.

[3] For purposes of this research, 'available' land excludes wetlands, floodplains, permanently protected open space, and developed land. In these areas, practical difficulties or regulatory constraints other than wastewater disposal standards are likely to be the dominant obstacle to development.

[4] An SDI of 1.0 indicates that the proportion of a specific class of soils within available land at the beginning of a period is equal to the proportion of that soil type within land developed during that period. A value over 1.0 indicates that the soil class is over-represented in developed land as compared to available land. Values below 1.0 indicate that developed areas contain relatively less of a soil class than the land available for development at the beginning of the period.

Summary of Results

I found that development that relies on septic systems tends to occur relatively more often on deep, permeable soils with a low water table. The presence of shallow groundwater appears to be a significant deterrent to development that relies on septic systems. This influence appears to have become more significant over time and is not consistently reflected in development served by public sewer.

I also found that during the period 1985-1999, slowly permeable soils experienced relatively low rates of development in unsewered areas. Slowly permeable soils and shallow bedrock areas were also associated with larger lot sizes, though this finding may be attributable to an observed systematic zoning bias in favor of larger minimum lot sizes on soils with limitations for on-site wastewater disposal.

My research also sought to estimate the potential influence of the pending Title 5 regulatory change. I found that the class of soils that would be affected by the proposed change (i.e., moderately permeable soils, without other limiting conditions) is relatively uncommon in the study area due to the geological history of the region, and that local bylaws stricter than Title 5 may still prevent development on these soils. It is likely that impacts of the proposed change will be greater where moderately permeable soils are more common and local health bylaws do not establish permeability standards.

Organization of the Thesis

A central organizing theme of this thesis is the idea that the apparatus of modern sanitation—both centralized sewer networks and decentralized on-site facilities—is a complex system that emerges from a variety of technical, institutional, social, and environmental factors. The evolving interaction of these four factors has contributed to the development of modern urban and suburban landscapes. The situation in Massachusetts exemplifies this interaction. Regulatory institutions (Title 5) stipulate the environmental (soil) conditions under which certain technologies (septic tanks) can be used; social and political pressures to increase housing production and reduce government regulation of the private market have supported changes in the regulatory institutions.

The evolution of centralized sewer infrastructure provides a robust example of evolving technical systems. Chapter 2 describes how legal institutions, social and political priorities, and the availability of technology have shaped sewer infrastructure systems; and traces the effect of these systems on urban and suburban development.

I find that the primary goals of 19th Century sewer systems were the protection of human health and the development of urban metropolises. In the 1970s, social pressures led to Federal policies that made environmental protection (including the protection of water quality and wildlife habitat) a primary goal of sanitation infrastructure. Subsequently, many states and municipalities incorporated explicit planning and land use objectives into sanitation policies, within the constraints imposed by legal institutions concerned with private property rights.

The application of on-site wastewater systems has also been shaped by technical, social, and regulatory constraints. Chapter 3 summarizes the history of on-site systems in the suburban environment, with attention to the expansion of regulatory control over their use, which occurred primarily at the state and local level.

A historical analysis shows that on-site systems enabled widespread suburban development in the decades following World War II. The environmental, aesthetic, and financial impacts of growth prompted many communities to adopt growth management policies,[5] including large lot zoning, refusal to create sewer utilities, and strict septic regulations. The exclusionary effect (if not intent) of these policies has been cited by critics who argue that the septic regulations are being used inappropriately—that is, as land use policies rather than health and environmental safeguards. As it turns out, they also proved to be ineffective land use policies that failed to prevent rapid growth rates and commonly resulted in inefficient, land-consumptive development.

Regardless of whether or not septic regulations are intended to control growth, they may influence land use patterns. Since suitable environmental conditions do not exist uniformly across the landscape, septic standards may enable development in some locations while they impede development in other locations. I provide hypothetical examples of mechanisms by which Title 5 standards may result in

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[5] Many critics would include social and racial prejudices as implicit (or, sometimes, explicit) reasons for these policies as well.

increased development costs or lower lot yield on soils with high groundwater, shallow bedrock, or slow permeability.

Chapter 4 describes the methodology of the analytical research, summarized above; Chapter 5 presents detailed results of this research (summarized above); and Chapter 6 includes interpretation and discussion of these results.

I conclude that on-site wastewater disposal regulations do influence the location of development in unsewered areas but they cannot be implicated as a primary impediment to the development of affordable housing in Massachusetts, an honor that belongs to uniform one- and two-acre zoning that both eliminates the potential for compact, multi-use development and prevents the preservation of open space. Finally, I present considerations regarding the role of sanitation policies in promoting sustainable development.

CHAPTER 2: THE ROLE OF SEWERS IN URBAN DEVELOPMENT

Modern urban development is made possible by a variety of technical systems, such as sewer networks, that influence the form and structure of the city. These technical networks enable the efficient use of resources and the accumulation of capital while minimizing losses due to mortality, natural processes, and disaster (Tarr, 1985, 1988). Because these technical systems mediate the relationship between human development and nature (Graham, 2000) and understanding of their complex interactions is key to tracing the creation of the modern urban landscape and planning for its future.

Technical systems are not comprised solely of physical elements such as sewer mains and flush toilets. Otis Dudley Duncan and Leo Schnore (cited in Melosi, 2000) described the city as an "ecological complex" of four basic components: environment, population, technology, and social institutions. These components are reflected in the technical systems that enable urban development. Institutional aspects of technical systems include administrative entities, financial interests, bodies of technical expertise, and regulatory structures that stipulate the conditions under which specific technologies may be used. Environmental conditions such as water availability and the presence of waterways create challenges and influence the physical form of wastewater systems. Urban residents create demands for certain technologies through market choices.

Technical systems exist "within limits imposed by the available technology [and environment], the hand of their operators, and the function dictated by their users" (Melosi, 2000). Their evolution may be precipitated by developments within any one of the four components, as a result of mounting environmental problems, new technology, popular demand, or other factors.[1]

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[1] The complex interaction among these many factors is a function of path dependence. The process of urbanism is guided by choices made throughout the process by individuals and institutions. Numerous factors influence and constrain these decisions, including information, technology, fiscal constraints, and dominant political objectives. Many of the existing conditions that constrain decisions are the result of previous arrangements and systems. Today's choices will, in turn, become constraints for tomorrow's decisionmakers. A decision that favors permanence and durability may result in an infrastructure network that cannot be readily adapted to changing social or environmental conditions. This path dependence controls the interaction between the four elements of a technical system (Melosi, 2000).

The identification of priorities (some sociopolitical, some technocratic and practical) drives technology choice and system design (Melosi, 2001; Graham, 2000). For example, centralized collection systems lend themselves to bureaucratic administrative systems, while social norms and user expectations reduce the practical feasibility of certain technologies such as composting toilets.

Wastewater Systems in 19th Century Industrial Cities

The interaction between centralized technical systems and urban development is exemplified in the development of water and wastewater systems in cities such as Philadelphia, London, Chicago, and New York (Tarr, 1988; Keating, 1985; Melosi, 2000; Moehring, 1985; Rosen, 1986). These growing cities needed ample supplies of clean water for industry, fire suppression, and human consumption.

The new waterworks brought huge volumes of water into the city, which exacerbated the problem of urban drainage. In the absence of wastewater systems, sewage flowed through the streets—fomenting pestilence, hindering transportation, degrading the city’s image, reducing productivity, and repulsing the growing middle class.

In response, planners, engineers, and politicians organized to develop sanitation systems. The designs of these systems were shaped by prevailing environmental theories, forecasts of urban growth, and the desire for centralization and modernism. The sought after ideal of the 19th century city planner/theorist/politician was the completely networked and automated city. The decentralized and labor-intensive systems of the preindustrial city would be replaced by sanitary, centralized, and capital intensive systems (Tarr, 1988). This modernist approach, in combination with the definition of sanitary services as a public good (Melosi, 2001), led to the development of the centralized water carriage system. Decisions about the design and funding of these systems had demonstrable influence on economic development, settlement patterns,[2] expansion of municipal boundaries,[3] and development of bureaucratic institutions.[4]

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[2] Ann Keating (1985) describes the development of the sewer system in Chicago, which extended sewers based on local requests, and recouped costs through a system of betterments. Once systems were constructed, betterment systems provided a financial inducement (and sanitary capacity) for property owners to construct denser development on the site in order to recoup the cost of the assessment. Meanwhile, many low-income

Sanitation became a central theme in organization of the city and in early formulations of the planning profession. Drainage and wastewater were dominant concerns of the first generation of comprehensive city plans in the late 19th and early 20th centuries, and was often the *raison d'etre* of many urban improvements such as the Muddy River improvements in Boston, designed by Frederick Law Olmsted (Zaitzevzsky, 1982).

Environmental Concerns and Sewer Extensions in the 1970s

Through the first half of the 20th century, sanitation remained the province of municipal governments and local or regional agencies. In the late 1960s, however, the issue of water quality and environmental protection rose to national prominence, largely as a result of the widespread impacts of unregulated septic system construction (discussed in the following chapter.)

The 1972 amendments to the Federal Water Pollution Control Act (Clean Water Act, or CWA) provided funding for both pollution prevention planning and construction of wastewater treatment facilities. What followed was the development of policies that responded to the environmental concerns of the day (and to the available funding sources) within the constraints of existing technology and dominant institutional structures.

Section 208 of the 1972 CWA amendments outlined a joint federal/state program to conduct planning efforts intended to improve one environmental component, namely water quality (US EPA, 1974). Not surprisingly, these planning efforts identified sanitary wastewater—from both point (discharge facilities) and nonpoint (septic

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neighborhoods with low ability and willingness to pay resisted the construction of sewers and ensuing betterments. Some low-income residents of Chicago actually moved to areas beyond city limits to avoid sewer assessments.

[3] Centralized sewer systems provided significant economies of scale. As they grew, outlying communities found it advantageous to petition for inclusion in city's sewer system. This process was usually accompanied by annexation into the city, which expanded the influence of the city government and eventually brought more land under control of centralized land use controls. The centripetal force of centralized utility districts provided a countervailing force for unity against the force of fragmentation in the metropolis (Tarr, 1988).

[4] Administration of centralized systems also required greater institutional capacity. The development of centralized sewer management agencies occurred parallel to the creation of sophisticated urban bureaucracies, planning agencies, data-collection and long-range forecasting capabilities, fiscal planning efforts, and growth in the profession of urban engineering (Moehring, 1985; Rosen, 1986).

tank) sources—as a primary cause of water pollution that needed to be addressed directly. The resulting plans commonly focused on centralized solutions such as sewer systems and wastewater treatment facilities, which provided certainty, facilitated monitoring of discharges, and ensured a relatively simple path for federal funding.

Section 201 of the 1972 CWA amendments established federal subsidies for the construction of wastewater treatment facilities and sewer interceptors (Binkley et al., 1975). Over the next eight years, Congress allocated $30 billion to this program. (O'Connell as cited in Rome p111.) The ensuing expansion and improvement of sewer networks and treatment facilities had dramatic impacts on water quality nationwide, and the program is widely considered to be one of the most successful environmental programs ever. The expansion of these networks also had significant secondary impacts on urban and suburban development.

Assessing the Land Use Impacts of Sewer Policies

The secondary impacts were the subject of numerous studies in the subsequent years. Some of these studies addressed the impacts of sewers on suburban development generally,[5] while others focused on the form of the federal grant program and its influence on financing, phasing, design, and location of decisions (Binkley et al., 1975; Stansbury, 1972.)[6]

The water quality objectives established by public institutions, and the dominant technology choices of the day had a demonstrable influence on development. The problem of failing septic systems was commonly addressed through the construction of sewer interceptors that connected remote areas to centralized treatment facilities. These interceptors often traversed undeveloped land where the need for wastewater

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[5] Among the most quantitative of the general studies is Grace Milgram's study of land price variation in relation to numerous factors, including sewer availability, in Northeast Philadelphia (Milgram, 1967). This research measured the cost of vacant land over an 18 year period and found that the price of land with access to public sewer was commonly two to four times higher than unsewered land. This difference might be attributable to two factors: 1) sewers led to increased market values through higher potential density and economic "rent;" or 2) authorities provided sewers to the most valuable and attractive areas where development pressure was greatest.

[6] At the same time, Bascom, et al (1975) published a review and bibliography of research on the secondary impacts of transportation and wastewater investments. This report identifies 15 studies concerned with the economic, social, political, legal, or land use impacts of wastewater projects.

disposal was a significant constraint on new construction. Thus the technical solution to the failing systems (connection to a centralized system) created development alternatives that would not exist if public agencies had chosen an alternative technology (such as a local wastewater facility to serve only the failing systems.)[7]

Even where sewer interceptors are present, technical constraints such as limited pipe capacity may limit overall development potential. However, Binkley et al. (1975) find that many of the federally-funded wastewater projects intended to remedy environmental problems were commonly designed and built with significant excess capacity that provided infrastructure capacity for growth where it may or may not have been desired based on other planning criteria. Excess capacity was a result of engineering assumptions about per capita use and elevated population projections that did not reflect local growth plans.[8]

Planning objectives rarely figured in wastewater planning due to poor coordination occurred between the sewer design process and broader land use planning efforts, despite the fact that this coordination was stipulated by the grant regulations. There was also limited public awareness of the potential growth impacts or distribution of costs association with sewer projects, and thus limited local demand for consideration of these impacts (Binkley et al., 1975).

Nor was consideration of land use impacts a priority of state or federal institutions. The recently-formed U.S. Environmental Protection Agency (EPA) was hesitant to require consideration of land use impacts or evaluation of alternative technologies.

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[7] The influence of new sewer construction is dependent in part on other limitations that may constrain development, such as restrictive zoning or limited access, which may prevent high-density development (Millgram, 1967). Yet under most conditions, new sewer construction alters site conditions to allow development at the maximum density allowed by zoning. Rapid subdivision construction occurs as developers seek to capitalize on the new conditions before land prices rise to reflect the greater development potential on the site (Stansbury, 1972.) Here is a potential analogue to changing septic regulations—if septic constraints are reflected in lower unit land prices, will there be a rush to develop on previously unbuildable, and therefore inexpensive sites with slowly permeable soil before prices adjust to reflect the new development potential?

[8] These growth projections were in some respects self-fulfilling as the availability of infrastructure enabled rapid development and funding mechanisms provided fiscal incentives for communities to approve new growth. Federal grants paid for 75% of the cost of construction; the remainder was often (though not always) covered by connection fees. The need to recoup local costs encouraged communities to approve proposed development projects and to grant density variances based on the capacity of the new sewer; as a result, the inflated population and development projections of sewer design tended to be self-fulfilling.

Institutional and statutory constraints led to a narrow focus on mitigation of narrowly defined "environmental" impacts such as erosion and, in some cases, air quality (which might be affected by increased development.) The EPA stated that mitigation for land use impacts "must be provided locally" (quoted in Binkley, et al., 1975), effectively divorcing the policies intended to improve water quality from those intended to promote desirable settlement patterns.

Other public interests impacted by sewer infrastructure construction may include the expansion of housing opportunities or the equitable distribution of development costs. Where sewers are subsidized by the federal government or local communities (through general bond issues), and not recouped through betterments or connection fees, new development pays only a fraction of the cost of the infrastructure that exists to support it. In some cases this may be appropriate, such as where new, dense development is desired by the community and provision of infrastructure is a recognized means of attracting investment. Similarly, reduced development costs may enable (though rarely ensure) the construction of moderately-priced housing.

Infrastructure Policies, Planning Objectives

As the influence of sanitation policies on development became more fully understood during the 1970s, planners and researchers developed sewer policies that could complement land use planning efforts. Many of these policies seek to promote compact development within sewer service areas and to discourage the extension of sewer service into areas planned for low-density development that could be served by on-site systems.

Strict delineation of the municipal service area (which may include planned expansions) in accordance with land use plans was commonly identified as a primary mechanism to discourage haphazard extensions (Downing, 1972; Biggs, 1990; Tabors, et al. 1976). Extension requests can also be discouraged through marginal cost pricing that involves higher user charges for properties in outlying areas. Binkley, et al. (1975) recommended reduction or elimination of federal subsidies for excess capacity designed to serve new development. Local communities would be free to provide additional capacity to serve future growth; economic efficiency considerations would promote the provision of this capacity in developed areas rather than in dispersed areas where the per-unit cost of infrastructure and municipal services is generally higher.

Compact development is also promoted through benefit assessments for all served properties (whether connected or not.) These assessments increase the carrying costs of undeveloped land in the service area and promote development, reducing demand for land in outlying areas. Meanwhile, lot-area based connection fees promote smaller lots and more compact development (Downing, 1972).

Subsequently, many municipalities sought to manage metropolitan development more effectively by providing closer coordination between land use planning and sanitation policies. The emphasis of these efforts has been on the delineation of urban service boundaries; less attention has been given to alternative financing structures[9].

In Minneapolis –St. Paul, Minnesota, the Metropolitan Council has authority over the provision of regional sewer and transit systems, and is responsible for creation of a regional plan, which is intended to coordinate land use objectives and infrastructure development (Mandelker and Cunningham, 1979).[10] Similar policies have been enacted in Sacramento, California, where the Sacramento Regional County Sanitation District can extend interceptors only to areas that have been formally designated by the City and County of Sacramento as designated growth areas (McCarthy, 2002).[11]

Other water and sanitation agencies, such as the Massachusetts Water Resources Authority in the Boston Metropolitan Area, require consideration of land use impacts through an environmental review process, though statutory limitations may prevent them from denying projects based on planning criteria (as opposed to “environmental” criteria such as endangered species impacts.)

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[9] Many communities have initiated the use of Development Impact Fees assessed to developments based on their estimated impact on the cost of municipal services, including water, sewer, roads, schools, and public safety.

[10] The Metropolitan Council does not have the authority to control or approve local land use plans. This often results in situations where local zoning does not permit densities as high as those envisioned by the regional plan and enabled by the capacity of sewer infrastructure. The Met Council also has no authority to manage development in areas scheduled for, but not yet served by, regional sewers. Where development pressures are strong, residential subdivisions may be constructed using septic systems, commonly at densities lower than proposed in the regional plan.

[11] This restriction extends even to the construction within the existing service area of oversized pipes designed to provide capacity sufficient for future expansion of the system.

Sanitation Policies are Constrained by Legal Institutions

Because planning-oriented infrastructure policies have tremendous potential to limit development opportunities, they have been repeatedly challenged as an infringement of private property rights. Property owners affected by the enactment of urban service area boundaries have claimed denial of equal protection, denial of due process, and takings without compensation. In these cases, courts scrutinize the nature of the expectation to receive service, the rationale for the refusal to serve, and the source and extent of the discretion exercised by the utility (Biggs, 1990; Herman, 1992; Ramsay, 1974; Stone, 1982).

The so-called "Public Utility Doctrine" requires a utility to provide connections for all those properties where it has "held itself out" as the provider of water or sanitation service (64 Am. Jur. 2d). This obligation is not created solely through formal declarations; utility actions that create an *expectation* of service constitute an informal contract that has been recognized by the courts.

Informal contracts notwithstanding, demonstrated "utility-related" (technical) reasons, such as capacity constraints, are generally accepted by courts as valid justifications for refusals to provide water or sewer service (Herman, 1992; Swanson v. Marin Co. 56 Cal. App. 3d). While courts generally grant municipal utilities significant discretion in delineation of the service area, technical rationale for refusals to serve may be invalidated as a denial of due process or equal protection where capacity is available or where communities permit "utility related" constraints to persist indefinitely without valid justification. The development of explicit planning or municipal rationale for service area boundaries can defuse both due process and equal protection claims.

Due process challenges may be sustained where there is not demonstrated nexus between infrastructure policies and valid public purposes. Public planning efforts can demonstrate that water and sanitation policies are rationally related to the exercise of a municipality's police power. As with zoning, these policies can be sustained if they further a community's goal to develop in an orderly and compact way.

Similarly, unequal protection claims can be defeated if a planning process has defined how one class of property owners (to be served) differs from another class (to be refused service) based on community-based planning criteria. It is also important to note that the implementing agency must be vested with the statutory authority to carry out land use planning policies.[12]

Takings challenges that arise from refusals of service are rarely sustained by courts since the absolute right to municipal water or sewer service is not a legally recognized property interest. Consequently, most refusals to serve do nothing to diminish the value of what aggrieved parties owned prior to the enactment of the disputed policy: unimproved land with no access to sewer infrastructure or a public water supply. A notable exception exists where local land use regulations require public sewer service prior to development, but public utility policies refuse service on non-technical grounds.[13]

There have been significant instances where courts have validated use of sewer policies as tools for implementation of planning goals.[14]

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[12] In Reid Development Corp. v. Parsippany Troy Hills Township (10 NJ 89a 2d, 1952), a court invalidated the Township's refusal to provide service to a development that did not meet the minimum lot sizes established by the public utility. Because the town had not adopted the New Jersey Planning Act, it was vested by the state with the authority to exercise planning and zoning powers.

In Hidden Valley, CA, which lacked a planning authority, the court approved efforts by the water/sewer utility to develop and implement explicit planning-oriented policies (Wilson v. Hidden Valley Mun. Water District, 256 Cal. App. 2d, 1967).

[13] An example is Charles v. Diamond (392 N.Y.S. 2d), in which the court ruled that the town could not prohibit development that relied on septic systems if the extension of public sewer system was unreasonably delayed.

[14] In Dateline Builders v. City of Santa Rosa (146 Cal. App. 3d, 1983), the City of Santa Rosa refused to extend service to an unincorporated area to serve a development inconsistent with the City's General Plan. On appeal, the court ruled that the refusal to serve was legal as "a proper exercise of the police power once the planning decision had been made," thus highlighting the role of sanitation policies as *implementation* mechanisms of land use plans, not as arenas where land use decisions are made.

During the period 1966-1969 the Town of Ramapo, New York adopted a master plan, a comprehensive zoning ordinance, and a capital improvements plan covering a period of 18 years. The capital improvements plan outlined the program for the extension of sewer infrastructure (among other municipal services) throughout the town; and the 1969 zoning ordinance amendments authorized the Town Board to refuse a permit for residential development for which adequate public services had not yet been provided under the capital plan. Developers were free to provide the municipal improvements necessary, and the authority of the Board to refuse special permit applications terminated at the end of the 18-year capital planning period, at which time all areas in the town should have been provided with the services required by the ordinance. Property owners and a builders association brought a facial attack on the ordinance, which was denied by the U.S. Supreme Court, which found a rational basis for "phased growth." (409 US 1003)

Expansion of Environmental Criteria and Institutional Change

More recently, state and federal institutions have recognized sustainable land use management as a valid environmental objective, and have adopted policies to promote certain forms of development. In a significant contrast with its approach to the Section 201 grants in the 1970s, the EPA has adopted a Smart Growth Agenda that goes beyond the traditional media-based regulatory approach to recognize settlement patterns and urban design as key influences on the environmental impacts of development.

The EPA has provided guidance (U.S. EPA, 2000) for states to promote smart growth through the distribution of money from State Revolving Funds (SRF). For example, Vermont is reforming SRF policies to include land use impacts as one consideration in determining priority projects for funding. Projects within designated growth centers would receive higher rankings, while those in outlying areas would receive lower rankings or might not be funded at all.[15]

Massachusetts limits the use of SRF funds to construct excess capacity.[16] The Ohio Clean Water SRF provided funds to support interceptor construction contingent upon the adoption of a connection moratorium in sensitive riparian areas. The State of Maine has proposed a "patient payback" period for qualifying sanitation projects funded through the SRF.[17]

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[15] "Leapfrog" projects that do receive funding may come with restrictions. For example, an interceptor constructed to an outlying property may be funded so long as the town is prohibited from making additional connections between the town center and the site.

[16] Collection systems must be designed with a capacity no greater than 133% of existing flows in April 1995.

[17] The cost of sewer construction is a disincentive to infill development when on-site treatment technology enables development on less expensive land. The program proposed in Maine would provide a three-year grace period for payback of money used to construct sewers in areas where the minimum density is 3 units per acre. Presumably, the presence of sewers and relatively high permitted density would, over the course of three years, attract development that will help to pay for the infrastructure (Monahan, 2002).

Key Findings

The history of sewer systems described here illustrates four key points that are useful to considering the role of on-site disposal policies in shaping suburban development.

- The *purpose* of the sanitation systems and policies has evolved in response to social and political priorities.
- The *mechanisms* of sanitation systems, including design, financing, and phasing have changed in response to technological and institutional forces.
- The *impacts* of sanitation systems are dependent on site conditions and other public institutions (such as land use controls.)
- The *legality* of sanitation policies is constrained by institutional arrangements, constitutional protections, and informal property rights.

CHAPTER 3: THE SEPTIC HISTORY OF SUBURBAN DEVELOPMENT

The sanitation systems that support human development are not limited to centralized sewer networks. On-site wastewater disposal systems constitute a specialized (though decentralized) apparatus that shapes the form of modern suburbia, just as the development of the water carriage system influenced the development of industrial cities. As with centralized networks, on-site systems contain four components: technology, environmental conditions, institutions, and communities.

These four components have been extensively studied individually. Innumerable technical and environmental reports describe the water quality impacts of wastewater disposal, the merits of various technologies, and the evaluation of disposal sites. Other researchers have studied administrative or institutional aspects of system operations such as permitting procedures and the establishment of successful septic system maintenance programs.

However, relatively few studies address the impacts of this complex technical system on land development patterns. Among these few, it is a common refrain that on-site systems enable metropolitan development beyond the boundaries of centralized sewer systems. Yet their influence across the landscape is not homogenous. Regulatory constraints control the application of specific technologies under various site conditions. The interaction of heterogeneous environmental conditions and local regulatory institutions influence landscape-scale patterns of development.

This chapter traces the influence of on-site disposal systems in metropolitan development as a function of technical, environmental, institutional, and social factors.

On-Site Disposal Technology

On-site wastewater systems include a variety of technologies that enable the treatment and discharge of wastewater within the confines of a single property or a small group of properties.[1] The dominant technology is the septic tank system,

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[1] The category includes primitive systems such as privies and cesspools as well as composting toilets and "living machines" that rely on constructed ecosystems to treat wastewater.

which consists of an underground tank and a subsurface disposal area (commonly referred to as a leach field) where wastewater is discharged into the soil.

The septic tank is designed so that solid material in the sewage settles to the bottom of the tank before wastewater moves to the disposal area[2] where it is discharged through perforated pipes or walls and percolates into the soil. Nutrients are oxidized and pathogens are digested in the anaerobic conditions that exist in unsaturated soil (Veneman, 1982).[3] Once the wastewater enters saturated soil below the level of the water table, oxidation and digestion effectively cease, and pollutants can be rapidly transported away from the site to surface water bodies or groundwater supplies. Consequently, vertical separation from seasonal high groundwater is a key design element of septic systems.[4]

Permeability is also a critical element of adequate treatment. Sandy, rapidly permeable soils provide good aerobic environments for oxidation of nutrients, but short residence times reduce the effectiveness of purifying biological activity. Slowly permeable soils may provide long treatment times, though they can also result in sewage backups, surface ponding, or saturated conditions that reduce treatment effectiveness. The size of the disposal area is a function of design flow and soil permeability; slowly permeable soils require more disposal area per unit of wastewater.

On-Site Systems and the Growth of Suburbia

On-site wastewater systems, including septic tanks and cesspools, were common in rural development throughout the first half of 20th century. Their usage grew dramatically during the housing construction boom following the Second World War. In 1945, 4.5 million homes used on-site wastewater systems (MacKenzie, 1953). Over the next 15 years, roughly 45% of new homes were built using septic tanks, so that by 1960 approximately 14 million residences utilized on-site systems (Nelson

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[2] "Disposal area" includes leaching pits, trenches, chambers, and fields.

[3] A "biomat" of organic material commonly forms at the lower surface of the disposal area and acts as the substrate for most of the bacteria that act on the wastewater as it migrates downward.

[4] Treatment also effectively ceases when wastewater reaches bedrock, where it collects and travels in saturated conditions.

and Dueker, 1989). Septic tanks were commonly constructed in huge numbers[5] on relatively small lots.

In the intervening years, the number of on-site systems has continued to increase, though they still account for roughly 25% of American households.

Table 1: Growth of On-Site Systems in United States[6]

Year	Number of on-site systems	Percent of all households
1970	16.6 million	25%
1980	20.9 million	24%
1990	24.6 million	24%

Source: U.S. Census

While sewer systems offer economies of scale and centralized management, many developers preferred septic systems for large subdivisions where their use did not limit net density (Twichell, 1978). On-site systems are less capital intensive than a sewer system and can be built incrementally. Permitting and approval are often simpler and require less bureaucracy and public involvement than sewer extensions. Septic systems are also institutionally simple because long-term maintenance is the responsibility of individual homeowner. Their economic advantages are due in part to the fact that no mechanisms exist to recover the direct and secondary environmental costs associated with their use.

The widespread use of septic tanks was one factor among many that promoted dramatic shifts in population to low-priced land in suburban and exurban[7] areas; others factors included shifts in employment location, increased mobility, and urban decline. Nelson and Dueker (1989) report that the population of exurban areas grew from 43 million in 1965 to 59 million in 1985. This rapid development, which relied largely on septic systems, created health, environmental, and social problems that contributed to the rise of the national environmental movement and more local

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[5] Rome (2001) reports that an 8,000-home subdivision relied on septic tanks (p 88.)

[6] The U.S. census recorded the number of on-site systems until 1990. The 2000 census did not collect this data.

[7] Nelson and Dueker (1989) define exurban areas as noncontiguous residential developments within 70 miles of major cities (population >2 million) or 50 miles of smaller cities (population 50,000 to 2 million.)

growth control efforts. The technical-regulatory matrix that exists today is product of these environmental and social factors.

Environmental Problems, Social Movements, New Institutions

During the first major wave of suburban development beginning in 1945, construction of septic systems was largely unregulated. If they existed at all, regulations established design guidelines, setbacks, and minimum lot size, but rarely addressed the suitability of site conditions to the disposal of waste. Consequently, many systems were built on sites with slow permeability and high groundwater (Rome), resulting in nuisances, health problems, and water quality degradation.[8]

The environmental impacts of ineffective wastewater treatment were numerous and dispersed. Inadequately treated sewage killed amphibians and wildlife, and caused eutrophication of ponds and streams. But it was public health concerns, not environmental issues, which created salience for the issue of septic tanks beginning in the 1960s. Outbreaks of Hepatitis and other diseases were traced to septic tank pollution. Alkly benzene sulfonate, the non-biodegradable sudsing ingredient of detergents, migrated through groundwater from septic tanks to drinking water wells, where it was extracted and produced unsightly and worrisome foam in drinking water (Rome, 2001).[9] Even if salamander extinction could be ignored, the presence of contaminants in drinking water caught the attention of the American middle class.[10]

Recognizing the growing social concern with septic systems and the pressure to control their impact, the development industry made efforts to improve its practices, promoting self-regulation in opposition to command and control mechanisms. Arguments against regulation often focused on the financial impacts of public intervention and their impacts on housing opportunities for middle class. Many developers claimed regulation would slow housing production at a time when more housing was desperately needed. This framing tactic set the two social concerns

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[8] These problems were compounded by poor construction (such as compaction of the soil under the disposal area) and inadequate maintenance.

[9] Public health officials were concerned that detergent might allow bacteria and viruses to travel farther in groundwater. The popular press speculated on the potential for these suds to cause stomach cancer if ingested.

[10] Meanwhile planners argued against the inefficiency of subdivisions served by on-site systems doomed to fail. They promoted the provision of public services to protect health/environment and promote rational development.

(environment and housing) as being in opposition to one another. Opponents of regulation also stated that on-site disposal standards would infringe on personal property rights. The US Public Health Service noted a "widespread misconception that the owner of a farm has a certain inalienable right granted to him by the Constitution of the United States to become a subdivider…" (quoted in Rome, 2001) even if this resulted in environmental and health impacts.

As described in the previous chapter, Federal institutions were primarily concerned with establishing water quality standards and funding sewage collection and centralized treatment projects. The direct regulation of on-site systems was the responsibility of states.[11] Section 208 of the 1972 CWA amendments required states to develop plans for the management of nonpoint source pollution (US EPA, 1974). Federal resources helped states to develop a better understanding of the technical and environmental aspects of wastewater disposal, in order to meet new water quality standards.

As a result, many states developed more stringent regulations controlling septic system construction, Massachusetts among them. The Commonwealth had regulated the construction of septic tanks through the 1962 and 1966 State Sanitary Code. In 1975, Title 5 of the State Environmental Code transferred responsibility for this regulation to the Department of Environmental Quality Engineering,[12] which enacted stricter septic regulations in 1977. Title 5 regulations were revised and expanded in 1995. A historical summary of Massachusetts wastewater disposal regulations is included as Appendix A.

The development of state regulatory institutions was justified by a compelling state interest in preventing water pollution impacts that often necessitated public expenditures, often in the form of sewer extensions. On-site disposal regulations were designed to achieve efficient distribution of scarce resources, and to reduce subsidies to development in exurban areas (Goehring and Carr, 1980). The adoption of detailed state standards for on-site wastewater disposal represented acceptance of

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[11] The Federal government did attempt to curb reliance on septic systems through the allocation of funds. In 1965, the Federal Housing Administration prohibited federal aid to large subdivisions that relied on septic tanks. This policy included one significant loophole: aid was available for those subdivisions where the extension of public sewers or construction of neighborhood sewer systems was deemed "infeasible."

[12] The DEQE was subsequently renamed the Department of Environmental Protection.

on-site disposal as a permanent solution for the management of suburban wastewater, rather than an interim solution until construction of sewers.

Local Growth, Local Controls

Local responses to suburbanization were not limited to the protection of water quality. To many observers, the growth of suburbia seemed a juggernaut destined to homogenize the American landscape. The water quality impacts of septic tanks were only one aspect of the problem. Other environmental impacts were the loss of open space and farmland, destruction of wetlands and wildlife habitat, increased energy usage, and degraded air quality.

Social and institutional impacts included the visual chaos of strip development and the impacts of rapid growth on town character and municipal finances. Only some of these impacts were addressed by the strictly "environmental" state and federal laws and regulations concerned with air quality, water quality, wetlands, and endangered species. Jurisdictional distinctions, emphasis on home rule, and geographically limited impacts of local settlement patterns prevented federal or state institutions from the direct management of land use. Even a wave of state land use planning efforts in the 1970s relied on local implementation of land use controls. (Rome)

Many towns took a simple approach to the dual problems of looming suburbanization and degraded water quality: they enacted zoning that permitted only single family homes on large lots, while rejecting proposals to construct sewers (Twichell, 1978; Rome, 2001). The enforcement of septic regulations was relatively unsophisticated, and many towns relied on large lot size standards instead of rigorous site evaluations. The intent of this approach was to minimize water quality impacts by limiting the overall density of on-site systems.[13]

Twichell (1978) suggests that the refusal to develop municipal sewer systems did not achieve the growth management objectives desired by many towns. Many Massachusetts towns that relied on on-site systems experienced growth rates of

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[13] Low-density development also impeded the economically efficient development of centralized systems in the event of widespread failure. Some communities were eager to prevent sewer construction even for remediation of failing systems, based on the concern that once the pipe had been laid, it would enable high-density development and spiraling utility costs due to compulsory service area expansion needed to remedy water quality problems. This has changed with the greater emphasis on decentralized alternatives in state wastewater planning guidance (Arenovski and Shephard, 1995).

50% or more during the period 1960-1970.[14] The regulatory measures adopted by these towns had mixed results regarding actual growth rates, though they did produce a many secondary social and land use impacts. Lack of sewer effectively prevents the widespread construction of apartments and dense single-family housing; large lot requirements in sanitary or zoning codes raise the cost of house lots and housing, resulting in exclusionary impacts. Large lot requirements also cause higher rates of land consumption per housing unit. Lack of sewers may also inhibit the development of industry that can strengthen the municipal tax base (Perkins, 2003).

Technology Advancements and Regulatory Evolution

The primary intent of state and local septic regulations is to limit the construction of septic systems to sites where soil conditions allow adequate treatment of wastewater. In the absence of feasible alternative waste disposal options, these regulations may effectively prevent (or reduce) development on unsuitable sites. Alternative technology may be available, but not financially feasible or commensurate with user expectations. Social, technical, and regulatory components of the on-site wastewater disposal system stipulate certain site conditions; the application of this technical system to support suburban development thus depends on the distribution of environmental conditions. The presence of suitable soil conditions may act as an organizing principle in suburban areas in a manner analogous to the location of sewer networks in urban areas.

The situation is not static. The social, regulatory, and technical components of sanitary systems evolve over time; consequently, the resulting influence of certain environmental conditions on development also varies. Growing social awareness of health or environmental problems may instigate expansion of regulatory controls that further restrict the use of on-site systems to in certain areas. Meanwhile, institutional acceptance of improved treatment technologies may allow development

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[14] During the period 1960-1970, 37 Massachusetts communities experienced population growth of more than 50%. In 33 of these towns, the proportion of households that relied on sewer systems was less than 35%. Meanwhile larger cities and towns with extensive sewer networks experienced lower relative rates of growth. Twichell concludes that the presence of sewers is not a strong growth incentive. This conclusion is tenuous; many cities experiencing "low" rates of growth actually added more units and residents than small towns experiencing "high" rates of growth.

to occur where environmental conditions prevent the use of conventional systems (Nelson and Dueker, 1990; Jacobs and Hanson, 1989). In Massachusetts, the social and political concern with housing production has been a leading factor in the decision to relax the permeability requirements for disposal areas (Governor's Commission, 2002; Flint, 2002).

Some researchers have recently explored the tension between social and political demands, regulatory institutions, and advancing technology, with attention to its influence on land development patterns. Jacobs and Hanson (1989; and Hanson and Jacobs, 1989) describe the impact of alternative on-site wastewater systems on land use development patterns in Wisconsin.[15] Their survey of rural residents finds that personal preference for rural settings creates the market demand for residential development in areas beyond the reach of sewer systems. Type of waste disposal was not a major factor in locational choices, though they do find that primary home owners avoided the use of holding tanks, which entail the higher operating costs of frequent pumping. This suggests that the cost of waste disposal, especially maintenance costs, may be a factor in locational or technology decisions.[16] A field survey of 240 sites found that development patterns did not vary greatly by the type of sewage system.[17] Jacobs and Hanson conclude that on-site systems in general

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[15] In 1980, Wisconsin initiated a program to test the use of mounded systems in rural areas. These systems would allow the use of on-site systems in areas of high groundwater and other limiting conditions. The environmental impact statement prepared before the initiation of the program suggested that the marginal impact of the program would be insignificant, based on the view that areas limited by high groundwater could already be developed through the use of holding tanks. Opponents of the program suggested that the mound system would permit development on a greater range of rural sites, especially critical land resources such as wetland buffers and agricultural land; and would promote greater outmigration of people from the states urban areas, leaving excess capacity of urban infrastructure and creating greater demands on public services in rural areas. Supporters suggested that alternative on-site systems would 1) allow more compact land development; 2) reduce pressure on prime farmland by allowing the conversion of marginal land; and 3) obviate the need for centralized infrastructure investment in rural areas. It is also conceivable that increasing the supply of developable rural land would lower housing prices and promote affordability.

[16] The observation that primary residences are less likely to rely on expensive holding tanks suggests that the cost of wastewater alternatives may have some influence on development decisions and locational choice, through consumer preference for lower cost options. Greater attention needs to be given to this influence as regulations are modified to accommodate new technologies and to complement the next generation of land use controls.

[17] Most systems were used on scattered, dispersed homesites. Roughly one third of all sites were used in clustered developments of five or more dwelling units. Only 6% of all systems were found in infill development (contiguous to or within 1/4 mile of an urbanized area.) The proportion of mounded systems in infill development was even smaller than that of

facilitate dispersed development on rural land, and that alternative technologies have a small marginal impact on settlement patterns when compared to the impact of conventional systems.

Massachusetts Septic Regulations and Development: Mechanisms of Influence

My research was precipitated by the debate over a proposed change in the Massachusetts regulations controlling the use of on-site systems. Both opponents and proponents of the change assert that current state and local regulations have a significant impact on development patterns, including location and density of housing. Presumably, the pending regulatory change will facilitate development on a wider variety of sites. An accurate understanding of the potential impacts of this change requires an understanding of how current regulations influence development. That is, how do technical and regulatory requirements affect development under various environmental conditions?

It is clear that septic regulations prohibit all on-site systems in certain areas, such as wetlands, floodplains, and areas served by public sewer systems. In marginally suitable areas, however, regulatory requirements may raise the cost of construction or the reduce the lot yield of a subdivision development.

I will present a series of hypothetical examples that demonstrate how regulatory elements have differential effects on development based on site conditions. I have not attempted to quantify the costs or cost differentials associated with these examples. My hypothesis requires only an understanding of the *relative* costs of waste disposal under certain conditions, not the absolute cost. My assumption is that, all other development factors being equal, development is more likely to occur on sites where wastewater disposal costs are lower and potential yields are higher.[18]

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conventional systems, suggesting that the role of mounded systems as an enabler of compact development on marginal sites was not significant. The most important application of mound technology may be on sites with poor soil conditions where conventional systems are prohibited by law and holding tanks are avoided for their long-term maintenance costs.

[18] Examples given here are based on a hypothetical four-bedroom house, a size not uncommon in suburban Boston. The design standards in Title 5 establish 110 gallons per bedroom per day as the design flow for disposal systems. For the calculation of effective infiltration area, I am assuming the use of infiltration trenches one foot deep and three feet wide, spaced nine feet apart, allowing the space in between to be used as a reserve area in

Slowly Permeable Soils May Affect Development Cost or Reduce Yield

One of the most basic standards in Title 5 is the relationship between permeability and size of the disposal area. Slowly permeable soils require larger disposal areas. Assuming favorable site conditions,[19] a four-bedroom house would require a disposal area of 1200-1400 square feet.[20] On more slowly permeable soils,[21] the same house would require a disposal area of 2380 square feet.[22] If a garbage grinder is proposed, Title 5 requires an increase of 50% in the infiltration area.[23] This would require a disposal area of 4,000 square feet.[24] Under the new standards, disposal areas are permitted on soils with percolation rates as slow as 60 minutes per inch, where a four bedroom house with garbage grinder would require an 8,000 square foot disposal area.

If the site evaluation determines that soils on the site include impermeable layers,[25] additional measures are required to permit development. If impermeable soils are located in the upper portion of a deep soil, they can be removed and replaced with clean, permeable fill. This will add to the design and construction costs of the system. If impermeable layers are deep in the soil profile at the proposed disposal site, the developer may need to look elsewhere on the lot, perhaps at some distance from the proposed home site. If the disposal area is higher than the house, a pump will be necessary, increasing the cost of both design and operation.

If suitable sites are present but limited at the site of a subdivision, a developer may need to create fewer, larger lots in order to include an area of permeable soils in each one. This will result in a lower development yield for the subdivision overall.

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case of failure This yields 5 square feet of effective infiltration area per foot of pipe. Required infiltration area is based on the Long Term Acceptance Rates based on permeability and soil texture, established in the Title 5 regulations (310 CMR 15.242).

[19] A deep, level, well-drained sandy loam with permeability of 10 minutes per inch.

[20] Title 5 would require 733 square feet of effective infiltration area. Two 75’ trenches would require roughly 1200 square feet, while three 50’ trenches would require 1400 square feet.

[21] e.g., a silt loam with a permeability of only 30 minutes per inch.

[22] This would provide an effective infiltration area of 1333 square feet.

[23] Garbage grinders lead to increased water usage and a higher “strength” wastewater with more organic solids that can clog a system.

[24] Four 100’ trenches.

[25] Defined by Title 5 as soils with a percolation rate slower than 60 minutes per inch.

High Groundwater May Increase Construction and Operation Costs

Title 5 requires a minimum vertical separation of 4 feet between the bottom of the disposal area and the elevation of seasonal high groundwater.[26] Sites subject to high groundwater conditions may require the construction of a mounded system that creates sufficient vertical separation. Mounds are expensive to construct and must be designed with retaining walls or shallowly sloping sides to prevent breakout. Construction of a 2′ high mound may double or triple the land area dedicated to wastewater disposal.[27] If the disposal area is raised above grade but the house is not, a pump will be necessary, raising the cost of construction and operation.

Shallow Bedrock May Increase Lot Size

The presence of shallow bedrock presents similar problems with the siting of disposal areas, since they require an area with at least four feet of naturally occurring soil. Shallow bedrock is commonly found in soil complexes where it may co-occur with areas of deep, permeable soils. Areas of suitably deep soils may comprise only a small portion of the total area, and they may be too small to serve as disposal areas. Development on properties with a limited number of suitable disposal sites may require increased lot size in order to include deep soils on each lot.

Summary

The increased cost of construction associated with these alternatives, or the decreased yield associated with increased lot size will affect the cost and income calculations that comprise a development decision. As noted above, I have not attempted to assess or quantify these costs. I have attempted to demonstrate the following: other factors being equal, development on deep, permeable soils with a low water table will have a higher yield and/or lower development costs than on marginal sites that have high groundwater, shallow bedrock, or slowly permeable soils. If this were true, then residential development would occur less often on constrained sites, and these sites would tend to have larger lots.

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[26] The required separation is increased to 5 feed in rapidly permeable soils (with percolation rates faster than 2 minutes per inch.)

[27] If a 2′ high mound were required to serve our hypothetical home with slowly permeable soils and a garbage grinder, it would require 15′ level area on either side of the disposal area and 6′ wide sloping sides. Grading necessary for a 4,000 square foot disposal area would increase the total area of construction to over 8,000 square feet.

Key Findings

On-site wastewater disposal is a technical system that evolves in response to changing social, technical, and environmental conditions. The influence of this technical system on land development depends on how technical, regulatory, and social constraints influence development under different site conditions. Prior to the development of rigorous septic regulations, septic technology allowed the extensive production of high-density single-family subdivisions in demand at the time. The ensuing phase of the system involved more stringent regulation of septic systems, coupled with land use controls intended to prevent high-density subdivisions. Many communities also avoided the construction of local sewer systems because of the potential for multifamily development and compulsory expansion that might lead to spiraling municipal costs. Current regulations include standards that—theoretically and according to conventional wisdom—prevent or discourage development on certain soil conditions. Social and political concerns with the production of housing have prompted the relaxation of permeability standards in Massachusetts. The effect of this regulatory change on land use patterns will depend on a) the current influence of soil-based siting regulations and b) the extent of geographical areas affected by the proposed change (i.e., those areas where development will be permitted.)

CHAPTER 4: RESEARCH METHODOLOGY AND DATA SOURCES

The intent of this research is to quantitatively assess the influence of state and local septic regulations on the location and density of residential development in Massachusetts. The last section of the previous chapter describes the mechanisms through which septic regulations might influence development and design decisions. Two questions arise:

- Does development occur more relatively more often on deep, permeable soils with a low water table, as compared to soils with conditions unfavorable for septic system construction?
- Does development on sites with unfavorable soil conditions tend to exhibit larger lot sizes than development on sites with favorable soil conditions?

Research Program

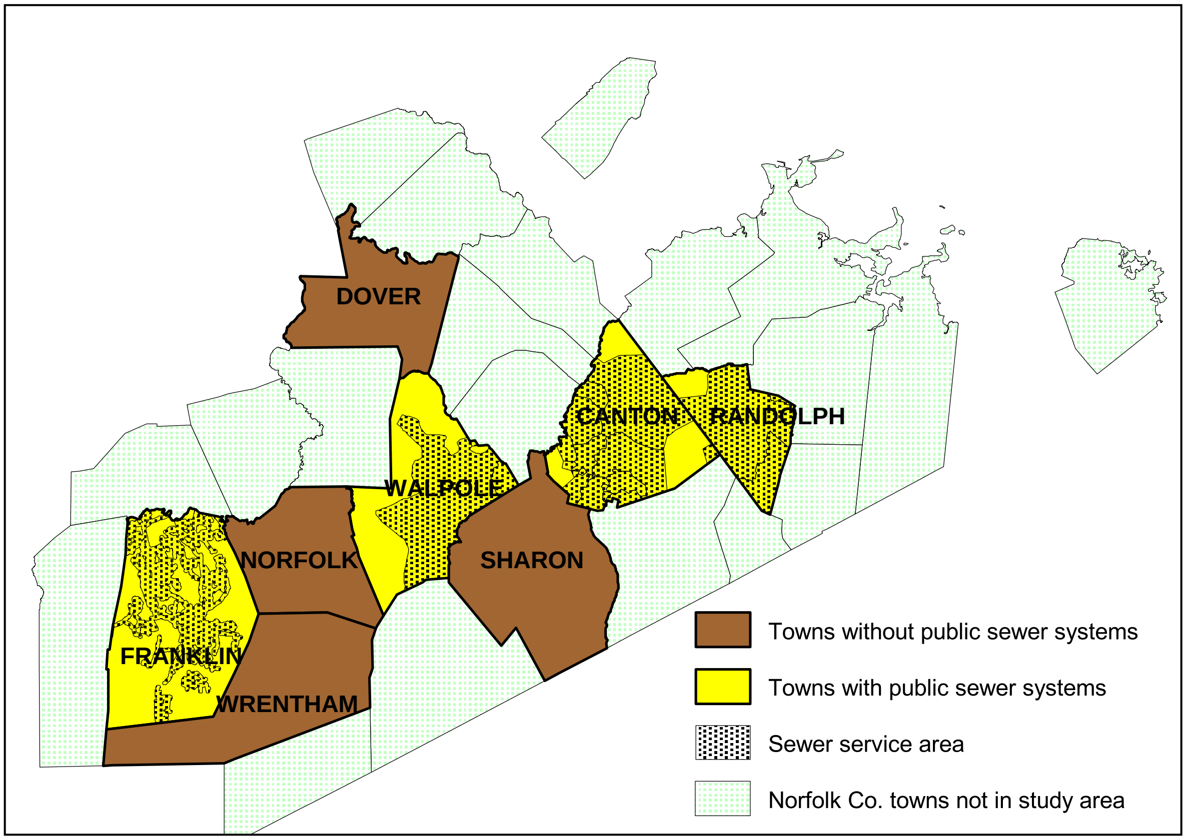
In order to test this hypothesis, I compared the distribution of soil types underlying unsewered, developed areas to the distribution of soil types in the "parent population" of available sites that existed prior to development. If soil conditions had no influence on residential development decisions, then I would expect these proportions to be roughly equal, or to vary randomly from town to town and through time. Evidence for the suspected influence might be found in systematic overrepresentation of "favorable" soils and underrepresentation of "unfavorable" soils in areas in different towns and over multiple time periods.

Soil conditions may have some influence on development decisions even in the absence of the requirements associated with septic system construction. For example, shallow bedrock may require blasting for foundation construction or road and utility installation. Consequently, I also evaluated the distribution of soils in developed areas served by centralized sewer systems.

Selection of Study Area

I conducted my analysis on eight cities and towns (all are referred to hereafter as towns) in Norfolk County, Massachusetts (Figure 1 and Table 2). The study area was chosen based on its location in Metropolitan Boston, the availability of digital soils data and interpretive tables, and reliance on different forms of wastewater disposal within the study area. Four of the towns studied rely almost exclusively on on-site

Figure 1: Study Area in Norfolk County MA; Boundaries of Sewer Service Areas



Sources: MassGIS (town boundaries); MWRA (Canton, Randolph, Walpole sewer service areas); U.S. Geological Survey (Franklin sewer service area)

Table 2: Summary Table of Town Characteristics

Name	Population, 2000	Population Growth, 1970-2000	Town Size (acres)	Residential land use, 1999 (acres)	New Residential Development 1971-1999 (acres)	households served by public sewer, 1990
Canton	20,775	21%	12,487	3,618	1,050	81%
Dover	5,558	23%	9,878	2,623	643	1%
Franklin	29,560	117%	17,269	5,548	2,987	70%
Norfolk	10,460	152%	9,853	2,816	1,700	4%
Randolph	30,963	19%	6,691	3,097	496	97%
Sharon	17,408	66%	15,626	4,311	1,707	6%
Walpole	22,824	53%	13,508	4,336	1,495	60%
Wrentham	10,554	113%	14478	3021	1601	7%

Source: U.S. Census, MassGIS, Harvard Map Library wastewater disposal; the other four towns have extensive public sewer systems. I also chose these towns because they experienced significant amounts of residential development during the study period; in most towns, at least 1,000 acres of land was converted from undeveloped land to residential uses during the period 1971-1999 (Table 1).[1]

The study periods were chosen based on the availability of historical land use data. Statewide land use maps, based on aerial photographs, were prepared in 1971, 1985, and 1999. Consequently, I have results for three development periods: pre-1971, 1971-1985, and 1985-1999.

Summary of the Analysis

The analysis was based primarily on geographic data obtained from MassGIS, a Massachusetts state agency.

I grouped soil types into seven interpretive classes based on their regulatory limitations for the construction of septic systems. This interpretive system has separate classes for soils characterized by high groundwater, slow permeability, high groundwater *and* slow permeability, and shallow bedrock. Another class includes soil types considered favorable for septic tank construction. Two additional classes include hydric soils and altered soils such as gravel pits and quarries. Additional information about these classes is provided in Table 3 (below) and in Appendix B.

I then identified land "available" for development at the beginning of each study period by excluding developed land, wetlands, waterways, floodplains, and permanently protected open space.[2] I calculated the proportion of soil classes within the available land. I also identified those areas converted from undeveloped to residential uses during a given time period[3] and calculated the relative proportion of soil classes underlying this residential land.

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[1] The exceptions are Dover and Randolph, which experienced 643 acres and 496 acres of new residential development, respectively.

[2] Wetlands and floodplains are not likely to have been significant regulatory constraints on development in the pre-1971 period, though they may have presented practical obstacles to development.. I excluded them from the analysis for this period for consistency's sake.

[3] For the pre-1971 period this is all residential development that existed in 1971.

In order to account for different soil distributions, different levels of development, and the scarcity problem that would be created by development on favorable soils, I created a Soil Development Index (SDI) that measures the extent to which soil classes are over- or under-represented in developed areas as compared to the land available for development at the beginning of the time period. This index is calculated by dividing the percentage of developed areas overlying a particular soil class by the percentage of available land containing the same soil. A value of 1.0 indicates a soil class comprises the same proportion of available and developed land. A value greater than one indicates that developed areas contain proportionately more of a particular soil type; a value of less than one indicates that developed areas have proportionately less of a particular soil type.

Soil Classes

The United States Department of Agriculture Natural Resource Conservation Service (NRCS) published the Norfolk County Soil Survey in 1989, based on aerial photos and field surveys.[4] The many map units that comprise a soil survey are distinguished based on soil structure, depth, texture, permeability, slope, stoniness, presence of organic material, depth to groundwater, and other features.

I am relying on a set of interpretive classes prepared by Jim Turrenne of the NRCS office in West Wareham MA. This system assigns each map unit to a class based on soil features pertinent to the construction of on-site wastewater systems. The original system had ten categories, with some complex soil units assigned multiple categories. I combined certain classes to create a system with seven categories, described in Table 3. The map units assigned to each class are identified in Appendix B.

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[4] This data was digitized in 1997. Digital soil coverages are based on 1:25,000 orthophoto base maps, which were scanned at 500 dots per inch, registered, and converted to vector data by NRCS.

Table 3: Soil Interpretive Classes, Soil Characteristics, and Considerations for Development

Interpretive Class	Septic Limitation	NRCS Permeability Rating	Depth to Seasonal High Groundwater	Depth to Bedrock	Soil Texture	Slope	Other Considerations for Development
1	None (Favorable)	Rapid (faster than 30 minutes per inch)	>5 feet	>5 feet	Sandy loam or loamy sand.	Level to steeply sloping (<25%)	Generally favorable for construction. May overly aquifer recharge areas.*
2	High Groundwater	Rapid (faster than 30 minutes per inch)	>5 feet	>5 feet	Sandy loam or loamy sand.	Level to gently sloping (<8%)	May be proximate to regulated wetlands. May overly aquifer recharge areas.
3	Slowly Permeable	Moderate to Very Slow (Slower than 30 minutes per inch)	18" to 5 feet	>5 feet	Loam with a restrictive layer of glacial till or silt and clay.	Level to steeply sloping (<25%)	Generally favorable for Construction.
4	Slowly Permeable/ High Groundwater	Moderate to Very Slow (Slower than 30 minutes per inch)	18" to 5 feet	>5 feet	Loam with a restrictive layer of glacial till or silt and clay.	Level to gently sloping (<8%)	May be proximate to regulated wetlands.
5	Shallow Bedrock **	Rapid to Moderate (Faster than 100 minutes per inch)	>5 feet	Varies; often <5’	Sandy loams over-lying shallow bedrock in varying thickness	Gently to very steeply sloping (<35%)	Shallow bedrock and steep slopes may impede construction of roads, foundations, & underground utilities.
6	Hydric Soils	Rapid to Very Slow	<18 inches	>5 feet	Peat, muck, silt loam	Level to very gently sloping (<8%)	Within or adjacent to protected wetlands.
7	Altered Soils	Varies	Varies	Varies	Varies: sand, gravel, bedrock	Varies	Landfills, Quarries, Gravel Pits, other excavated, filled, or industrial areas.

* Class 1 (Favorable Soils) also includes small areas of urban soils with impervious coverage of more than 75%. It is not possible to determine the predevelopment conditions of this soil, so I am assuming that urban soils are favorable for development.

** See discussion on following pages regarding heterogeneity of Class 5 (Shallow Bedrock) soils.

Soil Surveys and Scale

It is important to remember that soils conditions vary widely across the landscape, sometimes over small distances (USDA, 1995). Soil surveys and soil interpretive systems are limited by the scale of the source materials on which they are based. Soil units are mapped at a relatively small scale (1:25,000, in the case of Norfolk County.) They do not always represent transitions between different soil types accurately due to the challenges associated with identifying these features on aerial photos. There is also a problem with detail; 1:25,000 scale soil maps generally do not represent features smaller than 4-6 acres. They are mapped at the scale of a subdivision, not an individual house lot.

Individual map units may be comprised of co-dominant soil types or may contain inclusions of other soil types with different characteristics. Soil survey tables identify the proportion of a map unit that may be inclusions or other soil types. Fortunately, most map units within the study area of this research are relatively homogenous, commonly comprising 90% of the mapped area.[5]

Due to the scale of mapping and the existence of heterogeneity within soil units, it may therefore be possible to find conditions favorable for septic construction within areas mapped as septic-limited, just as there may be sites with limiting conditions within areas mapped as favorable. Soil types and interpretive classes representing a significant probability of finding certain soil conditions at a randomly selected site within a map unit, not a certainty.

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[5] The only complex with significant amounts of co-dominant soil types is comprised of Charlton Soils, Hollis Soils, and Rock outcrops in varying proportions; this complex is comprises Class 5 in my analysis. This class is characterized by significant heterogeneity; the three components are very different and are found in varying proportions throughout the study area. Charlton soils are generally deep soils with rapid permeability and depth to groundwater of greater than 5 feet. They comprise 25% to 45% of mapped areas within this complex. Hollis soils are shallow (less than two feet) sandy loams that are located on the tops and slopes of bedrock hills; they comprise 20% to 40% of this complex. Exposed bedrock is found in 10% to 50% of the mapped areas. Up to 25% of the mapped areas are covered with other soils, including sandy soils, loams, and wetland soils in low-lying depressions.

Land Use Data—Definition of Developed and Undeveloped Land

My analysis relies on land use data from MassGIS. Land use maps are based on aerial photos and classifications based on the MacConnell land classification system.[6] The first statewide land use map was created from aerial photos in 1971. Additional maps were created based on 1:40,000 scale aerial photos taken in the summer of 1985 and 1:25,000 scale photos taken in 1999.

The 21 categories of land uses are listed in Table 4. Shaded categories are considered developed land uses. Unshaded land uses are considered "available" for development based on the methodology for statewide town buildout analyses prepared by the Executive Office of Environmental Affairs.[7] Consequently, new residences built on previously developed land (infill or redevelopment) are not included in the class of "new residential development."

The buildout analysis methodology also considers Passive Recreation Land (7) and Urban Open Space (17) to be available land uses. In many cases these lands have limited protection or are undeveloped portions of public or private institutional or educational properties. Ownership and established uses are likely a more significant factor than septic disposal in limiting development on these sites (which may include cemeteries and urban public parks.) However, they constitute a relatively small portion of each town and their inclusion in the available land category is not likely to strongly influence the data.

I identified land developed during each time period by performing queries that excluded land in *any* developed category at the beginning of the period. (e.g.: (LU1985 = 10 or 11 or 12 or 13) and (LU1971 <7 or 17 or 21.))[8]

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[6] Photointerpretation and automation were conducted by the Resource Mapping Project (RMP) at University of Massachusetts, Amherst.

[7] While redevelopment or infill may be possible on previously developed sites, it is not a significant proportion of development in any of the towns studied, and is not a primary concern of this research, which is intended to assess conversion of land from undeveloped to developed use.

[8] Some residential land was reclassified from one density to another (e.g., from 1/2 acre to 1/4 acre) in 1985 or 1999. This land was not considered new residential development, as it cannot be determined whether to attribute this change to infill development or interpretation.

Table 4: MassGIS Land Use Classification System

Category	Description
1	Cropland
2	Pasture
3	Forest
4	Nonforested freshwater wetland
5	Mining; sand, gravel, and rock quarries)
6	Open land; abandoned agriculture, power lines
7	Participation recreation; golf, tennis, playground, skiing
8	Spectator recreation; stadiums, racetracks, fairgrounds
9	Water-based recreation; beaches, marinas, pools
10	Multifamily residential
11	Single family residential lots, <1/4 acre *
12	Single family residential lots, 1/4 – 1/2 acre *
13	Single family residential lots, >1/2 acre *
14	Salt Marsh
15	Commercial land; urban areas, shopping centers
16	Industrial land
17	Urban open; parks, lawns, cemeteries, vacant undeveloped land
18	Transportation; highways, freight storage, railroads, airports
19	Waste disposal; landfills, sewage lagoons
20	Water
21	Orchard, nursery, cranberry bog

Source: MassGIS. Lot sizes for residential land are based on aerial photo interpretation of average amount of developed area associated with each house, not on analysis of property boundaries.

Development Constraints

Unless explicitly noted as a “Town Total” analysis, all calculations in this research exclude lands constrained by wetlands, floodplains, or permanent open space protection, which are generally referred to as “constraints” and which are excluded from the definition of “available” land. Any development that occurred within constrained areas is not analyzed with respect to soil type.

Wetlands and Floodplains

State and local wetland and floodplain regulations are significant, though not absolute, constraints on development. Consequently, I excluded mapped wetlands and regulatory floodways from the definition of available land,[9] in order to more effectively isolate the effect of Title 5 and local septic regulations.[10] Table 5 demonstrates that very little development has occurred in these areas during the study period.

Table 5: Residential Development in Floodplains and Wetlands, 1971-1999.

TOWN	**Public Sewer?**	**Total Residential Development 1971-1999 (Acres)**	**Residential development in wetlands or floodplains, 1971-1999**	
			acres	%
Dover	No	643	14	2%
Canton	Yes	1050	53	5%
Franklin	No	2987	59	2%
Norfolk	Yes	1700	48	3%
Randolph	No	496	40	8%
Sharon	Yes	1707	61	4%
Walpole	No	1495	51	3%
Wrentham	Yes	1601	72	5%
Total		11680	398	3%

Permanently Protected Open Space

I also excluded permanently protected open space from land considered available for development in any of the three study periods. This step relied on an open space datalayer maintained by MassGIS, which identifies the current "protection status" of open space parcels.[11] Historical data on protection status is not available. The protection status of parcels may have changed over time;[12] and some parcels that lack permanent protection (such as state hospitals) may have been effectively unavailable

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[9] Wetland boundaries were obtained from MassGIS data based on interpretation of infrared aerial photos. Floodplain boundaries were also obtained from MassGIS and are digitized from maps prepared by the Federal Emergency Management Agency.

[10] Since these features systematically relate to certain soil types, the effect on the analysis is to remove significant amounts of hydric and floodplain soils from the stock of available land (as compared to the town overall.)

[11] Protection Status categories are: Permanent, Limited, Temporary, and None. Other datalayer attributes identify the owner (if available) and the name of the open space.

[12] e.g., land purchased for conservation by the town or a private land trust in 1990 may have been available for development up to that time. This classification problem will tend to exclude some potentially developable land from the class of available land, especially for earlier periods of the analysis.

for development through the entire study period.[13] Consequently, the current open space map may not be entirely accurate with respect to legal or practical protection of open space in the past. Overall, however, the amount of affected by this classification is small, and a majority of permanently protected open space is owned by the public agencies whose ownership likely extended prior to 1971.

Zoning

This analysis does not consider zoning constraints in the identification of available land. While current zoning maps are available through GIS, zoning restrictions and boundaries have changed through time. Historical zoning maps are not readily available and do not exist in digital format. Consequently, the calculation of available land includes areas that are zoned for commercial and industrial uses, a strong, though not absolute, disincentive against residential development (rezoning is always an option.) The inclusion of this land could affect the analysis if there is a systematic relationship between zoning and soil type, such that residential areas are more or less likely to be located on favorable or unfavorable soils.

I assessed the magnitude of this problem by comparing the proportion of soil types in available land to soil types in all residentially-zoned land. I found that the interpretive soil classes used in the analysis are not systematically over- or underrepresented in residentially-zoned land, with the exception of Altered Soils, which are associated with quarries and landfills, and which are underrepresented in residentially zoned areas in all towns. The results of this analysis are included in Appendix C.

Sewer Coverage

There is no central source or standard for the creation of sewer coverage databases in Massachusetts. I obtained generalized sewer coverage information for three towns (Canton, Walpole, and Randolph) from the MWRA,[14] and a digital map of the sewer collection system in Franklin.[15]

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[13] Where possible, I attempted to exclude these sites from available land on a case-by-case basis (e.g., Wrentham State School), but the effect of this classification problem is to include some (essentially) undevelopable land in the class of available land.

[14] The MWRA provided a single coverage for the portions of each town considered to be within the sewered area. In the absence of more accurate coverage or historical data about the expansion of the collection network, I assumed that *all* development within the currently sewered area was connected to the sewer service at the time of construction (and was therefore not subject to the

With the exception of Franklin, I excluded all new residential development outside of sewer service areas from the analysis, though I considered all land in town, whether sewered or not, to be available for development because of the history of sewer extensions in these towns.

The town of Franklin is only partially sewered and the unsewered portions of town experienced over 1300 acres of residential development during the period 1971-1999. Consequently, I divided the town into sewered and unsewered areas and evaluated them accordingly.[16] In this report, "unsewered areas" refers to the four unsewered towns and the portions of Franklin outside of the sewer service area.

Based on discussions with town officials in Sharon (Andrews, 2003), I also excluded from the analysis roughly 150 acres of residential development ("Sharon Woods") which was served by an extension of the Foxborough sewer system.

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restrictions of Title 5.) Thus the analysis of "sewered" development may include some residences originally or currently served by on-site septic systems. Consequently, my analysis may *under*estimate the differences between development patterns in sewered and unsewered areas, if they exist.

[15] The availability of this detailed information allowed me to more accurately identify recent development beyond the reach of the public sewer system (and therefore reliant on septic systems.) I created a buffer of 100 meters around the public sewer network and assumed that all development within this buffer was served by public sewer. Development outside of this buffer was assumed to be served by private septic systems; most of this development was separated from the buffer by some undeveloped land so it is unlikely that private, unmapped collection systems serve these sites.

[16] Available land for the sewer service area in Franklin includes all available land in town, while available land for the unsewered portion of Franklin excludes land within 100 meters of the sewer service area.

Data Analysis

I created a master table for each town by intersecting the multiple datalayers to form a coverage with attributes for each of the following:

- Soil Map unit
- Septic capability interpretive rating
- Land use (1971, 1985, 1999)
- Current zoning
- Wetlands
- Regulatory floodways
- Open space attributes
- Access to public sewer

I conducted the analysis by querying for the attributes that identified available land and land developed during certain periods. The results are presented in the following chapter.

CHAPTER 5: RESULTS

Patterns of Residential Development with Respect to Soil Type

The primary goal of this research was to assess patterns of residential development with respect to soil type in areas served by on-site wastewater disposal, and to compare these patterns to those in sewer service areas.

In order to account for the variation in soil distributions across towns and the different amounts of development in different time periods, I created a Soil Development Index (SDI.) The SDI is the ratio of the percentage of a soil type within land developed during a certain period, divided by the percentage of the soil type within land available for development at the beginning of that period. The SDI also accounts for the land scarcity problem potentially created by the conversion of favorable soils during prior periods.

Tables 6 and 7 present the results of this analysis for unsewered areas and sewer service areas, respectively. Soil Development Indices for each town, period, and soil type are graphed in Figures 2 and 3. A description of the results follows the Figures.

Table 6: Soil Distributions and Soil Development Indices in Unsewered Areas

	Pre-1971						**1971-1985**						**1985-1999**				
	All Available Land		**New Development**		**SDI**		**Available Land, 1971**		**New Development**		**SDI**		**Available Land, 1985**		**New Development**		**SDI**
Interpretive Class	**acres**	**%**	**acres**	**%**			**acres**	**%**	**acres**	**%**			**acres**	**%**	**acres**	**%**	
WRENTHAM																	
1-Favorable Soil	4678	45%	1023	72%	**1.6**		3267	39%	283	60%	**1.5**		2949	38%	606	58%	**1.5**
2-High Groundwater	328	3%	82	6%	**1.8**		201	2%	17	4%	**1.5**		184	2%	12	1%	**0.5**
3-Slow Permeability	468	4%	48	3%	**0.8**		414	5%	5	1%	**0.2**		409	5%	61	6%	**1.1**
4-GW & Permeability	418	4%	28	2%	**0.5**		390	5%	6	1%	**0.3**		383	5%	36	3%	**0.7**
5-Shallow Bedrock	3018	29%	122	9%	**0.3**		2796	34%	117	25%	**0.7**		2677	34%	267	25%	**0.7**
6-Hydric Soils	722	7%	51	4%	**0.5**		648	8%	18	4%	**0.5**		630	8%	46	4%	**0.5**
7-Altered Soils	822	8%	66	5%	**0.6**		609	7%	24	5%	**0.7**		546	7%	22	2%	**0.3**
TOTAL	10455	100%	1419	100%			8325	100%	471	100%			7777	100%	1050	100%	
SHARON																	
1-Favorable Soil	5576	60%	1811	70%	**1.2**		3516	55%	520	66%	**1.2**		2884	54%	503	70%	**1.3**
2-High Groundwater	466	5%	181	7%	**1.4**		254	4%	18	2%	**0.6**		236	4%	13	2%	**0.4**
3-Slow Permeability	760	8%	199	8%	**0.9**		508	8%	86	11%	**1.4**		386	7%	45	6%	**0.9**
4-GW & Permeability	507	5%	234	9%	**1.7**		272	4%	18	2%	**0.5**		254	5%	10	1%	**0.3**
5-Shallow Bedrock	817	9%	34	1%	**0.1**		779	12%	44	6%	**0.5**		709	13%	100	14%	**1.0**
6-Hydric Soils	859	9%	97	4%	**0.4**		729	11%	65	8%	**0.7**		663	12%	33	5%	**0.4**
7-Altered Soils	368	4%	49	2%	**0.5**		290	5%	33	4%	**0.9**		224	4%	20	3%	**0.6**
TOTAL	9353	100%	2604	100%			6348	100%	784	100%			5357	100%	723	100%	
NORFOLK																	
1-Favorable Soil	3925	56%	714	64%	**1.2**		3155	54%	585	62%	**1.1**		2556	53%	483	69%	**1.3**
2-High Groundwater	199	3%	49	4%	**1.5**		149	3%	10	1%	**0.4**		138	3%	16	2%	**0.8**
3-Slow Permeability	368	5%	44	4%	**0.8**		321	6%	88	9%	**1.7**		233	5%	15	2%	**0.5**
4-GW & Permeability	463	7%	95	8%	**1.3**		347	6%	69	7%	**1.2**		276	6%	7	1%	**0.2**
5-Shallow Bedrock	1263	18%	154	14%	**0.8**		1084	19%	156	16%	**0.9**		925	19%	147	21%	**1.1**
6-Hydric Soils	488	7%	34	3%	**0.4**		449	8%	31	3%	**0.4**		418	9%	26	4%	**0.4**
7-Altered Soils	361	5%	27	2%	**0.5**		295	5%	7	1%	**0.1**		275	6%	11	2%	**0.3**
TOTAL	7067	100%	1115	100%			5800	100%	946	100%			4820	100%	706	100%	

Table 6, Continued: Soil Distributions and Soil Development Indices in Unsewered Areas

	Pre-1971					1971-1985					1985-1999				
	All Available Land		New Development		SDI	Available Land, 1971		New Development		SDI	Available Land, 1985		New Development		SDI
Interpretive Class	**acres**	**%**	**acres**	**%**		**acres**	**%**	**acres**	**%**		**acres**	**%**	**acres**	**%**	
DOVER															
1-Favorable Soil	1983	31%	894	45%	**1.5**	1070	24%	36	13%	**0.5**	1034	25%	173	50%	**2.0**
2-High Groundwater	243	4%	105	5%	**1.4**	138	3%	3	1%	**0.3**	135	3%	10	3%	**0.9**
3-Slow Permeability	735	11%	200	10%	**0.9**	535	12%	58	20%	**1.7**	477	11%	23	7%	**0.6**
4-GW & Permeability	920	14%	282	14%	**1.0**	638	14%	33	12%	**0.8**	604	15%	35	10%	**0.7**
5-Shallow Bedrock	2062	32%	402	20%	**0.6**	1657	37%	141	49%	**1.3**	1515	36%	81	24%	**0.6**
6-Hydric Soils	456	7%	75	4%	**0.5**	380	9%	15	5%	**0.6**	366	9%	7	2%	**0.2**
7-Altered Soils	50	1%	21	1%	**1.4**	28	1%	0	0%	**0.0**	22	1%	15	4%	**8.0**
TOTAL	6450	100%	1980	100%		4446	100%	286	100%		4153	100%	343	100%	
FRANKLIN (Unsewered Area)															
1-Favorable Soil	2892	39%	319	63%	**1.6**	2540	38%	250	56%	**1.5**	2267	36%	500	55%	**1.5**
2-High Groundwater	138	2%	9	2%	**0.9**	118	2%	1	0%	**0.2**	117	2%	19	2%	**1.1**
3-Slow Permeability	910	12%	34	7%	**0.5**	874	13%	42	9%	**0.7**	832	13%	90	10%	**0.8**
4-GW & Permeability	906	12%	57	11%	**0.9**	847	13%	3	1%	**0.1**	844	13%	33	4%	**0.3**
5-Shallow Bedrock	1481	20%	73	14%	**0.7**	1399	21%	67	15%	**0.7**	1332	21%	178	20%	**0.9**
6-Hydric Soils	681	9%	12	2%	**0.3**	661	10%	9	2%	**0.2**	648	10%	39	4%	**0.4**
7-Altered Soils	489	7%	8	2%	**0.2**	311	5%	72	16%	**3.5**	225	4%	45	5%	**1.4**
TOTAL	7495	100%	510	100%		6751	100%	445	100%		6265	100%	904	100%	

Sources: MassGIS (land use data, wetlands, floodplains, permanently protected open space); NRCS (soil data); USGS (Franklin sewer network).
Interpretive Classes based on a system prepared by Jim Turenne of the NRCS West Wareham Office. See Table 3 for details. Available land excludes wetlands, floodplains, permanently protected open space. Soil Development Index (SDI) for each soil class is percentage of developed land divided by percentage of available land. See text for details. Franklin data excludes available land and residential development within 100m of existing sewer network.

Table 7: Soil Distributions and Soil Development Indices in Sewer Service Areas

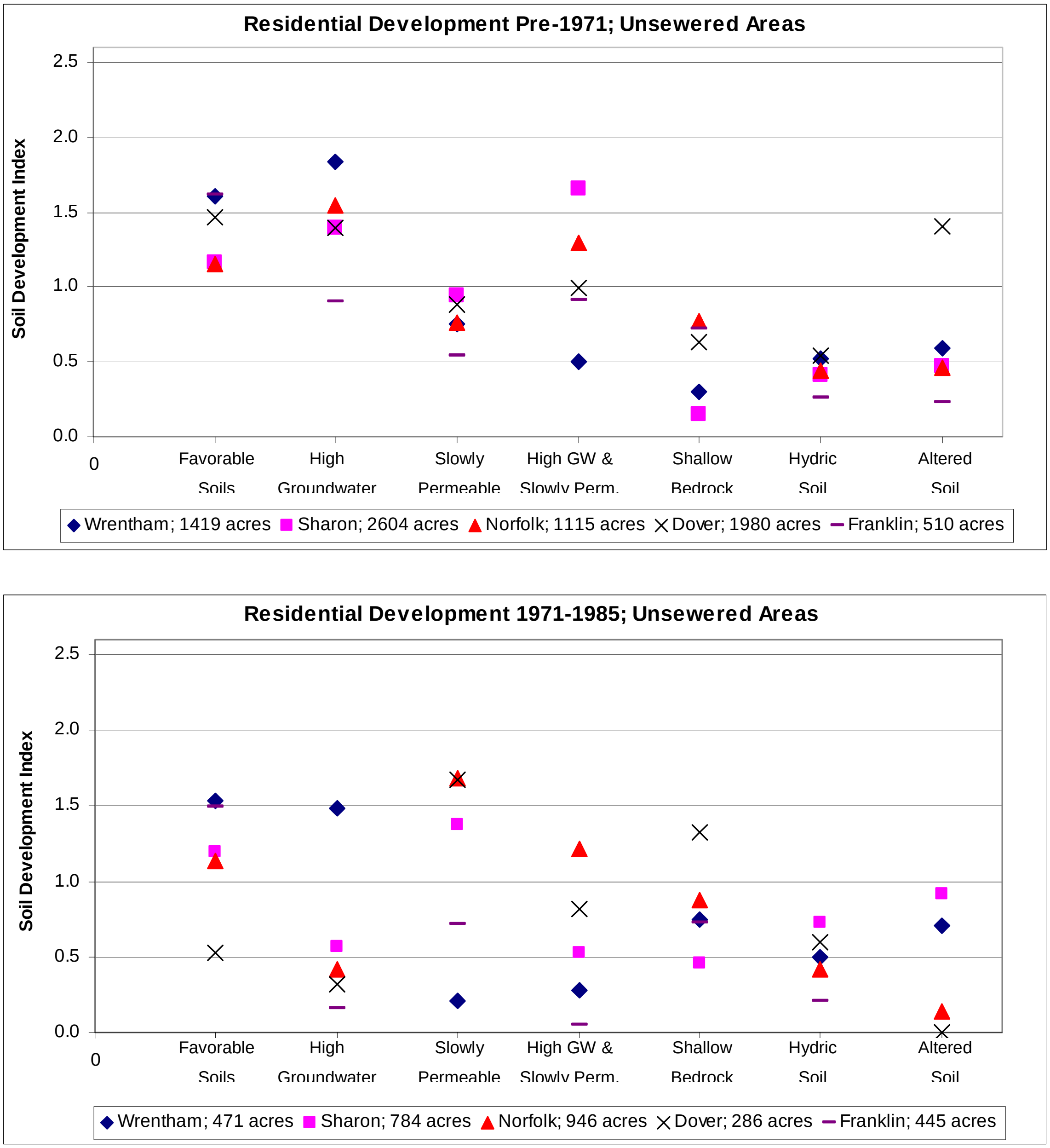
	Pre-1971					1971-1985					1985-1999				
	All Available Land		New Development		SDI	Available Land, 1971		New Development		SDI	Available Land, 1985		New Development		SDI
Interpretive Class	**acres**	**%**	**acres**	**%**		**acres**	**%**	**acres**	**%**		**acres**	**%**	**acres**	**%**	
FRANKLIN															
1-Favorable Soil	5367	39%	1312	51%	**1.3**	3885	37%	53	27%	**0.7**	3542	36%	575	42%	**1.2**
2-High Groundwater	263	2%	48	2%	**1.0**	205	2%	9	5%	**2.4**	195	2%	40	3%	**1.5**
3-Slow Permeability	2087	15%	577	23%	**1.5**	1506	14%	63	32%	**2.3**	1400	14%	271	20%	**1.4**
4-GW & Permeability	1679	12%	204	8%	**0.6**	1472	14%	21	11%	**0.8**	1448	15%	131	9%	**0.6**
5-Shallow Bedrock	2307	17%	307	12%	**0.7**	1975	19%	37	19%	**1.0**	1870	19%	233	17%	**0.9**
6-Hydric Soils	1128	8%	71	3%	**0.3**	1042	10%	5	3%	**0.3**	1021	10%	94	7%	**0.7**
7-Altered Soils	760	6%	43	2%	**0.3**	489	5%	6	3%	**0.7**	385	4%	39	3%	**0.7**
TOTAL	13592	100%	2561	100%		10574	100%	195	100%		9861	100%	1384	100%	
WALPOLE															
1-Favorable Soil	5702	59%	2139	75%	**1.3**	3287	51%	180	81%	**1.6**	2832	50%	302	57%	**1.1**
2-High Groundwater	192	2%	82	3%	**1.5**	105	2%	4	2%	**1.1**	100	2%	2	0%	**0.2**
3-Slow Permeability	916	9%	277	10%	**1.0**	632	10%	4	2%	**0.2**	528	9%	93	17%	**1.9**
4-GW & Permeability	881	9%	177	6%	**0.7**	699	11%	0	0%	**0.0**	632	11%	45	8%	**0.8**
5-Shallow Bedrock	359	4%	33	1%	**0.3**	325	5%	0	0%	**0.0**	309	5%	0	0%	**0.0**
6-Hydric Soils	930	10%	88	3%	**0.3**	832	13%	15	7%	**0.5**	794	14%	34	6%	**0.5**
7-Altered Soils	752	8%	46	2%	**0.2**	588	9%	20	9%	**1.0**	489	9%	56	10%	**1.2**
TOTAL	9731	100%	2841	100%		6469	100%	222	100%		5683	100%	532	100%	
CANTON															
1-Favorable Soil	3638	49%	1325	52%	**1.1**	1900	47%	153	63%	**1.3**	1497	44%	192	50%	**1.1**
2-High Groundwater	599	8%	285	11%	**1.4**	176	4%	8	3%	**0.8**	170	5%	27	7%	**1.4**
3-Slow Permeability	295	4%	175	7%	**1.7**	118	3%	5	2%	**0.7**	109	3%	22	6%	**1.8**
4-GW & Permeability	541	7%	267	10%	**1.4**	238	6%	6	3%	**0.4**	221	6%	53	14%	**2.1**
5-Shallow Bedrock	1043	14%	350	14%	**1.0**	660	16%	9	4%	**0.2**	589	17%	26	7%	**0.4**
6-Hydric Soils	524	7%	64	2%	**0.4**	445	11%	25	10%	**0.9**	410	12%	41	11%	**0.9**
7-Altered Soils	799	11%	102	4%	**0.4**	505	13%	36	15%	**1.2**	421	12%	22	6%	**0.5**
TOTAL	7439	100%	2568	100%		4042	100%	243	100%		3416	100%	384	100%	

Table 7, Continued: Soil Distributions and Soil Development Indices in Sewer Service Areas

	Pre-1971						1971-1985						1985-1999				
	All Available Land		New Development		SDI		Available Land, 1971		New Development		SDI		Available Land, 1985		New Development		SDI
Interpretive Class	**acres**	**%**	**acres**	**%**			**acres**	**%**	**acres**	**%**			**acres**	**%**	**acres**	**%**	
RANDOLPH																	
1-Favorable Soil	2080	45%	1274	49%	**1.1**		622	40%	111	42%	**1.0**		429	39%	92	49%	**1.3**
2-High Groundwater	883	19%	631	24%	**1.3**		202	13%	102	39%	**3.0**		88	8%	17	9%	**1.1**
3-Slow Permeability	167	4%	63	2%	**0.7**		71	5%	2	1%	**0.2**		66	6%	19	10%	**1.7**
4-GW & Permeability	122	3%	50	2%	**0.7**		62	4%	7	3%	**0.7**		55	5%	2	1%	**0.2**
5-Shallow Bedrock	624	14%	397	15%	**1.1**		190	12%	26	10%	**0.8**		163	15%	20	11%	**0.7**
6-Hydric Soils	176	4%	58	2%	**0.6**		108	7%	10	4%	**0.5**		96	9%	20	11%	**1.2**
7-Altered Soils	541	12%	129	5%	**0.4**		283	18%	4	2%	**0.1**		213	19%	18	9%	**0.5**
TOTAL	4592	100%	2600	100%			1538	100%	262	100%			1111	100%	188	100%	

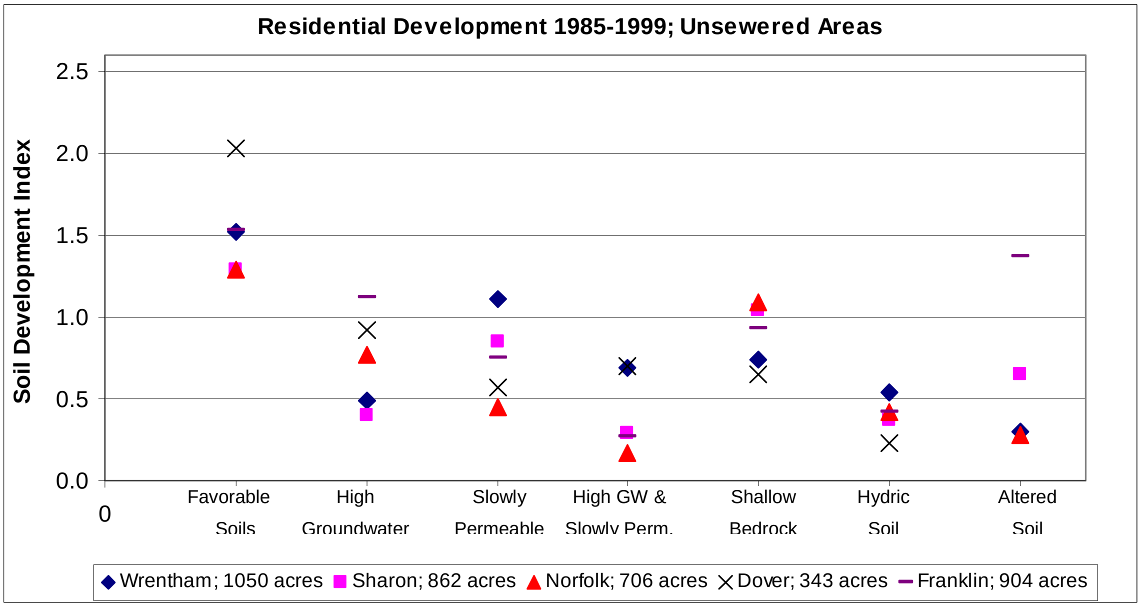
Sources: MassGIS (land use data, wetlands, floodplains, permanently protected open space); NRCS (soil data); USGS (Franklin sewer network).
Interpretive Classes based on a system prepared by Jim Turenne of the NRCS West Wareham Office. See Table 3 for details. Available land excludes wetlands, floodplains, permanently protected open space. Soil Development Index (SDI) for each soil class is percentage of developed land divided by percentage of available land. See text for details. Franklin data excludes residential development outside 100m buffer of existing sewer network.

Figure 2: Soil Development Index (SDI) values for Residential Development, Unsewered Areas



NOTES: The number of acres after each town name represents the total amount of unsewered residential development during that period. Soil Development index is calculated by dividing the percentage of soil type within developed areas, by the percentage in land available for development at the beginning of the period. See Table 3 for detailed descriptions of soil interpretive classes. Analysis excludes wetlands, floodplains, permanently protected open space, and previously developed land. Sources: MassGIS (land use and constraints) and NRCS (soil data).

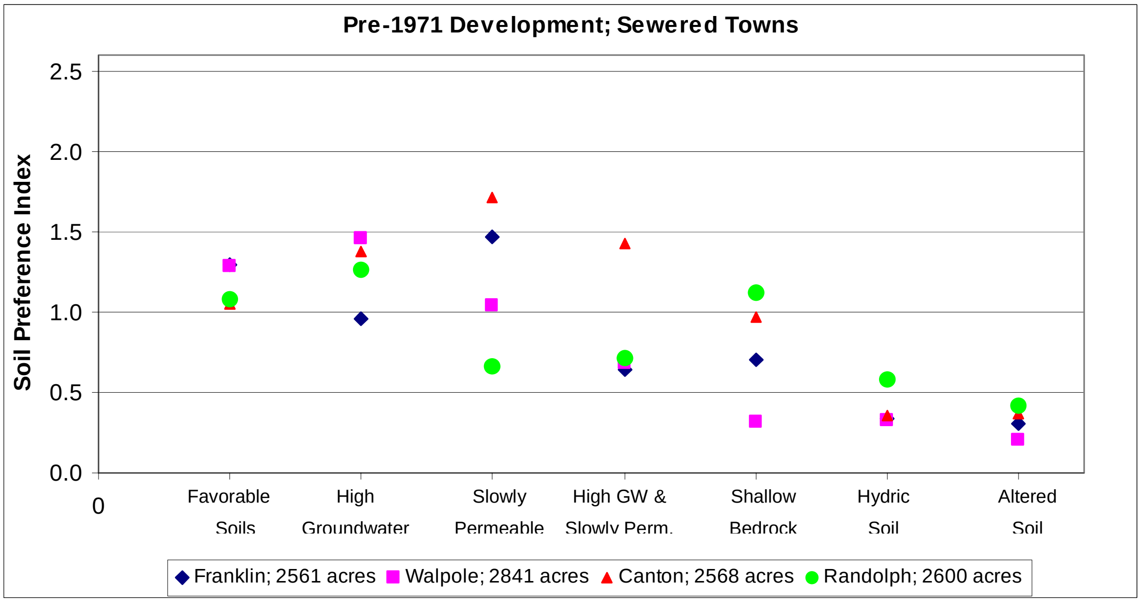
Figure 2, Continued: Soil Development Index (SDI) values for Residential Development, Unsewered Areas

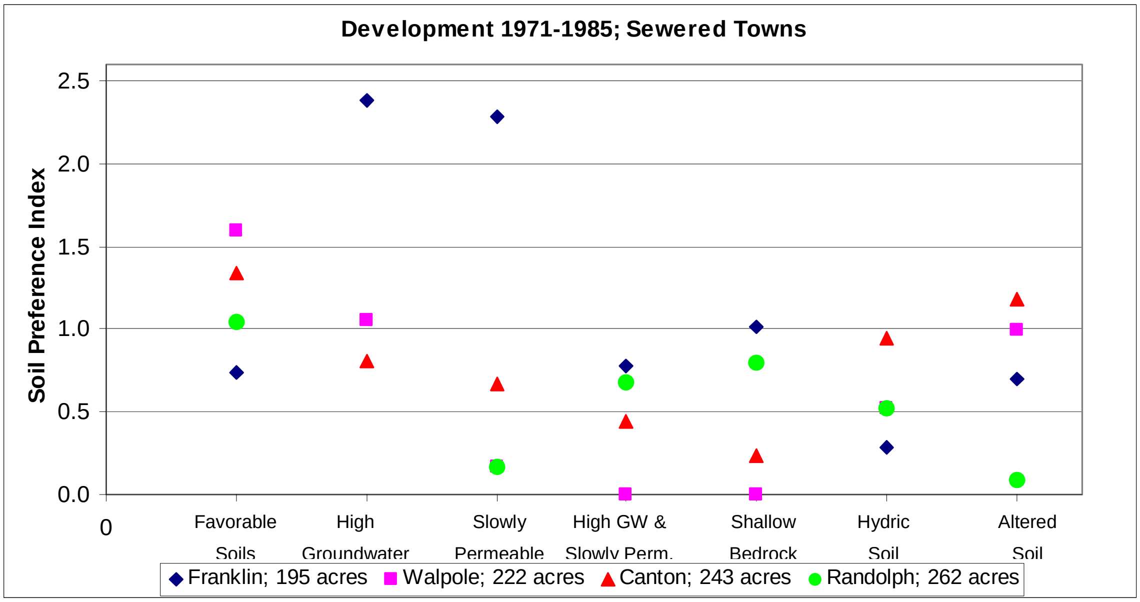


* SDI value for Altered Soils in Dover (1985-1999) = 8.0 (8% of total residential development)

NOTES: The number of acres after each town name represents the total amount of unsewered residential development during that period. Soil Development index is calculated by dividing the percentage of soil type within developed areas, by the percentage in land available for development at the beginning of the period. See Table 3 for detailed descriptions of soil interpretive classes. Analysis excludes wetlands, floodplains, permanently protected open space, and previously developed land. Sources: MassGIS (land use and constraints) and NRCS (soil data).

Figure 3: Soil Development Index (SDI) values for Residential Development, Sewer Service Areas

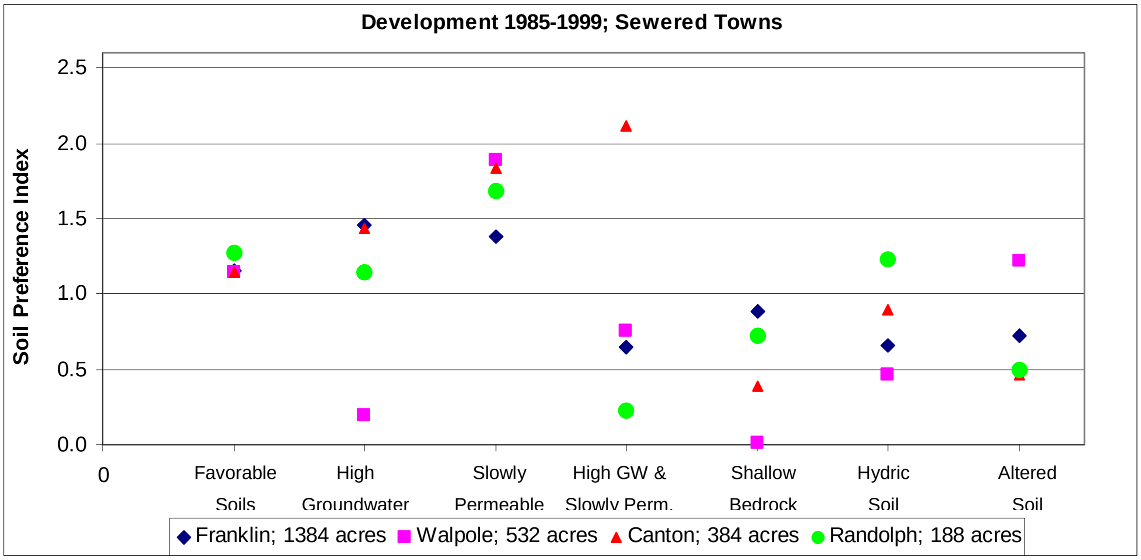




* SDI value for High Groundwater soils in Randolph (1971-1985) = 3.0 (39% of total residential dev't)

NOTES: The number of acres after each town name represents the total amount of residential development within sewer service areas during that period. Soil Development index is calculated by dividing the percentage of soil type within developed areas, by the percentage in land available for development at the beginning of the period. See Table 3 for detailed descriptions of soil interpretive classes. Analysis excludes wetlands, floodplains, permanently protected open space, and previously developed land. Sources: MassGIS (land use and constraints) and NRCS (soil data).

Figure 3, Continued: Soil Development Index (SDI) values for Residential Development, Sewer Service Areas



NOTES: The number of acres after each town name represents the total amount of residential development within sewer service areas during that period. Soil Development index is calculated by dividing the percentage of soil type within developed areas, by the percentage in land available for development at the beginning of the period. See Table 3 for detailed descriptions of soil interpretive classes. Analysis excludes wetlands, floodplains, permanently protected open space, and previously developed land. Sources: MassGIS (land use and constraints) and NRCS (soil data).

Class 1: Favorable Soils

Deep soils with rapid permeability and low water tables experience relatively high rates of development in both sewered and unsewered areas. With a few exceptions, SDI values for Class 1 soils are above 1.0 for all periods, indicating that favorable soils comprise a higher percentage of developed land than of land that was available for development at the beginning of the period.

Class 2: Soils with High Groundwater

Non-Hydric soils with seasonal high water levels less than 5 feet from the surface comprised only 3% to 5% of the original available land area in all four unsewered towns. They comprise 4% to 15% of original available land in towns served by public sewer systems.

Since 1971, high groundwater soils have experienced relatively little development that utilizes on-site wastewater disposal. The calculated SDI is below 1.0 in all the unsewered areas during the period 1971-1999 (range: 0.4-0.9), with the exception of Wrentham during the period 1971-1985 (SDI=1.5), and unsewered portions of Franklin during the period 1985-1999 (SDI=1.1.)

The patterns observed post-1971 are notably different from the earlier period, when development served by on-site systems occurred relatively often in high groundwater areas, despite the fact that these soils constituted a small portion of available land. Pre-1971 SDI values for Class 2 soils in the four unsewered towns range from 1.4 to 1.8, and the SDI value for Class 2 soils in Franklin is 0.9 during this period.

Development within sewer service areas exhibits higher and more variable SDI values for high groundwater soils. SDI values were above 1.0 in three out of four towns during each study period. Randolph shows a Class 3 SDI value of 3.0 during the period 1971-1999, when these soils constituted 13% of available land.

Class 3: Slowly Permeable Soils

Soils with moderate to slow permeability[1] comprise from 4% to 11% of the original available land in the four unsewered towns, and 4% to 15% of the original available land in towns with public sewer.

The tendency for unsewered development to locate on slowly permeable soils has varied over time, with relatively low rates of development occurring during the period 1985-1999. Pre-1971 development on Class 3 soils in the unsewered areas had SDI values between 0.5 and 1.0. During the subsequent period (1971-1985), relatively high rates of development occurred on slowly permeable soils; three towns had SDI values between 1.4 and 1.7 on these soils. Wrentham and unsewered areas of Franklin had values of 0.2 and 0.7, respectively. During the period 1985-1999, SDI values for Class 3 soils ranged from 0.4 to 1.1; four of five areas had values below 1.0.

Development within sewer service areas occurred relatively often on slowly-permeable soils during the pre-1971 period and in the period 1985-1999. During the interim period, SDI values were more variable. Franklin and Walpole, the only towns in which Class 3 soils constituted more than 5% of available land, exhibit SDI values of 2.3 and 0.2, respectively.

Class 4: Slowly Permeable Soils with High Groundwater

Class 4 soils, characterized by both slow permeability and high groundwater, are associated with relatively less development than either condition alone. These soils comprise 4% to 14% of original available land in the four unsewered towns and 3% to 12% of towns with public sewer.

SDI values for Class 4 soils in the unsewered areas are consistently below 1.0 for all unsewered areas 1971-1999, with the exception of Norfolk during the period 1971-1985 (1.2). This pattern differs markedly from development in the pre-1971 period, when SDI values were above 0.9 for the four areas in which slowly permeable soils constituted more than 5% of available land.

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[1] This class includes soils estimated to have a percolation rate slower than 30 minutes per inch, with estimated depth to seasonal high water greater than 5 feet.

Surprisingly, development within sewer service areas also occurs relatively rarely on soils with high groundwater and slowly permeable soils; SDI values for Class 4 soils within sewer service areas are generally less than 1.0. The exception is the Town of Canton, which shows SDI values above 1.4 during the pre-1971 period and between 1985 and 1999, when Class 4 soils constituted 7% and 6% of available land, respectively.

Class 5: Shallow Bedrock Areas

Shallow bedrock areas are prevalent in the study area. This class of soils comprises 9% of the original available land in Sharon and 18%-32% of the original available land in the other three unsewered towns. Shallow bedrock is also found in 14%-17% of the original available land in Canton, Randolph, and Franklin, and just 4% of the original available land in Walpole.

Overall, shallow bedrock areas experience low to moderate rates of development when compared to their availability. SDI values for all areas and time periods range from 0.0 to 1.4.

The relative frequency of septic-dependent development on shallow bedrock has increased slightly over time. SDI values for bedrock areas in were below 1.0 in five unsewered areas prior to 1971, in four unsewered areas in 1971-1985, and in three unsewered areas in 1985-1999.

Notably, SDI values for shallow bedrock soils within sewer service areas are consistently at or below 1.0 for the post 1971 periods.

Class 6: Hydric Soils

Hydric soils comprise 4% to 10% of the original available land in the study area. Development occurs relatively infrequently on these soils; SDI values are less than 1.0 for almost all towns and time periods. The highest range of SDI values for hydric soils is found in sewer service areas during the period 1985-1999; these values range from 0.4 to 1.3. Hydric soils appeared to be a constraint on development even in the pre-1971 period, suggesting that this pattern cannot be attributed solely to the regulatory influence of wetland or septic regulations.

Class 7: Altered Soils

Development occurs relatively infrequently on altered soils in unsewered towns and within sewer service areas. SDI values are generally below 1.0.[2]

The Influence of Soil Conditions on Lot Size

As discussed in previous chapters, the requirements for a permeable disposal area of suitable size may require developers to create lot sizes larger than would otherwise be required by market and zoning conditions.[3] If this were true, then a higher percentage of large lot development would overly restrictive soils, and a higher proportion of small lots would be located on favorable soils.

Figures 6 through 9 graphically represent the proportion of "small" (1/4-1/2 acre) and "large" (>1/2 acre) lots located on favorable soils, slowly permeable soils, and shallow bedrock areas, respectively.[4]

Favorable Soils

In unsewered areas, small lot residential development is more likely than large lots to be located on Class 1, Favorable soils, with the exception of Franklin. In sewer service areas, large lots occur (slightly) more often on favorable soils during the period 1971-1985, and small lots occur more often during the later period.

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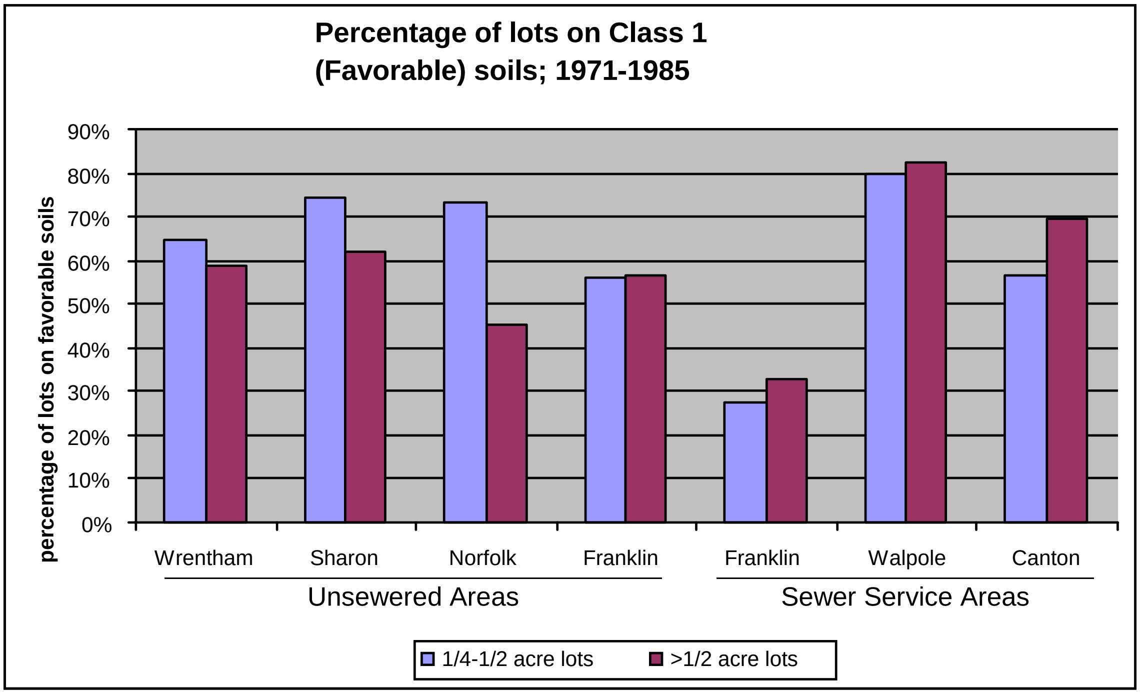
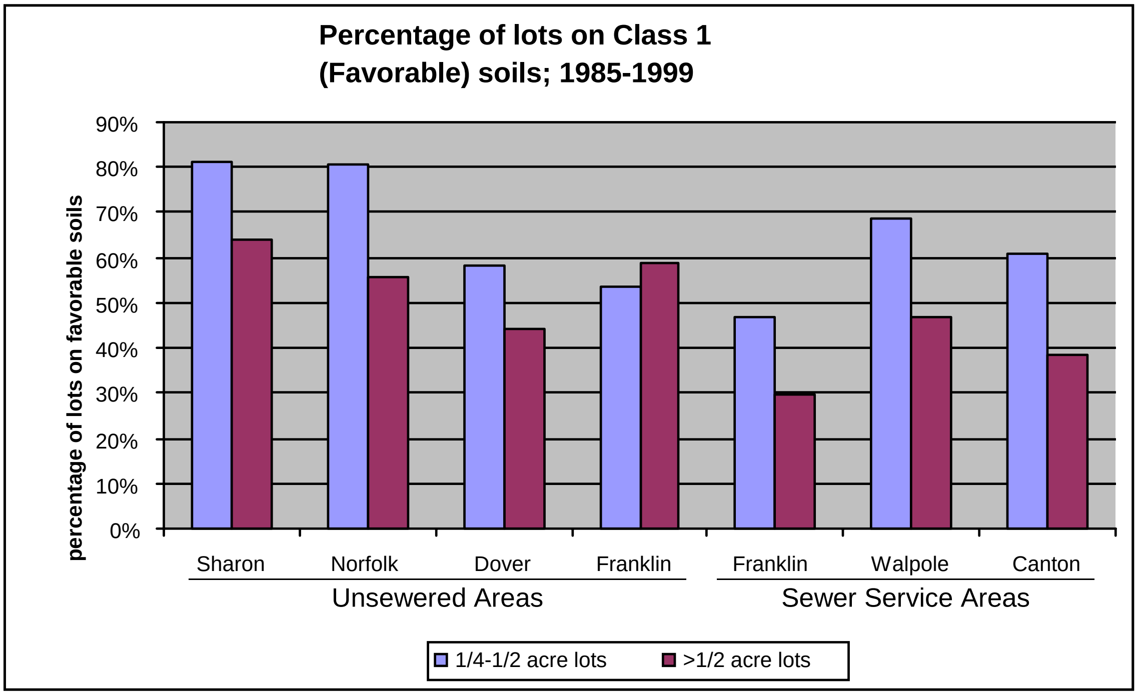
[2] The high values calculated for Dover during the pre-1971 period and between 1985-1999 are due in part to the fact that altered soils comprise just 1% of the available land in town during the three periods. Thus a small amount of development can result in high SDI values.

[3] This may be due to the need for a large disposal area or heterogeneous soil conditions that require large lots to include an area of suitable soils.

[4] Excluded from this analysis are towns where development was exclusively or predominantly one class of density. This includes Randolph, 1971-1999 (no lots >1/2 acre); Dover, 1971-1985 (no lots <1/2 acre); and Wrentham, 1985-1999 (lots <1/2 acre comprised only 6% of all development.) Consequently, I did not evaluate the relative distribution of lot sizes in these towns during the periods noted.

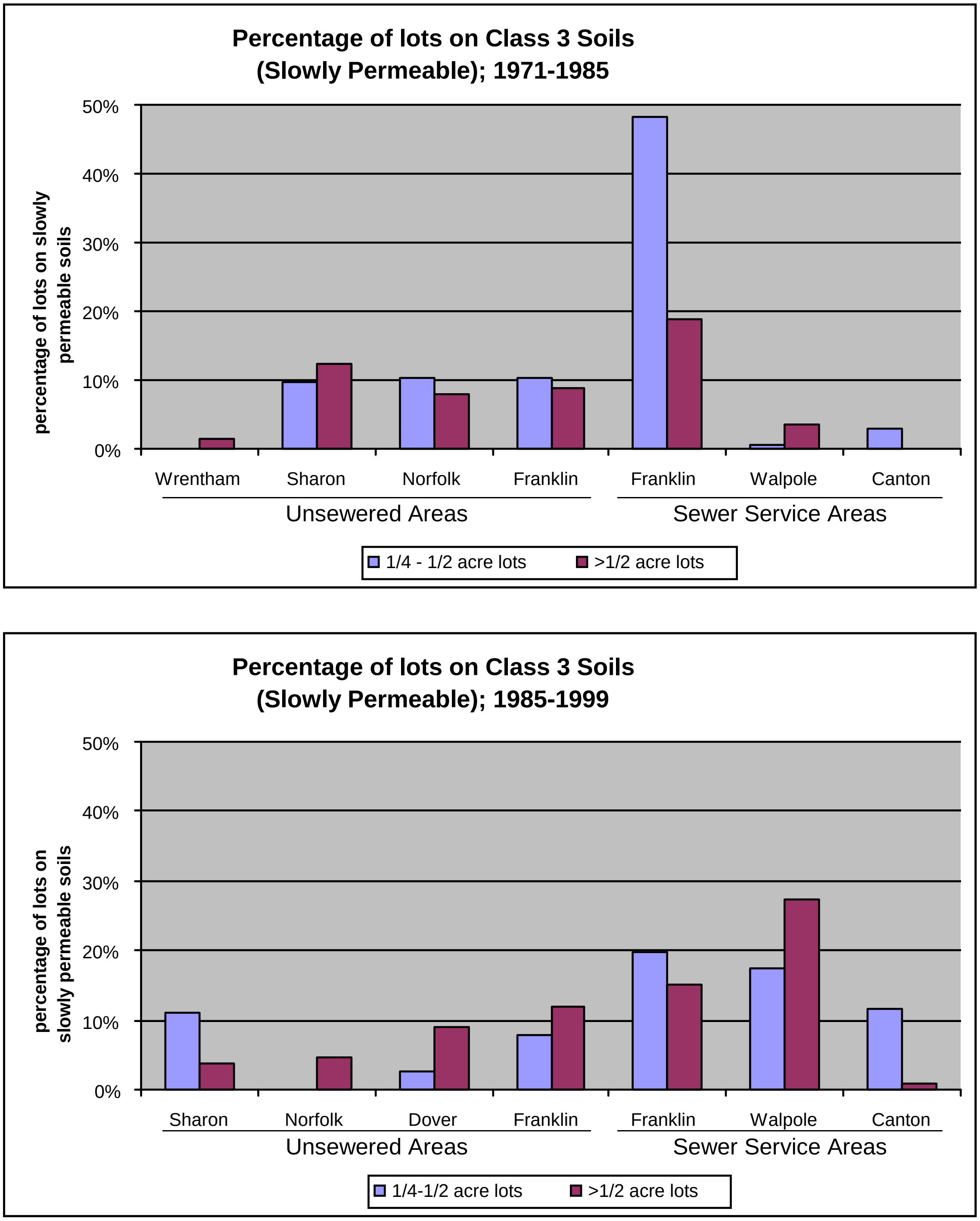
Figure 4: Lot Sizes on Class 1 (Favorable) Soils, 1971-1999





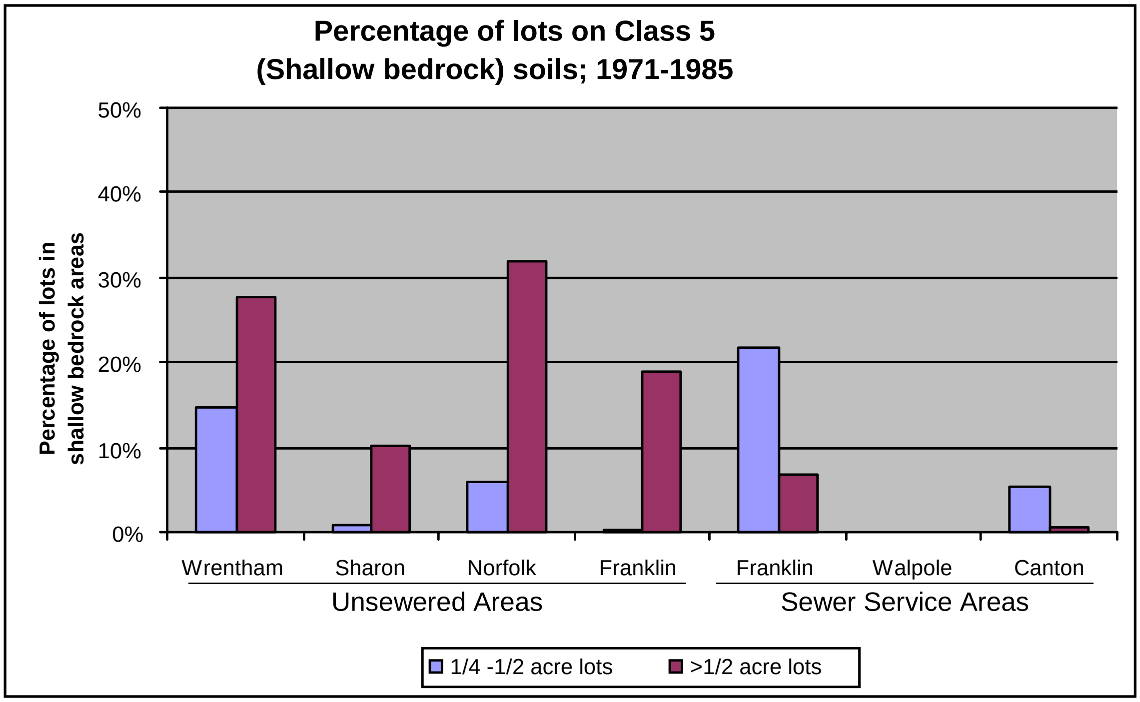
Note: Excluded from the analysis are towns where development was exclusively or predominantly one class of density. This includes Randolph, 1971-1999 (no lots >1/2 acre); Dover, 1971-1985 (no lots <1/2 acre); and Wrentham, 1985-1999 (lots <1/2 acre comprised only 6% of all development.) Lot sizes from MassGIS based on aerial photo interpretation. See Table 3 for definition of Soil Interpretive Classes.

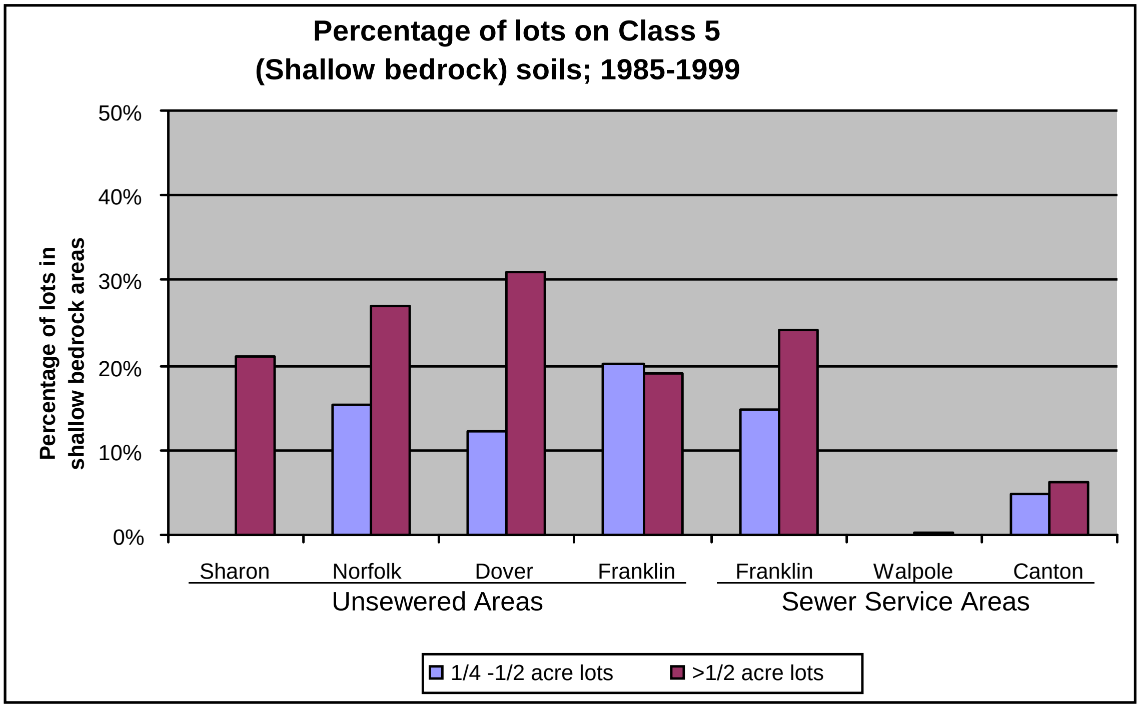
Figure 5: Lot Sizes on Class 3 (Slowly Permeable) Soils, 1971-1999



Note: Excluded from the analysis are towns where development was exclusively or predominantly one class of density. This includes Randolph, 1971-1999 (no lots >1/2 acre); Dover, 1971-1985 (no lots <1/2 acre); and Wrentham, 1985-1999 (lots <1/2 acre comprised only 6% of all development.) Lot sizes from MassGIS based on aerial photo interpretation. See Table 3 for definition of Soil Interpretive Classes.

Figure 6: Lot Sizes on Class 5 (Shallow Bedrock) Soils, 1971-1999





Note: Excluded from the analysis are towns where development was exclusively or predominantly one class of density. This includes Randolph, 1971-1999 (no lots >1/2 acre); Dover, 1971-1985 (no lots <1/2 acre); and Wrentham, 1985-1999 (lots <1/2 acre comprised only 6% of all development.) Lot sizes from MassGIS based on aerial photo interpretation. See Table 3 for definition of Soil Interpretive Classes.

Slow Permeability

During the period 1985-1999, in Dover, Norfolk, and the unsewered portions of Franklin, large lot residential development occurred more often on Class 3 (slowly permeable) soils than did small lot development. This contrasts with the development that occurred 1971-1985; during this period, large and small lots using on-site systems occurred with roughly equal frequency on slowly permeable soils.

In towns with public sewer, a higher percentage of all development is located on slowly permeable soils, though the data do not demonstrate that large or small lots are more common on these soils.

Shallow Bedrock

The presence of shallow bedrock is correlated with larger lot sizes in unsewered areas. In the four unsewered areas where a mix of lot sizes could be analyzed for each period, a greater proportion of large lots versus small lots were located in shallow bedrock areas, with the exception of Franklin during the period 1985-1999, when large and small lots were located on shallow bedrock with equal frequency.

In sewer service areas, small lot development is more common on shallow bedrock areas during the period 1971-1985; this correlation is reversed in the following period, when large lots are more common on shallow bedrock areas.

High Groundwater

The presence of Class 2 (High Groundwater) and Class 4 (High Groundwater/Slow Permeability) soils is not associated with a higher frequency of small or large lots in unsewered areas. However, I did find that larger lots occur more frequently on these soils in sewer service areas.

The Influence of Zoning on Lot Size

It is important to note that the observed association of large (>1/2 acre) lots with certain restrictive soils in unsewered areas is not necessarily a result of restrictive septic regulations that cause developers to create larger lots. The minimum lot sizes embodied within zoning regulations also have a critical impact on lot size. The distribution of soil classes within *currently available land* in various zoning districts is presented in Table 8.

Table 8: Available Land in Residential Zoning Districts: Soil Type and Minimum Lot Size

	Available land 1999 (all zoning districts)	Residentially Zoned Available Land, by Minimum Lot Size			
		>2 acres	1-2 acres	1/4-1 acre	<1/4 acre
DOVER					
TOTAL ACRES	3815	2400	669	13	0
1-Favorable	23%	18%	51%	73%	-
2-High Groundwater	3%	2%	11%	4%	-
3-Slowly Permeable	12%	17%	7%	0%	-
4-GW & Permeability	15%	19%	7%	7%	-
5-Shallow Bedrock	38%	35%	13%	0%	-
6-Hydric Soil	9%	9%	11%	16%	-
7-Altered Soil	0%	0%	1%	0%	-
NORFOLK					
TOTAL ACRES	4116	0	2359	674	0
1-Favorable	51%	-	49%	82%	-
2-High Groundwater	3%	-	3%	1%	-
3-Slowly Permeable	5%	-	3%	0%	-
4-GW & Permeability	7%	-	9%	0%	-
5-Shallow Bedrock	19%	-	22%	10%	-
6-Hydric Soil	9%	-	12%	4%	-
7-Altered Soil	6%	-	2%	3%	-
SHARON					
TOTAL ACRES	4625	1021	3171	238	6
1-Favorable	51%	39%	56%	45%	32%
2-High Groundwater	5%	3%	6%	3%	42%
3-Slowly Permeable	7%	4%	8%	15%	26%
4-GW & Permeability	5%	4%	5%	15%	0%
5-Shallow Bedrock	13%	30%	10%	0%	0%
6-Hydric Soil	14%	15%	12%	15%	0%
7-Altered Soil	4%	6%	3%	7%	0%
WRENTHAM					
TOTAL ACRES	6593	3830	1860	577	0
1-Favorable	35%	22%	55%	66%	-
2-High Groundwater	3%	4%	4%	1%	-
3-Slowly Permeable	5%	7%	2%	0%	-
4-GW & Permeability	5%	5%	6%	1%	-
5-Shallow Bedrock	36%	48%	26%	3%	-
6-Hydric Soil	9%	11%	5%	8%	-
7-Altered Soil	7%	3%	2%	22%	-

Source: MassGIS, NRCS. Zoning districts based on data from MA EOEA buildout analysis. Available land excludes wetlands, floodplains, permanently protected open space, and developed land. See text for details.

This table shows that, in towns lacking public sewer, zoning districts with small minimum lot sizes tend to include a higher percentage of soils favorable for on-site waste disposal, and large-lot districts include a higher percentage of restrictive soils.[5] Higher density districts also include significantly smaller amounts of shallow bedrock areas as compared to low-density districts. Also with the exception of Sharon, low-density districts include more slowly permeable soils (Class 3 and Class 4) than do higher density districts.

Consequently, the higher lot sizes may not be a direct result of septic regulations but rather of zoning districts that reflect the existing limitations and mandate large lots *a priori* of any site evaluation regarding feasibility of on-site disposal. It is important to note that, in the towns studied, the overwhelming majority of residentially zoned land has minimum lot sizes greater than 1 acre.

Land Consumption Rates

I evaluated land use and household data to assess patterns of land conversion in sewered and unsewered towns.

I compared the number of new households to the amount of land converted to residential uses during (roughly) the same period (Figure 9). I found that in towns lacking public sewers, development consumed a significantly greater amount of land per new household. The weighted average of the four unsewered towns is 0.88 acres per household, while in towns with public sewer the rate of land conversion is 0.37 acres per household. For each new household, towns lacking public sewer are converting land to residential uses at a rate *more than twice* that of towns with public sewer.

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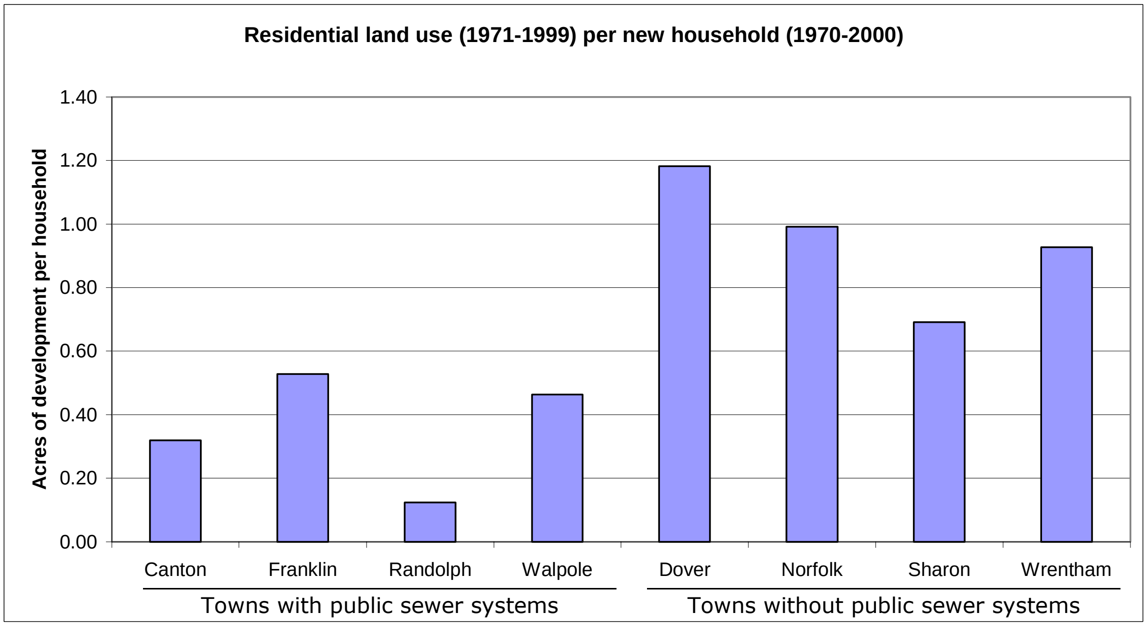
[5] This is true with the exception of the 1/4 – 1 acre district in Sharon, which constitutes just 5% of available, residentially zoned land.

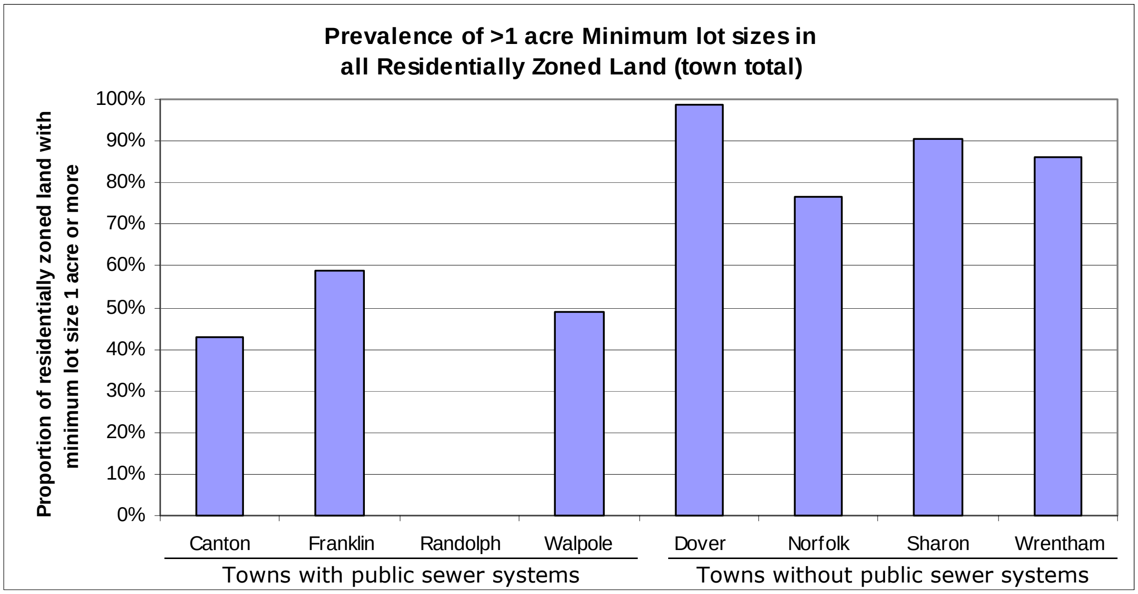
Figure 7: Land Consumption (1971-1999) per New Household (1970-2000)



Sources: MassGIS (land use data) and U.S. Census (household data)

This difference in land conversion rates cannot be attributed solely to the land use requirements of on-site waste disposal. Towns without public sewers generally have zoning codes that require lower densities over larger proportions of the town, as shown in Figure 10.

Figure 8: Prevalence of minimum lot sizes >1 acre



Because towns often enact large lot zoning as a means of "slowing growth" and preserving open space, I compared the amount of land developed during the period 1971-1999 to the amount of land available at the beginning of the period, to determine whether towns with large lot zoning are effectively conserving their available land. The results are presented in Table 10.

Table 9: Proportion of Available Land (1971) Converted to Residential Uses, 1971-1999

	Available land, 1971, (acres)	Residential Development 1971-1999	
		acres	% of available land
Sewered Towns			
Canton	4042	999	25%
Franklin	10574	2928	28%
Randolph	1538	450	29%
Walpole	6469	1444	22%
Unsewered Towns			
Dover	4446	629	14%
Norfolk	5800	1651	28%
Sharon	6348	1646	26%
Wrentham	8325	1521	18%

Source: MasGIS; Analysis excludes wetlands, floodplains, and permanently protected open space

Impacts of the Pending Regulatory Change

The pending change in the Title 5 regulations will permit construction of on-site waste disposal systems on soils where the measured percolation rate is 30-60 minutes per inch. I will refer to these soils as "moderately permeable" soils.[6] Previously, on-site disposal was permitted only on rapidly permeable soils where percolation rates are faster than 30 minutes per inch. The land use impacts of this change will depend on the distribution of moderately permeable soils, and the extent to which their presence impedes development under the current regulatory regime.

Evaluation of the soil types within the study area shows that there are three soil types where permeability is the primary limitation on septic system construction.[7]

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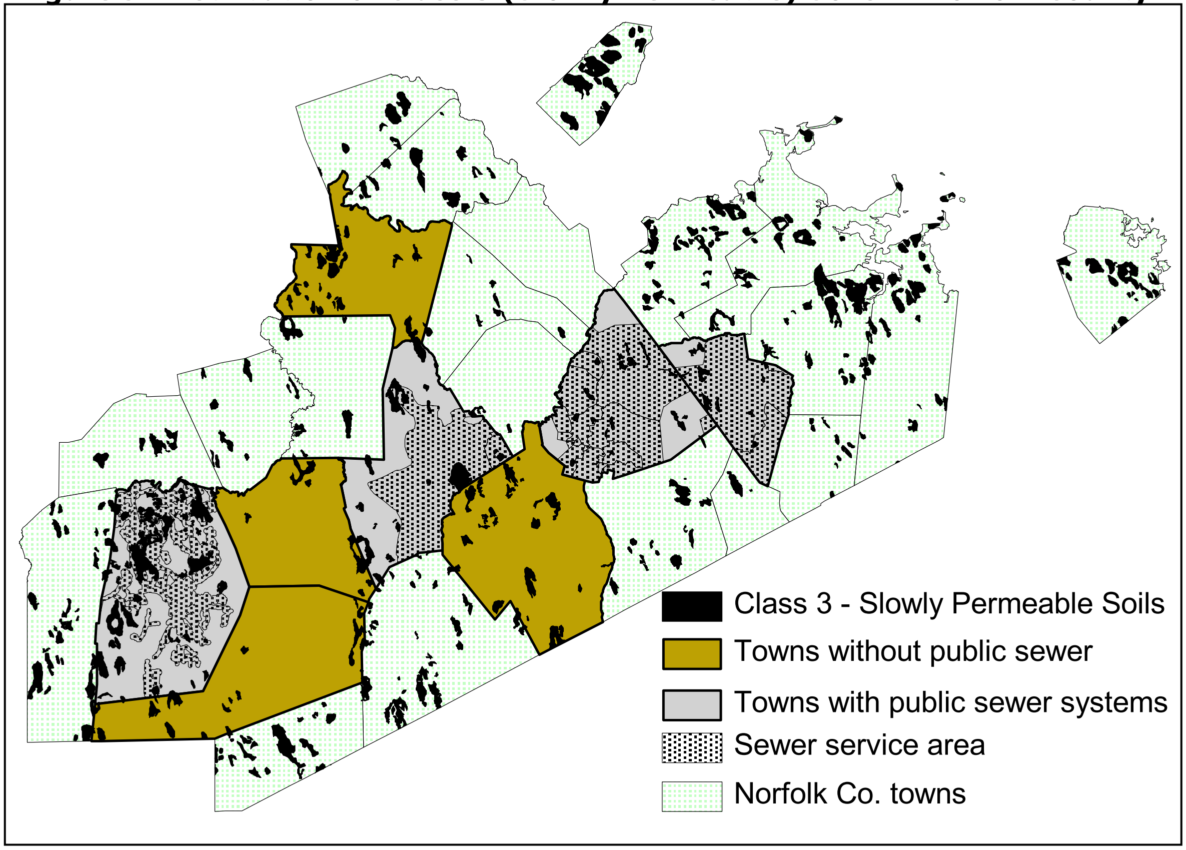
[6] The NRCS definition of Moderately Permeable soils includes those with listed percolation rates of 30 – 100 minutes per inch.

[7] These are the Montauk, Newport, and Paxton soils.

These soils, which comprise Class 3 of my analysis, have a relatively limited distribution within the study area, depicted in Figure 11.

Figure 9: Distribution of Class 3 (Slowly Permeable) Soils in Norfolk County



Sources: MassGIS (town boundaries); MWRA (Canton, Randolph, Walpole sewer service areas); U.S. Geological Survey (Franklin sewer service area)

I also calculated the amount of moderately and slowly permeable soils within available land in each unsewered town.

Table 10: Available Land with Class 3 (Slowly Permeable) Soils, Unsewered Towns

Town	% of Available, residentially-zoned land, Class 3 soils
Dover	15%
Norfolk	3%
Sharon	8%
Wrentham	5%

Source: MassGIS, NRCS; Available land excludes developed areas, wetlands, floodplains, and permanently protected open space.

It is important to note that in Dover an existing local Board of Health Bylaw prohibits development on soils with percolation rates slower than 25 minutes per inch. This standard will be unaffected by the pending change in Title 5.

The proposed regulatory change will permit development only on a subset of these soils; namely, those with moderate permeability. While the NRCS soil survey reports that the three Class 3 soils types have moderate permeability (30-100 minutes per inch) in the upper layers, they have moderately slow to very slow permeability deeper in the soil column. A thorough site evaluation of a soil with typical characteristics should determine that it would not satisfy even the relaxed standards of the new code.[8] However, soils do exhibit considerable heterogeneity, and not all soils exhibit typical characteristics. Consequently, it is possible that the pending regulatory change will allow developers to identify adequately permeable soils on sites with marginally permeable suitable conditions.

It is also important to note that slow permeability is generally associated with silt and clay soils derived from glacial till. The underlying geology of the study area is primarily sand and gravel outwash deposits overlying bedrock.[9] The presence of glacial till is generally limited to the tops and sides of hills. Different conditions are found in Central and Western Massachusetts, where the surficial geology is dominated by glacial till deposits, and coarse outwash deposits are rare. Consequently, the potential impacts of the proposed regulatory change may be more significant in that region.

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[8] Jim Turrene of the NRCS speculated that the Montauk Soils (with a listed permeability of moderate/moderately rapid in the upper layer, and moderately slow to slow permeability in the substratum) may be able to pass a percolation test under the new standards.

[9] Jim Andrews, the Health Agent of Sharon, provided a simple description of soil conditions in that town: “sand and rocks.”

CHAPTER 6: DISCUSSION OF FINDINGS

Four key findings emerge from the data presented in the previous chapter. First, residential development patterns with respect to certain soil types are different in towns with and without public sewer systems; unsewered development occurs less often on soils with slow permeability or shallow groundwater. Second, the patterns of unsewered residential development have changed over time, reflecting the changes in state and local regulations that govern on-site wastewater disposal. Third, the limited distribution of moderately permeable soils within the study area suggests that the pending regulatory change will have a small marginal impact on the location of residential development. Finally, lot sizes and per-new-household land use are significantly higher in towns that lack public sewers; the prevalence of large lots on favorable soils suggest that these land-consumptive patterns may be attributable more to zoning and market demand than to septic regulations.

Influence of High Groundwater on Development Patterns

High groundwater soils (whether rapidly or slowly permeable) are strongly correlated with relatively low rates of septic-dependent development.[1] Further, the relative frequency of unsewered residential development on these soils has decreased over time. This change parallels the enactment of stricter standards on the siting of disposal areas, from the 1966 State Sanitary Code through the 1978 and 1995 Title 5 regulations.[2]

The presence of high groundwater does not appear to be a strong influence on lot sizes in unsewered areas; the proportion of large and small lots on high groundwater soils varies significantly from town to town and over the two study periods. This

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[1] It is also important to note that high groundwater areas (especially those with rapid permeability) are also often associated with aquifer recharge districts, where state and local regulations may impose stricter standards on wastewater disposal regardless of soil type. I did not evaluate the potential influence of these standards.

[2] The 1966 State Sanitary Code required either two or four feet of separation from groundwater, depending on soil conditions, and did not proscribe procedures for assessing the elevation of the water table. The 1977 Title 5 regulations stipulated a 4-foot separation in all soils and required observation of the water table at the time of maximum elevation. The 1995 Title 5 regulations mandate a 5-foot separation in very rapidly permeable soils and require determination of seasonal high water by certified soil evaluators. See Appendix A for a more complete discussion of regulatory history of state and local septic regulations in Massachusetts.

suggests that increased lot size does not provide a significant opportunity for overcoming the practical and regulatory limitations associated with on-site wastewater disposal in high groundwater areas.

The observed influence of regulatory constraints on locational decisions is supported by the fact that development within sewer service areas occurs relatively frequently in high groundwater areas with rapid permeability. However, the data also indicate that development has occurred relatively infrequently on soils with high groundwater and *slow* permeability over the entire study period. This finding suggests that relatively low rates of land conversion on high groundwater/slow permeability soils may be attributable to constraints that apply to both sewered and unsewered development such as wetland regulations, general soil limitations on development, or landscape position. I also observed an unexplained positive correlation between the presence of high groundwater and larger lot sizes in sewer service areas. Additional research is necessary to assess the influence of high groundwater and slow permeability on development rates and lot size in sewer service areas.

The Influence of Slow Permeability on Development Patterns

Since 1985, unsewered residential development has occurred on soils limited by slow permeability alone at rates equal to or slightly lower than would be expected based on their distribution in available land. This observed pattern contrasts markedly from that of development served by public sewer during the same period, which occurred relatively frequently on the same soils. I attribute this difference to the influence of state and locate septic regulations that establish minimum permeability rates for on-site disposal.

Data from 1985-1999 also indicate that, in unsewered areas, residential house lots larger than 1/2 acre are somewhat more likely to be located on slowly permeable soils than are lots smaller than 1/2 acre. This suggests that in areas of heterogeneous soil conditions, larger lot sizes may allow developers to satisfy regulatory requirements by including an area of suitably permeable soils in each lot, or that the larger disposal area required may affect lot size.

Interestingly, on-site disposal standards did not exert a strong influence on location or density of development on slowly permeable/deep groundwater soils during the period 1971-1985, when both small lot and large lot development occurred relatively frequently on these soils.

If the change in development patterns on slowly permeable soils from 1971 to 1999 is attributable to regulatory constraints, it is probably not due to changing percolation rate limits, (which have remained relatively constant at 30 minutes per inch) but to increasing accuracy of percolation tests, the methodology of which was described with increasing levels of detail and specificity in the 1966, 1978, and 1995 state codes, as well as in local septic bylaws. (See Appendix A for a more detailed description of the standards of each code.)

The Influence of Shallow Bedrock on Development Patterns

Shallow bedrock, which is relatively common in most of the towns in the study area, is associated with moderate to low rates of development. The frequency with which unsewered development has occurred in shallow bedrock areas has increased very slightly over time. Sewer service areas also experience low rates of development on these soils, and the rate of development has decreased very slightly over time.

I observed a strong correlation between larger lot sizes and shallow bedrock in unsewered towns. A similar correlation is not observed in sewer service areas. The heterogeneity of these soils may enable developers to find small pockets of soils suitable for construction of on-site systems, though at the expense of smaller lot sizes, and current zoning codes generally include a higher proportion of shallow bedrock areas in districts with larger minimum lot sizes. In towns with public sewers, I suspect (admittedly without hard evidence) that undulating topography, steep slopes, and extensive ledge may impede the construction of gravity drained sewer systems. Additional research is necessary to assess the mechanisms by which shallow bedrock may influence development decisions in shallow bedrock areas.

Impacts of the Pending Change In Title 5 Percolation Standards

My findings suggest that the pending change in Title 5 regulations to permit on-site wastewater disposal on sites with percolation rates of 30-60 minutes per inch will have a relatively small incremental impact on development patterns in the study area, as compared to the effect of current regulations.

Due to geologic conditions, soils that limit on-site waste disposal due to moderate permeability are rare in the study area. Slowly permeable soils free from other limitations on wastewater disposal comprise just 4% to 8% of the land area in the four unsewered towns studied, and just 3% to 8% of residentially-zoned land classified as “available” for development in Norfolk, Sharon, and Wrentham. These soils also constitute less than 5% of the Vacant Developable Land identified through a different methodology developed by the Massachusetts Executive Office of Environmental Affairs for conduct of a statewide Buildout Analysis.

It is important to note that Class 3 (slowly and moderately permeable) soils comprise 15% of the available residentially zoned land in Dover. However, a local bylaw prohibits on-site wastewater disposal on sites with percolation rates slower than 25 minutes per inch. This bylaw will remain in effect following the change in Title 5, highlighting the institutional complexity of controls on wastewater disposal.

The decreasing frequency of development on slowly permeable soils over time (when the standards remained relatively constant) also demonstrates the increasing sophistication of the permitting process in general and the role of percolation test methodology in particular. Stricter local regulations and more meticulous enforcement of existing regulations may partially compensate for the relaxation of standards at the state level.

I also find that the current percolation rate standards are not an overwhelming deterrent to development, which occurs on slowly permeable soils with deep groundwater at rates that are comparable to or slightly less than would be expected based on their distribution within available land. The prevalence of large lots on slowly permeable soils indicates that larger lots allow developers to find areas of suitably permeable material on otherwise marginally suitable sites. Because a strong market exists for these larger lots, the cost of the land can be rolled into the sale price.

These historical patterns suggest that, if percolation rate standards are influencing lot sizes, then the relaxed standards might enable development of smaller lots on slowly permeable soils. However, my data demonstrate that the vast majority of available, residentially zoned land with slowly permeable soils is located in zoning districts with minimum lot sizes of at least 1 acre (Sharon and Norfolk) or 2 acres (Dover and Wrentham.) Due to the heterogeneity of soil conditions, it is likely that developers may be able to find suitably permeable sites on such large lots, whether the standard is 30 minutes per inch or 60 minutes per inch.

Septic Regulation and Zoning

The observed tendency in unsewered towns for zoning districts with smaller minimum lots sizes to include relatively larger amounts of favorable soils suggests that soil conditions and their relation to on-site wastewater disposal may be one factor that is considered during the zoning process. Twichell (1978) reports, on the basis of interviews with local officials, that many communities enact large lot zoning in order to minimize the potential health and environmental impacts that may occur in the event of system failure.

Large lot zoning may be construed by these communities an anticipatory measure to prevent concentrated water quality impacts. It also has the effect of ensuring that, in the event of widespread failure, the burden for remediation will lie with homeowners, since construction of centralized wastewater collection systems is generally less cost effective in low-density areas. This latter point is especially critical for communities that wish to avoid the construction of sewer systems because of their potential to enable higher density development.

Concerns regarding septic system failure are valid, especially since the development of effective septic management districts designed to ensure proper use, management, and repair of systems has proved elusive. However, zoning codes that tend to require larger lots on unsuitable soils rarely permit significantly higher densities on more suitable soils. While lower-density (>1 acre) zoning districts may include the majority of the slowly permeable soils in most towns, they also cover most of the favorable soils, where careful permitting, siting, and construction could allow the use of conventional on-site systems at moderate to high densities, and advanced technologies or shared systems at high densities.

Considerations for Environmental Sustainability and Housing Affordability

The findings of this research demonstrate that the current technical-regulatory system of on-site wastewater disposal has some effect on spatial distribution of development. Yet I also find that this sanitation system is bound up in a system of land use controls that prevent the efficient use of land, regardless of natural opportunities or constraints on waste disposal. The result is development that consumes land at dramatically higher rates than are observed in towns with public sewer.

On average, each new household in the unsewered towns studied here consumes *twice as much land* as each new household in towns with public sewer systems. In all the sewered towns combined, approximately 6,000 acres of new residential development (1971-1999) accommodated roughly 24,000 new residents in 16,100 new households (1970-2000.) A comparable amount (5,700 acres) of residential development occurred in the unsewered towns, though population growth here was just 15,100 new residents, housed in 6,500 new households.

Meanwhile, the system of septic systems and large lot zoning does little to prevent growth or mitigate its effects. The population of unsewered towns in the study area grew 23% to 125% during the period 1970-2000, as compared to 15% to 66% in the towns with public sewer systems. The pattern of this growth did little to conserve the supply of undeveloped land. From 1971-1999, the proportion of available land converted to residential uses in unsewered towns was comparable to, or slightly less than, the proportion of available land converted in unsewered towns.[3]

Many researchers and members of the development community in Massachusetts claim that septic regulations are significantly limiting the production of housing and contributing to the housing crisis in Massachusetts (Flint, 2002, Euchner, 2003). I find these claims to be unsubstantiated by this research. Septic regulations remove from the market land with soils unsuitable for on-site disposal, thus influencing the location of new residential development. However, low-density zoning codes mandate a highly inefficient use of the land that does remain, regardless of its suitability for on-site disposal. As demonstrated by the population growth in my study area, there is a consumer market for the product of this system (namely, houses on large lots.) Relaxing the standards of septic regulations will thus permit the development community to create a slightly greater supply of the same product.

Yet it is debatable as to whether an increased supply of this product will help to achieve the housing affordability, growth management, and land stewardship goals of the Commonwealth and its individual communities. Large lots require a significant investment in land that places homeownership beyond the reach of many residents of the metropolitan area. Dispersed development places increased pressure on community services, impedes access to schools and recreation facilities, and contributes to auto-dependency, with its resulting air quality and traffic impacts. Widespread conversion of undeveloped land disrupts ecological infrastructure (LaGro,

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[3] Development in unsewered towns during the period 1971-1999 consumed 14% to 28% of land available for development in 1971, while development in the four sewered towns consumed 22% to 29% of available land.

1994), destroys prime farmland soils at a time when there is growing market support for local agriculture, and contributes to water quality and wildlife habitat degradation through increased runoff (Center for Watershed Protection, 1998).

An alternative approach to land use and housing affordability promotes compact development in areas easily accessible to commercial districts and public transit, while enabling construction of clustered housing or very low-density development designed to preserve wildlife habitat and protect water quality (Katz, 2002; Arendt, 1996). A new approach to land use controls is clearly fundamental to achieving this vision. Components of this approach might include multi-use districts, site design guidelines, and programs to enable the transfer of development rights. Complementary measures include acquisition of open space; taxation policies that promote preservation of undeveloped and agricultural land, while ensuring equity across communities; and transportation policies that promote public transit and limit public investments in road improvements in outlying areas.

Complementary sanitation polices are also critical to achieving sustainable development patterns. Local wastewater treatment districts, whether publicly or privately operated, will enable compact multi-use development. On-site disposal regulations that facilitate the construction of clustered housing will promote more efficient use of land in outlying areas. Septic system requirements that more fully account for the secondary environmental and financial impacts of dispersed development (including future costs) will discourage the use of individual systems to serve land-consumptive subdivisions. In particular, wastewater management districts may be one mechanism to create a greater public interest in on-site disposal and the land uses it enables.

Additional research is necessary to demonstrate the link between on-site wastewater disposal and the secondary impacts of the development it enables, and to explore the legal and institutional challenges associated with the creation of on-site disposal policies with explicit planning components.

CHAPTER 7: CONCLUSIONS IN THE CONTEXT OF SUSTAINABILITY

Sanitation systems—comprised of technical, institutional, environmental, and social elements—are fundamental to urban and suburban development. The creation of centralized sewer systems facilitated the rise of urban metropolises in the 19th Century, and the availability of on-site wastewater disposal systems enabled the enormous growth of suburban development since the 1950s. Through time, sanitation systems have been structured to serve specific purposes; and through time they have also had diverse secondary impacts on development patterns and environmental quality. As the institutional, technical, and social factors of sanitation systems have changed, so have the resulting secondary impacts.

The current system of privately owned and operated on-site wastewater disposal systems, the use of which is controlled by state and local regulations, has had a demonstrable impact on development patterns in the study area of this research over the past 30 years. On-site systems have enabled extensive settlement of areas not served by centralized sewer systems. This influence became prominent in the 1960s and continues to shape current land use patterns in Massachusetts, where extensive single-family residential development occurs in outlying suburban and exurban towns.

Increasing awareness of the water pollution attributable to the inadequate treatment provided by many on-site systems led public institutions to enact regulations that control the siting, design, and construction of these systems, in order to minimize threats to public health and water quality. These standards permit on-site disposal only where suitable conditions are present, resulting in landscape-scale development patterns that reflect the thickness, permeability, and depth to water table of underlying soils.

My research found that unsewered development since 1985 has occurred relatively more often on deep, rapidly permeable soils with a low water table, and relatively less often on slowly permeable soils or rapidly permeable soils with high groundwater, as compared to development within sewer service areas. The tendency for development to avoid slowly permeable soils or soils with high water tables has increased over time, reflecting increasingly restrictive standards regarding depth to groundwater, and increasing sophistication of the permitting process with regard to assessment of percolation rates.

My findings suggest that the pending change in Title 5 regulations that will permit on-site disposal on some slowly permeable soils will have a small marginal impact on development in the study area, especially in comparison to the effect of existing sanitation policies and land use controls. Slowly permeable soils without other limiting conditions are relatively rare in this portion of Massachusetts, and the regulatory change will affect only a small class of these—those with percolation rates between 30 and 60 minutes per inch. The change in Title 5 will also have no effect on development where local health bylaws establish stricter limits on permeability.

The change in the state standards is likely to have a greater effect where slowly permeable soils constitute a greater proportion of developable land, such as Central Massachusetts, where slowly permeable soils derived from glacial till are more common. Many small towns also lack the willingness or capacity to develop stricter local standards and consistently enforce them. This example vividly demonstrates the importance of institutional and environmental factors with regard to the influence of on-site sanitation systems on development patterns.

Many critics of strict local septic bylaws contend that they are being used as implicit planning mechanisms to control growth, rather than as sanitation policies to protect health and water quality. My research suggests that concerns over wastewater disposal are important components of, and justifications for, broader systems of growth control. Yet the primary mechanisms of these systems are zoning codes that mandate minimum lot sizes of one or two acres throughout a town, not septic bylaws that prohibit development on a limited class of soils.

Regardless of whether or not sanitation policies are implicated in the efforts of many communities to limit growth, I find that these efforts do not necessarily result in land use patterns that further the goals of housing affordability, livability, or environmental sustainability. The primary characteristic of these patterns is rapid loss of open space and inefficient use of land, which places homeownership beyond the reach of most families in the metropolitan area. The septic bylaw reform called for by the development community may increase the effective supply of land or facilitate more rapid development, but it will not promote the efficient use of land. Rather, it will enable greater production of a product (large lot housing) that consumes large amounts of open space but does not provide housing opportunities for the residents of the Commonwealth who need it most.

Many researchers, planners, and advocates have identified more sustainable land use models that promote land-efficient development and the preservation of open space, with land use controls as the primary implementation mechanism. A sophisticated approach to wastewater management will be required to enable compact density where it is desired and to discourage development in outlying areas. My research demonstrates that sanitation policies have a demonstrable influence on the location of residential development. Thus the capacity of soils to treat wastewater might act as one organizing principle for land use plans, and on-site wastewater disposal policies may be a useful mechanism for their implementation.

Many observers state that it is inappropriate to use septic regulations as implementation mechanisms for land use plans; they argue that the purpose of these policies should be limited to the protection of human health and the prevention of a narrowly defined set of water quality impacts. I find that the history of sanitation systems in the United States demonstrates that it is conceptually and legally feasible to modify the institutional and technical components of sanitation systems to achieve broader planning and municipal goals.

As a result of changing social priorities, political and bureaucratic institutions have expanded the stated purpose of sanitation policies over time. Witness the emphasis on health in industrial cities; the increased focus on water quality impacts during the massive sewer-building phase of the 1970s; and the adoption of funding, phasing, and locational policies designed to promote desirable settlement patterns in more recent years. These sanitary policies evolved to address a wider variety of development impacts as public awareness and political salience of these issues increased.

A similar pattern can be found in the history of on-site disposal regulations in Massachusetts. Over time, these policies have evolved to more effectively protect an increasingly comprehensive set of environmental resources, such as wetland ecology (through requirements for increased setbacks) and enclosed, nitrogen-sensitive embayments (through density limitations and enhanced treatment.)

I submit that on-site wastewater disposal policies can continue to expand in scope to more comprehensively address the secondary impacts of development. Research that clarifies the link between the use of this sanitation system and the land consumptive patterns it enables, with their appurtenant environmental and socioeconomic impacts, will foster the development of sanitation policies with *explicit* planning objectives.

Finally, I must note the fact that such an approach will, inevitably, challenge conceptions of private property rights. So be it. Our courts have repeatedly reaffirmed the right—and the duty—of communities to prevent harm through the control of activities that have demonstrable negative impacts on public and private resources. There is a growing awareness across many segments of society that today's unsustainable land use patterns are damaging our environment and threatening the livelihood of future generations. This awareness justifies public efforts to ensure responsible development, and the imperative nature of the problem necessitates the use of whatever tools we have at hand, sanitation policies among them.

BIBLIOGRAPHY

Albertson, Doug. December 5, 2002. Letter to Sharon Pelosi, Watershed Permitting Program, Massachusetts Department of Environmental Protection.

American Planning Association. 1988. *Development Impact Fees: Policy Rationale, Practice, Theory, and Issues*. Chicago, IL. Planners Press, American Planning Association.

Andrews, Jim. 2003. Phone Interview with Jim Andrews, Health Agent for Engineering, Town of Sharon.

Arendt, Randall. 1996. *Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks*. Washington, D.C. Island Press.

Arenovski, A.L., and F.C. Shepard. 1995. A Massachusetts Guide to Needs Assessment and Evaluation of Decentralized Wastewater Treatment Alternatives. Chestnut Hill, MA. Marine Studies Consortium.

Bascom, S.E., K.G. Cooper, M.P. Howell, A.C. Makrides, and F.T. Rabe. 1975. *Secondary Impacts of Transportation and Wastewater Investments: Review and Bibliography*. Prepared for Council on Environmental Quality, U.S. Department of Housing and Urban Development, and U.S. Environmental Protection Agency. Washington, D.C.: Office of Research and Development, US Environmental Protection Agency.

Biggs, Julie Hayward. 1990. No Drip, No Flush, No Growth: How Cities Can Control Growth Beyond Their Boundaries by Refusing to Extend Utility Services. *The Urban Lawyer*. 22, 2: 285-305.

Binkley, Clark, Bert Collins, Lois Kenter, Michael Alford, Michael Shapiro, Richard Tabors. 1975. *Interceptor Sewers and Urban Sprawl*. Lexington, MA. Lexington Books.

Burchell, Robert W. 1995. *Land, Infrastructure, Housing Costs, and the Fiscal Impacts Associated with Growth: The Literature on Impacts of Sprawl versus Managed Growth*. Cambridge, MA. Lincoln Institute of Land Policy.

Center for Watershed Protection. 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community*. Ellicott City, MD. Center for Waterhsed Protection.

Commonwealth of Massachusetts, Department of Environmental Protection. 1995. 310 CMR 15.000: The State Environmental Code, Title 5: Standard Requirements for the Sitiing, Construction, Inspection, Upgrade and Expansion of On-site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage.

Commonwealth of Massachusetts, Department of Environmental Protection. 1978. 310 CMR 15.000: The State Environmental Code, Title 5: Standard Requirements for the Sitiing, Construction, Inspection, Upgrade and Expansion of On-site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage.

Downing, Donald A. 1972. *The Role of Water and Sewer Extension Financing in Guiding Urban Residential Growth*. University of Tennessee, Water Resources Research Center, Report Number 19.

Euchner, Charles. 2003. *Getting Home: Overcoming Barriers to Housing in Greater Boston*. Boston, MA. Pioneer Institute for Public Policy Research.

Ewing, Reid. 1997. Is Los Angeles-Style Sprawl Desirable? *Journal of the American Planning Association*. 63, 1: 107-126.

Flint, Anthony. 2002. Septic rule change may spur building. *Boston Globe*. 1 December, 2002, Page A1.

Goehring, Darryl R., and F. Robert Carr. 1980. Septic System Problems on an Urban Fringe. Journal of the Water Resources Planning and Management Division, Proceedings of the American Society of Civil Engineers. 106, WR1: 89-102.

Governor's Commission. 2002. *Report of the Governor's Special Commission on Barriers to Housing Development*. Boston, MA. Commonwealth of Massachusetts.

Graham, Stephen. 2000. Introduction: Cities and Infrastructure Networks. *International Journal of Urban and Regional Research*. 24, 1: 114-119.

Hanson, Mark E., and Harvey M. Jacobs. 1989. Private Sewage System Impacts in Wisconsin; Implications for Policy and Planning. *Journal of the American Planning Association* 55, 2:169-180.

Herman, Dennis. 1992. Sometimes There's Nothing Left to Give: The Justification for Denying Water Service to New Customers to Control Growth. *Stanford Law Review*. 44: 429-467.

Jacobs, Harvey M., and Mark E. Hanson. 1989. Land Use Impacts of Private Seage Systems in Wisconsin. *Journal of Soil and Water Conservation*. 44, 2: 149-152.

Katz, Bruce. 2002. *Smart Growth: The Future of the American Metropolis?* London, England. London School of Economics, Centre for Analysis of Social Exclusion.

Keating, Ann D. 1985. From City to Metropolis: Infrastructure and Residential Growth in Urban Chicago. In *Infrastructure and Urban Growth in the Nineteenth Century*. Chicago, IL. Essays in Public Works History #14.

LaGro, James A. Jr. 1994. Population Growth Beyond the Urban Fringe: Implications for Rural Land Use Policy. *Landscape and Urban Planning*. 28: 143-158.

LaGro, James A. Jr. 1996. Designing Without Nature: Unsewered Residential Development in Rural Wisconsin. *Landscape and Urban Planning*. 35: 1-9.

MacKenzie, V.G. 1953. Research Studies on Individual Sewage Disposal Systems. *American Journal of Public Health*. 42: 411

Mainewatch Institute. 1992. Green Development: Balancing Development with Conservation; Nine Case Studies of Rural Subdivisions. Hallowell, ME. Mainewatch Institute.

Mandelker, D., and R. Cunningham. 1979. *Planning and Control of Land Development: Cases and Materials*. Indianapolis, IN. Bobbs-Merril Co.

McCarthy, Mike. 2002. The Roots of Growth. *Sacramento Business Journal*. October 25, 2002.

Melosi, Martin. 2000. The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present. Baltimore, MD. Johns Hopkins University Press.

Melosi, Martin. 2001. *Effluent America: Cities, Industry, Energy, and the Environment*. Pittsburgh, PA. University of Pittsburgh Press.

Metropolitan Area Planning Council. 2002. Testimony of the Metropolitan Area Planning Council Regarding the Proposed Amendment to 310 CMR 15.000, the State Environmental Code, Title 5, November 20, 2002.

Millgram, Grace. 1967. The City Expands: A Study of the Conversion of Land From Rural to Urban Uses; Philadelphia, 1945-1962. Washington, DC. U.S. Department of Housing and Urban Development.

Moehring, Eugene. 1985. Space, Economic Growth, and the Public Works Revolution in the Nineteenth Century. In *Infrastructure and Urban Growth in the Nineteenth Century*. Chicago, IL. Essays in Public Works History #14.

Nelson, Arthur C., and Kenneth J. Dueker. 1989. Exurban Living Using Improved Water and Wastewater Technology. *Journal of Urban Planning and Development*. 115, 3: 101-113.

Nelson, Arthur, ed., *Development impact fees: policy rationale, practice, theory, and issues*, Planners Press, American Planning Association, Chicago (1988)

Nicholas, James C. 1991. *A Practitioner's Guide to Development Impact Fees*. Chicago, IL. Planners Press, American Planning Association.

O'Connell, Brian (1989) The Federal Role in the Suburban Boom. In *Suburbia Re-*examined, Barbara M. Kelley, ed. Westport. Greenwood Press.

Perkins, Barry. 2003. Phone Interview with Barry Perkins, Health Agent for the Town of Avon, MA. March 26, 2003.

Popper, Frank J. 1980. Unshaping Growth: The Potential Land-Use Implications of the Sand Filter and Related Alternative Wastewater Treatment Technologies. Washington, D.C.: American Land Forum.

Popper, Frank J. 1981. Unshaping Growth. *American Land Forum*. 2, 2:8-14.

Poradek, J. 1997. *Minnesota Law Review*. 81: 1343-1375.

Public Utilities, 64 American Jurist 2d. Sections 9-37.

Ramsay, Barbara. 1974. Control of the Timing and Location of Government Utility Extensions. *Stanford Law Review*. 26: 945-963.

Real Estate Research Corporation. 1974. The Costs of Sprawl: Environmental and Economic Costs of Alternative Residential Development Patterns at the Urban Fringe. Washington, D.C.: Council on Environmental Quality.

Rome, Adam. 2001. The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism. New York, NY. Cambridge University Press.

Rosen, Christine. 1986. Infrastructure Improvement in Nineteenth-Century Cities: A Conceptual Framework and Cases. *Journal of Urban History*. 12, 3: 211-256.

Stansbury, Jeffrey. 1972. Suburban Growth: A Case Study. *Population Bulletin*. 28.

Stone, Carol. 1982. The Prevention of Urban Sprawl Through Utility Extension Control. *The Urban Lawyer*. 14, 2: 357-377.

Tabors, Richard D., Michael H. Shapiro, and Peter B. Rogers. 1976. *Land Use and the Pipe: Planning for Sewerage*. Lexington, MA: Lexington Books.

Tarr, Joel. 1985. Building the Urban Infrastructure in the Nineteenth Century: An Introduction. In *Infrastructure and Urban Growth in the Nineteenth Century*. Chicago, IL. Essays in Public Works History #14.

Tarr, Joel. 1988. Sewerage and the Development of the Networked City in the United States, 1850-1930. In *Technology and the Rise of the Networked City in Europe and America*, Joel Tarr and Cabriel Dupuy, eds. Philadelphia, PA.

Town of Dover, Massachusetts. 1995. Board of Health Regulations, Section VI., Sewage Disposal.

Town of Norfolk, Massachusetts. 1997. Norfolk Board of Health Regulations for the Siting, Construction, Inspection, Upgrade, Repair, and Expansion of On-Site Wastewater Disposal Systems.

Twichell, Joseph H. 1978. *The Effects of the Use and Regulation of Septic Tank Systems upon Land Use in Massachusetts*. Amherst, MA. University of Massachusetts, Water Resources Research Center.

U.S. Census. 2002. Historical Census of Housing Tables; Sewage Disposal. http://ww.census.gov/hhes/www/housing/census/historic/sewage. Accessed February 21, 2003.

U.S. Environmental Protection Agency. 1974. *Draft Guidelines for Areawide Waste Treatment Management*. Washington, D.C., U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. 2000. *Potential Roles for Clean Water State Revolving Fund Programs in Smart Growth Initiatives*. Washington, D.C., US EPA Office of Wastewater Management.

United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center. 1995. Soil Survey Geographic (SSURGO) Data Base: Data Use Information. Miscellaneous Publication Number 1527. Fort Worth, TX, National Cartography and GIS Center, USDA.

Urban Systems Research and Engineering, Inc. 1976. *The Growth Shapers: The Land Use Impacts of Infrastructure Investments*. Washington, D.C.: U.S. Government Printing Office.

VanderVelde, Lea. 1977. Utility Extensions: An Untested Control on Wisconsin's Urban Sprawl. *Wisconsin Law Review*. 1977: 1132-1156.

Veneman, Peter L.M. 1982. *The Septic Tank as a Wastewater Treatment and Disposal Facility*. Amherst, MA. University of Massachusetts, Water Resources Research Center, Publication Number 128.

White, Bernard. 1989. Septic Tank Density and Groundwater Contamination: An Annotated Bibliography. Council of Planning Librarians, Bibliography 234.

Zaitzevsky, Cynthia. 1982. *Frederick Law Olmsted and the Boston Park System*. Cambridge, MA. Harvard University Press.

APPENDIX A

SUMMARY OF MASSACHUSETTS SEPTIC REGULATIONS SINCE 1966

MASSACHUSETTS REGULATORY ENVIRONMENT

This chapter summarizes the development of on-site disposal regulations in Massachusetts since the 1960s and their relevance to development decisions. I will pay particular attention to requirements regarding soil and site conditions.

1966 State Sanitary Code

In 1966 Massachusetts adopted amendments to Article XI of the State Sanitary Code: Minimum Requirements for Disposal of Sanitary Sewage in Unsewered Areas. These regulations were enacted in response to widespread failures of septic tanks and cesspools constructed during first wave of suburbanization. Enforced through local boards of health which had to approve issuance of all building permits to ensure compliance, the state code established licensing requirements for septic system installers and forbade the construction of a septic system if connection to a public sewer was feasible.

Site Requirements

Article XI required developers to conduct a percolation test, and prohibited construction in soils with percolation rates slower than 30 minutes per inch. The standards also required a 4-foot vertical separation between seasonal high water table and the bottom of the disposal area, though this standard was reduced to 2 feet in rapidly permeable soils (faster than 2 minutes per inch.) This is odd because wastewater that moves rapidly through the soil column must travel farther to achieve the same level of treatment as soil that moves slowly through tighter soils. The code provided minimal guidance on percolation test procedures and determination of seasonal high water. There was no requirement for a certain depth of naturally occurring pervious soil underlying the disposal area. Thus systems could be constructed in fill over shallow soils. Article XI also established setbacks from both constructed and natural features. Disposal areas were prohibited within 100 feet of a water supply well or surface water supply, and within 25 feet of watercourses.

Design Standards

It established sizing standards for infiltration area, based on percolation rate and design flow (a function of the number of bedrooms.) It required a 25% increase in the size of the disposal area if a garbage grinder was proposed, and it also required evaluation and designation of a reserve area for disposal if the first system were to fail. Unlike later codes, the code identified seepage pits as the preferred design for on-site disposal, rather than fields or trenches. It permitted the usage of composting toilets and cesspools, though the latter were discouraged.

Implementation

Enforcement of the 1966 code varied widely. The factors that influenced implementation include: institutional and technical capacity of the municipal board of health, local health and water quality conditions, and the level of local concern with growth and development issues. The code required property owners to maintain septic systems, though it did not require inspections.

Adoption of Title 5

Section 208 of the 1972 Clean Water Act amendments provided federal funding for nonpoint source pollution prevention planning. While point sources of pollution can be managed through treatment at or before the point of discharge, nonpoint sources (which may include construction areas, agricultural fields, roads, and malfunctioning septic systems) are numerous and diffuse, requiring a systematic approach to management. Recognizing the broad environmental impacts of on-site wastewater disposal, the Massachusetts legislature moved responsibility for the regulation of these systems from the Department of Public Health to the new Department of Environmental Quality Engineering [or DEP?] through the adoption of Title 5 of the state Environmental Code in 1975. DEQE immediately adopted, with minor modifications, the 1966 State Sanitary Code, and then set about developing its own regulations. [Footnote: The only modification of significance to this study was a requirement that disposal areas be located on sites with at least 4 feet of naturally occurring pervious material.]

1978 Title 5 Regulations

In 1977 DEQE developed a new set of regulations for the management of on-site wastewater disposal (310 CMR 15.000.) The purpose of these regulations was to "provide minimum standards for the protection of human health *and the environment*." (emphasis added.) [Footnote: These regulations were adopted in 1977 and became effective January 1, 1978. Consequently, they are sometimes referred to as the 1977 regulations, and sometimes as the 1978 regulations.] The new regulations were considerably more sophisticated than those based on the sanitary code, with detailed standards for site evaluation, design, and construction.

Site Requirements

The 1978 code required a more thorough site evaluation than previous regulations. Proponents were required to dig at least two observation holes at the site of a disposal area, at the "time of maximum elevation" in order to determine the height of seasonal high water. Vertical separation from groundwater was required to be four feet in all soils. The regulations also provided more detailed guidance on the methodology for a percolation test. The 1978 code maintained the required separation of 100 feet between disposal areas and wells and surface water supplies, while increasing the required setback for watercourses from 25 to 50 feet. It also established a 25 foot setback from subsurface drains.

Design Standards

As with previous sanitary codes, the size of the infiltration area was based on the permeability of the underlying soil. The code permitted the use of leaching pits, galleries, and chambers, and included design standards for these facilities. The slowest permissible permeability of underlying soil was 30 minutes per inch, but soils with percolation rates slower than 20 minutes per inch would not count towards the effective infiltration area if located in the "bottom area" of a trench or leaching chamber. The disposal area was to be increased by 50% if a garbage grinder was proposed. Systems serving multiple households were prohibited. Reserve areas were prohibited.

Implementation

As with previous codes, local boards of health were authorized to enforce the regulations. They were also permitted to grant variances from certain requirements.

1995 Title 5 Regulations

Roughly ten years after implementation of the 1978 regulations, the Department of Environmental Protection funded a report on the effectiveness of Title 5. This report, prepared by the consultant DeFeo-Wait, was issued in 1991, after which DEP developed new regulations.

Site Requirements

The 1995 regulations established new requirements for siting on-site disposal systems. It included more detailed procedures for the conduct of percolation tests, and permitted a limited number of pilot systems to be built in soils with percolation rates between 31 and 60 minutes per inch.

Recognizing the fact that travel times affect treatment effectiveness, the new regulations also increased the vertical separation between disposal area and seasonal high water from four feet to five feet in soils with a percolation rate faster than 2 minutes per inch. The placement of fill was permitted if necessary to achieve the required vertical separation to groundwater. Such "mounded" systems must have gentle side slopes (no greater than 3:1) or waterproofed, reinforced concrete retaining walls. The new code also permitted use of soil indicators to determine the elevation of seasonal high water at any time during the year.

DEP retained the requirement for four feet of naturally occurring pervious soil underlying disposal areas. Upper, slowly permeable layers can be removed if four feet of suitable material exist below the depth of excavation. If natural soil depths are less than four feet due to bedrock, however, fill or replacement will not permit construction.

The 1995 code established new controls on wastewater disposal in Nitrogen Sensitive Areas, where nutrients can affect drinking water quality or cause eutrophication of enclosed waterbodies. The code limits system capacity to four bedrooms per acre, unless the system uses enhanced nitrogen removal technology or site planning ensures acceptable densities.

The new regulations also increased the required separation from disposal areas to natural features. A 100-foot setback is required for vernal pools, private water supply wells (no change), and wetlands or surface drains contributing to a surface water supply. Setbacks for surface water supplies and their tributaries were increased to 400 feet and 200 feet, respectively. Systems are prohibited within the Zone 1 (direct recharge area) of public water supply wells. The 1995 code also prohibited construction within regulatory floodways.

Design Standards

In a significant change, the 1995 regulations required leach field sizing based on Long Term Acceptance Rates, instead of soil percolation rates. The LTAR account for the influence of the biomat that forms underneath the disposal area and slows percolation. The new code also permitted the use of shared systems. It also established procedures for the evaluation and use of alternative/innovative systems

(A/I systems) such as composting toilets, recirculating sand filters, effluent tee filters, and others. In general, alternative systems are only permitted for general use in new construction on sites where a site evaluation has demonstrated the feasibility of a conventional septic system and disposal area.

Implementation

The new standards for determining the elevation of seasonal high groundwater require specialized technical assessment of soil features. This procedural change required training and certification of soil evaluators. The 1995 regulations established transition periods during which compliance with 1978 standards is permitted on pre-1995 lots where compliance with new standards is not feasible.

Local Regulations

Consistent with the strong emphasis on "home rule" in Massachusetts, Title 5 allows local authorities to enact regulations more stringent than state standards in order to protect public health and the environment in the context of local environmental or site conditions. Numerous communities have adopted local septic bylaws since 1978. At least 125 have filed local regulations with the DEP, as required by Title 5. A 2002 report (Barriers to Housing) identified six classes of requirements in local bylaws:

- Procedural requirements, such as limits on the timing of percolation tests, or methodology for the assessment of high groundwater. These may be necessitated based on site conditions, such as sandy soils that make it difficult to determine elevation of seasonal high water tables based on soil features.
- "Oversizing" requirements, such as an automatic increase of 50% in the required disposal area. These are precautionary measures in case of later additions or post-construction installation of garbage grinders.
- Additional requirements for reserve areas, such as setbacks or requirements that the reserve area be constructed at the same time as the primary disposal area.
- Stricter limits on percolation rates, which may prohibit construction in either rapidly or slowly permeable soils, in order to prevent pathogen transmission or ponding, respectively.
- Restrictions on the construction of mounded systems or systems constructed in fill, or an increase in the required vertical separation between disposal areas and groundwater.
- Limitations or prohibitions on the use of alternative or shared systems.

It is important to note that there is (apparently) no systematic inventory of municipal septic bylaws that provides data on the prevalence of various types of local restrictions. It is impossible to ascertain whether the examples above are widespread or unique; and other categories of local restrictions may exist. Determining the content, rationale, and effectiveness of local bylaws would be a significant project in and of itself. It is sufficient to note that communities have enacted diverse regulations that contribute to the complexity of the regulatory environment.

APPENDIX B

SOIL INTERPRETIVE CLASSES

Interpretive Class	Soil Map Unit
1	Canton fine sandy loam, 3 to 25 % slopes
	Haven very fine sandy loam, 0 to 8 % slopes
	Hinckley gravelly sandy loam, 3 to 8 % slopes
	Hinckley loamy sand, 15 to 35 % slopes
	Hinckley sandy loam, 8 to 15 % slopes
	Merrimac fine sandy loam, 0 to 15 % slopes
	Windsor loamy sand, 0 to 15 % slopes
	Canton - Urban land complex 3 to 15 % slopes
	Merrimac-Urban land complex 0 to 8 % slopes
2	Deerfield loamy sand, 0 to 8 % slopes
	Sudbury fine sandy loam, 3 to 8 % slopes
	Udorthents, wet substratum
	Woodbridge - Urban land complex 3 to 15 % slopes
3	Montauk fine sandy loam, 3 to 15 % slopes
	Newport loam, 3 to 25 % slopes
	Paxton fine sandy loam, 3 to 25 % slopes
4	Pittstown loam, 3 to 8 % slopes
	Scio very fine sandy loam, 3 to 8 % slopes
	Scituate fine sandy loam, 3 to 8 % slopes
	Woodbridge fine sandy loam, 0 to 8 % slopes
5	Charlton-Hollis-Rock outcrop complex 3 to 35 % slopes
	Hollis-Rock outcrop-Charlton complex 3 to 35 % slopes
	Rock outcrop-Hollis complex 3 to 35 % slopes
6	Freetown muck or peat, 0 to 3 % slopes
	Ipswich muck peat
	Raynham silt loam
	Ridgebury fine sandy loam, 0 to 8 % slopes
	Scarboro and Birdsall soils
	Swansea muck
	Walpole fine sandy loam 0 to 5 % slopes
7	Pits, Gravel
	Pits, Quarry
	Udorthents

NRCS Required disclaimer: "The Norfolk County Soil Survey geographic database was produced by the US Department of Agriculture NRCS and cooperating agencies. The soils were mapped at a scale of 1:25,000 with a 4-acre minimum size delineation. Enlargement of the maps to scales greater than that at which they were originally mapped may cause misunderstanding of the detail of mapping. If enlarged, maps do not show small areas of contrasting soil that could have been shown at a larger scale. The depicted soil boundaries and interpretations derived from them do not eliminate the need for onsite sampling, testing, and detailed study of specific sites for intensive uses. Thus, the soil survey and interpretive tables are intended for planning purposes only.”

APPENDIX C

SOIL CLASS DISTRIBUTIONS WITHIN TOWN, AVAILABLE LAND, AND RESIDENTIALLY ZONED LAND

Septic Interpretive Rating	Town Total, excluding water		Town Total, excluding Constraints		Residentially-zoned land 1999 (developed and undeveloped), excluding constraints		
WRENTHAM	acres	%	acres	%	acres	%	SZI
1-Favorable	5165	37%	4678	45%	4163	35%	0.8
2-High GW	411	3%	328	3%	322	3%	0.8
3-Permeability	586	4%	468	4%	428	5%	1.2
4-GW & Perm.	491	4%	418	4%	404	5%	1.3
5-Bedrock	4262	31%	3018	29%	2854	36%	1.2
7-Hydric	2105	15%	722	7%	695	9%	1.3
8-Disturbed	875	6%	822	8%	466	7%	0.9
	13895	100%	10456	100%	9333	100%	
SHARON	acres	%	acres	%	acres	%	SZI
1-Favorable	7296	49%	5576	60%	5366	60%	1.0
2-High GW	646	4%	466	5%	453	5%	1.0
3-Permeability	1010	7%	760	8%	751	8%	1.0
4-GW & Perm.	882	6%	507	5%	502	6%	1.0
5-Bedrock	1611	11%	817	9%	815	9%	1.0
6-Floodplains	55	0%		0%		0%	1.0
7-Hydric	3044	20%	859	9%	806	9%	1.0
8-Disturbed	472	3%	368	4%	321	4%	0.9
	15016	100%	9353	100%	9015	100%	
NORFOLK	acres	%	acres	%	acres	%	SZI
1-Favorable	4433	46%	3925	55%	3491	60%	1.1
2-High GW	353	4%	199	3%	149	3%	0.9
3-Permeability	372	4%	368	5%	230	4%	0.8
4-GW & Perm.	519	5%	463	7%	394	7%	1.0
5-Bedrock	1392	15%	1263	18%	1038	18%	1.0
6-Floodplains	162	2%	11	0%	9	0%	1.0
7-Hydric	1932	20%	488	7%	396	7%	1.0
8-Disturbed	418	4%	361	5%	107	2%	0.4
	9581	100%	7079	100%	5816	100%	
DOVER	acres	%	acres	%	acres	%	SZI
1-Favorable	2780	29%	1983	31%	1853	33%	1.1
2-High GW	408	4%	243	4%	238	4%	1.1
3-Permeability	814	8%	735	11%	734	13%	1.1
4-GW & Perm.	1250	13%	920	14%	1531	27%	1.9
5-Bedrock	2889	30%	2062	32%	848	15%	0.5
6-Floodplains	70	1%	7	0%	7	0%	1.1
7-Hydric	1448	15%	456	7%	391	7%	1.0
8-Disturbed	56	1%	50	1%	40	1%	0.9
	9715	100%	6456	100%	5642	100%	

Septic Interpretive Rating	**Town Total, excluding water**		**Town Total, excluding Constraints**		**Residentially-zoned land 1999 (developed and undeveloped), excluding constraints**		
FRANKLIN	acres	%	acres	%	acres	%	SZI
1-Favorable	6018	35%	5367	39%	4665	41%	1.0
2-High GW	348	2%	263	2%	239	2%	1.1
3-Permeability	2394	14%	2087	15%	1932	17%	1.1
4-GW & Perm.	1894	11%	1679	12%	1157	10%	0.8
5-Bedrock	2633	15%	2307	17%	2098	18%	1.1
6-Floodplains	288	2%	31	0%	30	0%	1.0
7-Hydric	2693	16%	1128	8%	926	8%	1.0
8-Disturbed	890	5%	760	6%	416	4%	0.7
	17159	100%	13623	100%	11462	100%	
WALPOLE	acres	%	acres	%	acres	%	SZI
1-Favorable	6594	50%	5702	59%	4840	60%	1.0
2-High GW	288	2%	192	2%	157	2%	1.0
3-Permeability	987	8%	916	9%	857	11%	1.1
4-GW & Perm.	1032	8%	881	9%	794	10%	1.1
5-Bedrock	433	3%	359	4%	335	4%	1.1
6-Floodplains	37	0%	9	0%	4	0%	1.0
7-Hydric	2900	22%	930	10%	791	10%	1.0
8-Disturbed	857	7%	752	8%	350	4%	0.6
	13129	100%	9740	100%	8129	100%	
NORFOLK	acres	%	acres	%	acres	%	SZI
1-Favorable	4575	38%	3638	49%	2783	47%	1.0
2-High GW	903	8%	599	8%	489	8%	1.0
3-Permeability	383	3%	295	4%	290	5%	1.2
4-GW & Perm.	796	7%	541	7%	530.34	9%	1.2
5-Bedrock	1437	12%	1043	14%	923	16%	1.1
6-Floodplains	790	7%	23	0%	13	0%	1.0
7-Hydric	2270	19%	524	7%	442.32	8%	1.1
8-Disturbed	885	7%	799	11%	425.68	7%	0.7
	12039	100%	7462	100%	5897	100%	
RANDOLPH	acres	%	acres	%	acres	%	SZI
1-Favorable	2429	39%	2080	45%	1783	45%	1.0
2-High GW	960	15%	883	19%	818	21%	1.1
3-Permeability	261	4%	167	4%	153	4%	1.1
4-GW & Perm.	252	4%	122	3%	114	3%	1.1
5-Bedrock	827	13%	624	14%	578	15%	1.1
6-Floodplains	186	3%	16	0%	15	0%	1.0
7-Hydric	703	11%	176	4%	164	4%	1.1
8-Disturbed	669	11%	541	12%	310	8%	0.7
	6288	100%	4608	100%	3936	100%	

Source: MAssGIS. Constraints= Wetlands, Floodplains, Permanently Protected Open Space. SZI=Soil Zoning Index (Proportion in residentially zoned land/proportion in available land)