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Management of the Su-As-CoWatershed

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Abstract

The purpose of this report is to suggest alternative strategies for managing non-point source (NPS) pollution in the Su-As-Co Watershed. To achieve this, information gathered through archival research, including GIS data and interviews with key individuals, was analyzed and used to provide recommendations to improve water quality. Emphasis is placed on watershed organizations and their role in water quality improvement efforts. This report concludes that there are several easily implemented strategies for managing NPS pollution in the Su-As-Co Watershed.

Authorship

All members of the team completed the following tasks:

1. Writing of the Abstract, Executive Summary, Introduction, Background, Methodology, Results, and Conclusions & Recommendations
2. Attending Interviews with Key Informants
3. Proofreading and Editing of Report

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1. Transcribed interviews with Nancy Bryant, Paul Hogan, and Ron McAdow
2. Writing of Sections: 2.2.2, 2.2.3, 3.2, 4.2, and 4.3
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1. Transcribed the interview with Savas Danos
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Executive Summary

The Sudbury-Assabet-Concord (Su-As-Co) Watershed is located in eastern Massachusetts, encompassing thirty-six cities and towns and covering 377 square miles. Non-point source (NPS) pollution is a growing problem in the Su-As-Co Watershed, with runoff and other decentralized sources being the main causes. Pollution from all sources has created major problems in water quality, most notably high nutrient levels and contamination of fish in the watershed. However, with the point source pollution in the Su-As-Co Watershed decreasing NPS pollution is going to become an increasingly significant problem.

The goal of this project was to provide recommendations for better management of the Su-As-Co Watershed, specifically focusing on NPS pollution. To achieve this goal we concentrated on four major objectives. The first of which was to identify the most successful NPS pollution cleanup efforts in the United States and determine how they can be applied in the Su-As-Co Watershed. We accomplished this through archival research on successful cleanup efforts and interviews among watershed advocacy groups in the Su-As-Co Watershed. Influential members of organizations who have implemented successful NPS pollution efforts were also consulted.

Our second objective was to identify collaborative efforts among Su-As-Co Watershed groups and assess how they are affecting NPS pollution remediation and control. And the third objective was to determine the current and potential role of community participation in combating NPS pollution within the watershed. Both of these objectives were achieved through a series of interviews with influential individuals in the Su-As-Co Watershed. The interviewees represent a diverse area of the watershed and have varying foci for their improvement efforts.

The final objective was to determine linkages between development and water quality in the Su-As-Co Watershed. Linkages were determined based on Mass GIS data coupled with water quality data. This allowed us to make an accurate comparison of land development patterns (residential, commercial, and industrial) to water quality over approximately thirty years. Additionally, sources of pollution in the Assabet were analyzed to determine if there existed other observed phenomena that correlate with changes in water quality.

After identifying the most successful cleanup efforts in the United States, we identified three successful cleanup methods to improve water quality in the Su-As-Co Watershed. The first was sediment removal. Removing sediment can be done effectively using two procedures: dam removal and man-made wet lands. Dam removal regains water flow in rivers, which allows contaminated sediment to be taken away with the flowing water. Introducing a man-made wetland creates an area that can intercept storm water and allow it to be naturally filtered before entering the natural water sources. It can also be dredged which is a relatively inexpensive method to remove sediment. The second method we identified was nutrient removal. Nutrients can be removed using three methods: alum treatments, cascading vegetative swales and rain gardens. An alum treatment is a method in which a chemical compound is placed into the body of water that reacts with nutrients to create a precipitate that is no longer harmful to humans or animals. Cascaded vegetative swales catch water during high-flow events and naturally remove nutrients from the water with vegetation. Much like a vegetative swale, rain gardens are a landscaped depression that additionally filter water during high flow events. These are typically created by individuals living near a specific body of water. The last method we identified was to increase public participation. In all the instances in which the other methods were used, public participation and education were found to be critical to the success of any project or program.

Identifying collaboration efforts among watershed groups in the Su-As-Co was our next objective. We found that prior to the Watershed Initiative, a government run program that worked with influential organizations in the watershed, collaboration had not only been less than ideal, but even detrimental. The Initiative allowed groups to work together toward the same goals as opposed to competing over funds and each having their own agenda. Unfortunately, the Initiative was cut by the state due to lack of funding. The Su-As-Co Watershed Community Council, a watershed group that focuses on promoting collaboration among all groups, has somewhat taken over the responsibility of encouraging the collaboration among watershed groups. This organization has done a tremendous job, but not being a part of the government and lacking significant funding has made the Su-As-Co Community Council's job more difficult.

When determining the current and potential role of public participation in reducing NPS pollution, we found participation in the Su-As-Co watershed to be relatively good compared to the rest of the state. One major reason for the large amount of public participation in the watershed is an annual festival, Riverfest. This event is hosted by the Su-As-Co River Stewardship Council, part of the National Park Service, and provides a good opportunity to unite efforts run by watershed groups and varying levels of the government. We found, however, that many events focus on getting the public on the river as opposed to education on such topics as the use of low impact development (LID) to control NPS pollution. LID has proven effective, and yet it has not gotten the level of support necessary to reach its potential effectiveness in the Su-As-Co Watershed.

Lastly, we found that population growth and development of land correlate to water quality, but mainly through their effects on point sources of pollution within the watershed. It is important to note that 97% of the phosphorous content in the water has come from point sources, most significantly waste water treatment plants. Also, nearly all NPS phosphorous pollution in the watershed comes from sediment fluxes, which suggests that NPS pollution created from runoff is not significant at this time.

We have drawn several conclusions from the results listed above. First, alternative cleanup efforts may be applicable to the Su-As-Co Watershed. These include LID, alum treatments and dam removal. Umbrella groups in the watershed are key to collaborative efforts among watershed groups and should be sustained indefinitely. Although current umbrella groups are satisfactory, a government run umbrella program, the Watershed Initiative, has proven to be far more effective and ideally will be reintroduced by the state. The level of public participation, despite being relatively high, should be more focused on the most effective cleanup approaches, such as LID. If these recommendations are followed, we believe the water quality in the Su-As-Co Watershed can be greatly improved.

1. Introduction

Since the inception of the Environmental Protection Agency (EPA) in 1970, there have been many efforts to reduce the amount of pollution in watersheds around the United States. The Clean Water Act (CWA) of 1977 specifically aims to accomplish this goal by outlining processes to determine the best water quality management practices, allocate funds to execute these practices, and raise public awareness to help curb further pollution. Getting the public to participate in these efforts is a major objective for not only the EPA but much smaller activist groups that focus on individual watersheds. Gaining public participation is a major goal for these groups because "education and outreach efforts increase awareness and understanding of issues and challenges, generate more data, help determine priorities, increase support for remediation programs, and generally enhance the likelihood of implementing successful management measures" (Arizona's Nonpoint Source State Management Plan, 2003, pp. 24-25). This is especially true for non-point source (NPS) pollution. Without the help of the general public in cleaning up and preventing NPS pollution, the goal of reducing pollution in water cannot be accomplished.

The Sudbury-Assabet-Concord (Su-As-Co) Watershed is no exception. This watershed consists of three major drainage basins from each of the three major rivers: the Sudbury, the Assabet and the Concord. The watershed occupies about 377 square miles of drainage area in eastern Massachusetts and is shared by thirty-six towns. A map of the Su-As-Co may be seen in Figure 1.1. Ideally, the Su-As-Co Watershed would not face elevated nutrient levels, nor PCB and mercury accumulation in fish. The water would be safe to drink and the fish safe to eat. All in the community would share a collective interest in preserving the watershed's pristine state.

Figure 1.1: The Su-As-Co Watershed in Massachusetts (O'Brien, 2005, p.12)

And the conservation organizations would work in unity with one another to maintain the watershed. Additionally, the EPA would provide funding to aid their usual suggestions for improvement. Reality, however, stands in contrast to the ideal situation. The bulk of surface water is designated Class B by the EPA, which discourages direct consumptive use (O'Brien, 2005). By and large, individuals in the relevant communities are unaware of possible solutions to the problems facing the watershed. To the credit of activist groups, recent education campaigns have implemented community outreach and education programs, albeit the effectiveness of these programs is not yet known (Conway, 2007).

Advocacy groups have been created to inform the public of their responsibility and to urge citizens to participate in the improvement of the Su-As-Co Watershed. Groups such as Sudbury Valley Trustees (SVT), Organization for the Assabet River (OAR), Assabet River Stream Watch (ARSW), Sudbury River Watershed Organization (SRWO), and Su-As-Co Watershed Community Council (SWCC) have been established to perform cleanup events, create entertainment events in order to gain public interest, and to conserve highly vulnerable property. Also, the government has funded several studies on TMDL (total maximum daily loads) of various pollutants and has given grants to multiple watershed groups to fund their various projects.

While the Su-As-Co Watershed has many interest groups with plans to help clean it, there are not many definitive data available on the state of the watershed, and many are incomplete. Many of the geographic information system (GIS) data on the Su-As-Co Watershed are incomplete regarding land that is protected and land that is threatened by NPS pollution (SVT, 2000). In short, past data are lacking, and this makes it difficult to judge progress and the effectiveness of past programs. On top of that, there is a possibility of less than optimal cooperation among groups interested in solving problems within the watershed, and public participation to prevent NPS pollution may not be what it ideally could be. The incomplete data, imperfect collaboration among activist groups, and the public's lack of awareness and interest in water quality issues must be addressed in order to solve the problems of NPS pollution facing the Su-As-Co Watershed.

The goal of this project was to provide recommendations to help improve the water quality in the Su-As-Co Watershed with emphasis on non-point source pollution. Despite seeing improvements in water quality, there are still problems present. In order to achieve our goal we compared alternative successful management methods to those in the Su-As-Co Watershed. We also conducted interviews with watershed groups which identified current collaboration efforts among watershed groups and current community participation in the watershed. Finally, using data from the Massachusetts Department of Environmental Protection and the state's geographical information system, the Office of Geographic and Environmental Information, we reviewed the possible correlation between commercial and residential development and water quality. We made recommendations on management of the watershed for stakeholders and other important members in the Su-As-Co Watershed. These suggestions should help them improve current management practices in the watershed and lead to better water quality.

2. Background

To analyze current efforts and problems within the Sudbury-Assabet-Concord Watershed, it is important to first understand both the watershed's current condition and its relationship within the larger context of water systems. The chapter is divided into two parts; the first provides information pertaining to all watersheds, while the second part focuses on the Su-As-Co watershed specifically. In both sections we discuss the water quality problems, cleanup efforts and groups and organizations currently working to clean up the watershed.

2.1 Characteristics of Watersheds

All watersheds share a number of basic physical properties and, consequently, are subject to the same narrow range of problems. The similarity of problems and physical properties of watersheds permits the use of common solutions to solve problems in many watersheds. Frequently, organizations of citizens and municipalities work to improve conditions within watersheds.

2.1.1 Definition

A watershed, or drainage basin, is an area that is drained by a specific body of surface water. In most cases, the term watershed describes an area that provides a river system with all of its water. As scientist and geographer John Wesley Powell once remarked, a watershed is "that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community" (USEPA, 2007d, p. 1). It is easy to see, from Powell's words, that water quality management is a rather important issue for both community and environment in the watershed.

2.1.2 Common Watershed Problems.

While there are a number of problems that plague a vast majority of watersheds, four in particular fall within the scope of this report. The majority of pollution enters the system via point sources. In the case of nutrients, the vast majority are discharged by waste water treatment plants. All four are quite connected and in fact influence one another. The primary problem is elevated nutrient levels (Fling, 2006). In turn, nutrient levels prompt the eutrophication that currently plagues many watersheds. Surface disruption is a major factor in the elevated nutrient levels and also in the fourth problem: heavy metals. The four major problems are connected quite intimately, making it quite difficult to address one at a time or make significant progress in one problem independent of the others.

2.1.2.1 Nutrient Levels

The primary issue facing water quality is elevated nutrient levels. Point sources, specifically waste water treatment processes, contribute the vast majority of phosphorus to natural water systems. The introduction of fertilizers and organic wastes from both point and non-point sources has increased the nutrient levels to concentrations above any natural expectations (Fling, 2006). Phosphorus and nitrogen constitute the bulk of excess nutrients in the water system, with most of the nutrients entering the surface water via non-point sources coming from fertilizers and lawn care practices. Other phosphorus sources include cleaning products and livestock (The Organization for the Assabet River, 2005). Fertilizers, organic wastes and livestock constitute the bulk of non-point sources for phosphorus.

Fertilizers often include supplements of phosphorus and nitrogen to increase plant growth, typically in simple molecules that are readily used by plants. In most cases, phosphorus is available the form of in phosphate ions and nitrogen is contained in ammonium ions, nitrate ions or urea (Mugraas, 2007). Since common fertilizers are somewhat soluble in water, they are easily carried away by large quantities of rainwater. Consequently, it is easy to achieve elevated concentrations of many fertilizer compounds in surface water (Eckert, 2007). Upon reaching surface water, the chemicals are no less potent and can affect the growth of any plant that may absorb them. As one might expect, the nutrients assist the growth of plants in and near bodies of surface water. The phosphorus and nitrogen do not cause any significant damage directly to most animals that may encounter fertilizer or fertilizer-heavy water. However, the minerals may create a state of eutrophication, where the plants benefiting from the fertilizer damage the ecosystem (Manitoba Agriculture, Food and Rural Initiatives, 2007). Excessive nutrient levels are responsible for algal blooms and overgrowth of plants near surface water.

The problems created by fertilizer are compounded when coupled with poor lawn care practices. Improperly designed runoff systems and improper fertilizing practices tend to increase the amount of phosphorus and nitrogen that enter the water system. Rain runoff tends to pick up fertilizer minerals readily (Brown, 1996). Properties with poorly designed runoff systems include features like long, steep slopes or large paved areas, which reduce the amount of runoff that may enter the ground water (USEPA, 2006a). By contrast, if nutrient heavy water can flow downward into groundwater, it is filtered as it moves through the soil. Plants, bacteria and soil remove the excess phosphorus and nitrogen, making the water more suitable for use in a stable ecosystem once it reaches groundwater (Chester County Water Resources Authority, 2005). Subpar practices like using exceedingly soluble mixtures, over fertilizing and applying fertilizer before a rainstorm also increase the amount of fertilizer that enters the watershed. Additionally, poor practices are less effective at performing their intended task and typically prompt the use of even more fertilizer in response (Eckert, 2007). Fertilizer sources of phosphorus are typically linked to suburban and agricultural communities more than urban centers.

While fertilizers contribute the vast majority of excess nutrients, cleaning products and livestock and pets also introduce unnecessary levels of phosphorus to the watershed. Cleaning products often contain phosphorus as an ingredient (typically in the form of a phosphate ion). Citing the Centre Européen d'Etudes sur les Polyphosphates, the Organization for the Assabet River (2005) claims that somewhere between 9% and 34% of the phosphorus generated within a home is from cleaning detergents. Waste from livestock contains inordinately high phosphorus concentrations from the food they eat. Rainwater washes the animal waste into surface water and readily solvates phosphates (Manitoba Agriculture, Food and Rural Initiatives, 2007). Lacking septic systems and livestock, urban centers tend not to contribute non-point source phosphorus to the watershed.

The largest source of non-point source of phosphorus is sediment flux, which is the release of stored phosphorus from sediment (ENSR, 2001). As is discussed in section 2.1.2.3, sediment absorbs pollutants and serves as a means of transport for them. When watersheds experience a reduction of phosphorus content in the water, phosphorus is released by the sediment. There are three major ways to deal with this problem: dam removal, dredging and encapsulation. Dam removal, as the name suggests, involves removing dams. Removing a dam prevents or at least curtails the deposition of sediment in some areas, allowing the sediment to flow downstream to be deposited in a large body of water like a lake or the ocean. It merely removes the sediment, rather than remove phosphorus from the sediment. Dredging involves the removal of sediment from the bottom of the river and dumping it on land somewhere. Again, this merely removes the problem rather than solve it. Lastly, encapsulation involves sequestering pollutant laden sediment in an impermeable (usually concrete) container. Like the other two methods, this fails to address the issue of contaminants in the sediment and merely removes the sediment. There is one method, alum treatment, which does address the issue of the phosphorus in sediment. Alum treatment is discussed in section 2.1.4.4.

2.1.2.2 Heavy Metals Contamination

Heavy metals present problems for watersheds because even in low concentrations they can prove quite dangerous. The term heavy metals is quite broad, encompassing twenty-three elements. A number of these are not dangerous, and a number are quite important to biochemical processes. Elements that cause concern are those that are toxic at low concentrations. There are four such elements that are relevant to non-point source pollution in most watersheds: Arsenic, Chromium, Lead and Mercury (Barthenhagen, 2003). The latter two of these elements are particularly dangerous because they are not involved in any biochemical pathways. Each is deadly in low concentrations and may be found in watersheds. In high concentrations, Arsenic inhibits Succinate Dehydrogenase, preventing cellular respiration, while chronic low dose exposure causes cancer (USEPA, 2007b). Hexevalent Chromium is a potent mutagen and carcinogen. Exposure to Lead causes a number of central nervous system disorders (Agency for Toxic Substances and Disease Registry, 2007a). Mercury can severely damage the central nervous system and kidneys and tends to bioaccumulate. Because it has a predisposition to induce bioaccumulation within food chains, mercury is commonly found in fish (Agency for Toxic Substances and Disease Registry, 2007d). Because of their close association with manufacturing, heavy metals have become nearly ubiquitous in industrialized regions.

Most heavy metals enter the water system via point sources. However, non-point sources do contribute to heavy metals in water systems. The primary non-point sources for heavy metals are mining operations, landfills, vehicle emissions and urban runoff (Brown, 1996). Mining operations and landfills leech metals into the ground when exposed to rainwater or snow melt.

In the case of mines, the contaminants may be introduced directly into bodies of groundwater (Anderson, 2007). Unlined landfills are especially harmful. Lacking any isolation from ground water, unlined landfills readily permit pollutants to enter ground water. Vehicle emissions and urban runoff make up the other two major sources of non-point source heavy metal pollution. Heavy metals deposited on road surfaces are washed away with storm water, and often flow with little interruption into surface water (Davis, 2001). These methods of entry into the watershed are typically quite direct and the effects potentially disastrous, but amounts of heavy metals deposited by non-point source are dwarfed by point source contributions. Typically, rainfall leeching into ground water does not carry with it heavy metals. Studies show that metal concentrations tend to drop off sharply with increasing depth (Turer, 2000). Concentrating near the surface leaves heavy metals particularly vulnerable to transport via erosion.

2.1.2.3 Surface Disruption.

Surface disruption is defined as any changes to the surface of the landscape that prompt changes in the watershed's behavior. This consists of a number of individual problems for watersheds. Disruption of hydrology is the most general, consisting of any change that alters the path along which water flows. Erosion and sediment constitute the other two major problems, each dealing with movement of surface soil and debris by flowing water. Disruption of hydrology tends to induce erosion and thus sediment movements.

Disruption of hydrology constitutes any alteration that changes the path by which water reaches its ultimate destination. Typically, this consists of pavement or another surface with a similarly low porosity. Naturally, soil is quite good at absorbing water and allows the liquid to trickle downwards or infiltrate, eventually collecting in ground water. Low porosity surfaces, however, force water to flow over the surface and collect in another location. The same tends to happen in areas with clay surfaces or steep grades. In an unaltered landscape, water is filtered by layers of soil as it infiltrates. The result is cleaner water in the aquifer (Adams, 1986). Should the water collect any contaminants on the surface, they would most likely be disposed of before reaching the ground water. Infiltration both reduces the quantity of pollutants entering the surface water and allows for a larger amount of groundwater. When the water must flow over the ground rather than sink through, it tends to collect surface debris. As it flows over the surface of the landscape, the water readily carries with it sand, loose soil, nearly any liquid and anything soluble (Brown, 1996). With nowhere else to go, this flow ends in surface water, resulting in an unfiltered solution of water, sediment and pollutants. Disruption of hydrology is a major reason for the previously discussed methods of transfer of nutrients and heavy metals into the water system.

Erosion, in general terms, is the removal of solids by a current. For the purposes of this report, however, erosion is considered the movement of soil by flowing water. Runoff water flowing over or through loose soil collects soil particles and deposits the particles further in the direction of flow. This creates a bulk movement of soil that can be on the order of thousands of tons over a long period of time. Adverse effects of erosion in watersheds are primarily due to transporting sediment and contaminants. Runoff is the primary motive force in transport of nutrients and heavy metals because it tends to carry with it the contaminants contained within the loose surface soil (Francek, 2005). Turer (2000) observes that the highest concentrations of metal are in the top fifteen centimeters of soil. Thus, removal of the top layer of soil by erosion tends to put the most pollutants into the water system. This transport mechanism also proves to be the primary method by which nutrients reach surface water.

Sediment consists of solid particles that are carried and eventually deposited by fluid flow. In the case of watersheds, the solid is soil and the fluid flow is surface water. In a watershed, sediment creates problems by transporting contaminants, increasing turbidity and changing river flow patterns. Just as erosion carries pollutants, so does sediment. According to Anderson (2007), up to 90% of heavy metal waste is frequently transported in the river's solid phase. Increased flow volume tends to increase mobility of sediment. This relationship means that increases in runoff induce increased sediment movement and thus an elevation in contaminant mobility. Thus, via sediment movements, runoff is again linked to pollution mobility within watersheds.

2.1.2.4 Organic waste

Consisting of anything from animal waste and food scraps to discarded motor oil and solvents, organic waste constitutes a rather diverse area of contaminants. Discarded motor oil enters the environment along with urban runoff. Also, oil is very much akin to metals in that its transport tends to be dominated by solid movements (Delvigne, 2002). Most solvents enter water systems via point sources in industrial areas. Non-point sources for solvents are typically limited to incorrect disposal of paints or paint thinners and certain cleaning products. These sources are typically linked to urban runoff in very much the same manner as oils (Wojnowski, 2004). Animal wastes and food scraps tend to contribute nutrients to the watershed. Livestock animal wastes are a major source of phosphorus in agricultural communities, while pet wastes contribute to the nutrient load of urban suburban areas (Manitoba Agriculture, Food and Rural Initiatives, 2007). In the case of food and animal leftovers, organic wastes often exert influences on the watershed similar to excess nutrients.

Of particular interest when considering organic wastes are polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and aliphatic hydrocarbons (Sorenson, 2005). PAHs tend to occur naturally from the vast majority of chemical reactions that involve combusting organic carbon sources. Forest fires and coal burning are two examples of common natural creators of PAHs. In conjunction with burning coal, PAHs are also released from combustion of petrochemicals, constituting the bulk of PAHs' non-point sources. It is important to note that the bulk of PAHs are released from industrial (point) sources like tar production and hydrocarbon refining. While humans tend not to experience severe effects from PAHs, animals have been observed to be greatly harmed by PAH exposure. Mice, for example, tend to experience reproductive problems and immune system disorders (Agency for Toxic Substances and Disease Registry, 2007b).

PCBs are a class of aromatic chemicals that are distinguished by their dual ring structure featuring chlorine substitutions. Their primary use has been as a cooling medium in electrical applications, owing largely to the material's relatively low vapor pressure and poor electrical conductivity. Sources of PCBs are now limited mostly to landfills, since PCBs have not been manufactured in the US or used extensively since 1977. When exposed to PCBs, animals tend to develop skin conditions akin to acne and severe liver and thyroid gland injuries (Agency for Toxic Substances and Disease Registry, 2007c).

Aliphatic hydrocarbons are most commonly found in gasoline and other petrochemical fuel sources. Consequently, the primary source for these compounds in watersheds is urban runoff from vehicles. These compounds tend to be less toxic in contrast to other organic wastes. Very high exposures may cause nerve damage and damage reproductive ability. Most effects, however, are reversible when exposure is terminated (Agency for Toxic Substances and Disease

Registry, 2007d). These compounds, like heavy metals, tend to be closely tied to industry and regional development.

2.1.3 Organizations on a National Level

There are several organizations and agencies, including the EPA, that concern themselves with water pollution on a national level. This section describes two of those groups' contributions.

2.1.3.1 EPA

Many of the small watershed groups that operate on a local level operate under the guidelines established by the EPA. The EPA was founded in 1970 when the "White House and Congress worked together to establish the EPA in response to the growing public demand for cleaner water, air and land" (EPA, 2007, About EPA). This was the first time the government recognized the need for environmental legislation and pollution prevention (EPA, 2007). Since its establishment, the EPA has done much for the environment, including overseeing and enforcing the Clean Water Act passed in 1977. This piece of legislation outlines processes to control water pollution and eventually reduce it.

The Clean Water Act was modified in 1987 to include the regulation of non-point source pollution. The act did not previously address this problem but did recognize the need to do so. The amendment became section 319 of the Clean Water Act and it requires each state in the United States to have a plan to assess non-point source pollution in all of its navigable waterways. A navigable waterway is defined as:

> Navigable waters of the United States are those waters that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. A

> determination of navigability, once made, applies laterally over the entire surface of the water body, and is not extinguished by later actions or events which impede or destroy navigable capacity (Navigation and Navigable Waters, 2007).

This is a very broad definition which means that practically all rivers, streams, lakes, and ponds are considered to be navigable waterways. Section 319 of the Clean Water Act says that the Governor of each state must identify which bodies of water cannot meet acceptable water quality standards without additional action to control non-point source pollution, where the pollution comes from, the process for best management, which includes identification of best management practices and identifying the best methods and programs to achieve the goal. While doing this, the Governor and his staff must make sure no laws are broken, keep ground water intact, find federal assistance, and dispose of waste properly. There are funding programs set up which assist each state with its management programs (Clean Water Act, 1994). This section of the Clean Water Act is very important to the efforts of many watershed groups' success.

2.1.3.2 River Network

Another group that concerns itself with watershed pollution on a national level is the River Network. The River Network was founded in 1988, and it is an organization based out of Portland, Oregon, that provides support to smaller local watershed groups. Their philosophy is "that the solutions to river degradation are primarily local and must be created by citizen action watershed by watershed" (River Network, 2007, Mission Statement). They provide programs for local watershed groups including funding, educational training, and publications. In 1998 they combined efforts with the River Watch Network, another organization with similar goals. The River Watch Network was based out of Vermont and was founded in 1987. It was comprised of both students and residents of the area, and their work was based mostly on community involvement in cleaning polluted waterways (River Network, 2007). The River Watch Network helped local watershed groups monitor rivers, determine problems with the rivers, study the health of rivers, and use what they found to improve the ecosystem of the rivers. After the merging of the River Watch Network and the River Network to form the River Network, the group now has a “$3-million budget, with 19 staff working in three offices across the United States. [They] continue to provide personalized assistance, training and information to more than 700 Partner groups through [their] watershed programs” (River Network, 2007, Mission Statement). Groups like this are essential to smaller watershed groups as there are financial and political obstacles the smaller groups could not overcome otherwise.

2.1.4 Successful Efforts at Combating Non-Point Source (NPS) Pollution

There have been many efforts that have had success in cleaning up NPS pollution. This section describes a few of them and how they have been successful. A key to success, as evidenced in this section, is funding.

2.1.4.1 EPA and CWA

Although it can never be said that an effort to clean a watershed has been completely successful because it is indeed an ongoing process, there are many efforts going on around the United States that are making good progress. It starts with the EPA, whose mission statement includes “working for a cleaner, healthier environment for the American people” (EPA, 2007, About EPA). The Clean Water Act, established in 1977, “established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave EPA the authority to implement pollution control programs such as setting wastewater standards for industry” (EPA, 2007, Clean Water Act | Laws & Regulations). The CWA evolved from the Water Pollution Control Act (WPCA) which was established in 1948. Later, the WPCA was amended in 1972 to provide whistleblower protection to anyone who reports their employers for environmental infractions. These amendments led to the WPCA becoming the CWA in 1977. At first the CWA focused on point source pollution. Point source pollution is usually in the form of hazardous waste such as raw sewage and industrial waste which comes from a definite source. The CWA did, however, recognize the need to also combat NPS pollution and later was amended with section 319 in 1987 to regulate the NPS problem. Under the CWA, funding is allocated to each state to build and maintain water treatment plants as well as programs to combat water pollution in ways unique to a given watershed. Many of these programs have had success cleaning watersheds which are much better off due to the help of the CWA.

2.1.4.2 Clean Charles River Initiative

One example of a program that has had success under the EPA's Clean Water Act is the Clean Charles River Initiative (CCRI). The CCRI began in 1995 and came from efforts that began in 1988 to reduce the amount of combined sewage overflows (CSOs) in Boston Harbor and its surrounding area (EPA, 2006) CSOs are a result of "heavy rainfall or snowmelt events that cause surges of wastewater to enter sewer systems that are not equipped to handle the excess amounts, resulting in sewage being directly discharged into nearby waterways" (EPA, 2006, Massachusetts Water Resources Authority). CSOs can contain pollutants such as human waste, industrial waste and hazardous waste (EPA, 2006).

The Charles River has been known for years to be a very polluted and unclean river. Since 1995, the CCRI has made a lot of progress by "using sound science, cutting-edge technologies and, when necessary, strong enforcement" (EPA, 2007, Charles River History). This includes handling illicit sewer connections, separating sewer lines, and closing pipes that cause pollution (EPA, 2007). In 2006, the Massachusetts Water Resources Authority (MWRA) announced a plan to drastically reduce the pollution in the Charles by utilizing an unused sewage pipe during storms, optimizing resources at treatment facilities, separating sewage systems, and investigating construction of new pipes, real time controls, and better balancing flow of sewage (EPA, 2006, Massachusetts Water Resources Authority). These methods along with others that have been successful are sure to boost the progress the CCRI has made over the years.

A grading system is used to determine progress of the water cleanup. The system is based on the percent of days the Charles River meets swimming and boating standards according to the Massachusetts bacterial water quality standard. These standards state that waters "shall meet a geometric mean of 200 Colony Forming Units/100 ml of water with no more than 10% of the samples exceeding 400 cfu/100ml" (EPA, 2007, How EPA Evaluates Progress). Through the efforts of the CCRI, the Charles River has gone from a grade of D in 1995, passing swimming standards 19 percent of days and boating standards 39 percent of days, to a grade of B+ in 2006, passing swimming standards 50 percent of days and boating standards 97 percent of days (EPA, 2007, How EPA Evaluates Progress). This progress shows that the CCRI has been successful and has plans to continue improvement.

2.1.4.3 Pennsylvania: Manatawny Creek and Tributary

One watershed that benefited from section 319 grants is the Manatawny Creek, located in Southeastern Pennsylvania. The watershed covers 91.6 square miles. Ninety thousand dollars in section 319 grants were given to efforts to clean up the watershed. It suffered from "nonpoint source runoff from agricultural fields and operations [which] delivered high nutrient and sediment loads to Manatawny Creek and its tributaries" (EPA, 2007, Pennsylvania: Section 319 Success Stories). There was also an abandoned dam that "blocked migratory fish passage and caused stagnant flows, which allowed sediment to accumulate" (ibid). The watershed did not meet aquatic life standards because of low dissolved oxygen concentration, accumulated sediments, and high water temperature due to stagnant waters.

To solve the problems with the watershed, an abandoned dam was removed, stream channels were stabilized to reduce erosion, and buffers were restored to further reduce erosion. The Pennsylvania DEP and other project partners also did several things to increase community involvement in preventing this kind of pollution,

> In addition to engineering approaches, project partners used public education throughout the project's duration. They conducted public meetings on the dam removal project, participated in formal meetings with borough officials and residents to discuss riparian vegetation management, and distributed project information through print and television media (EPA, 2007, Pennsylvania: Section 319 Success Stories).

These efforts greatly helped reduce the water quality problems in this watershed. When reassessing the water afterwards, “Pennsylvania removed 20 miles of Manatawny Creek and 2.3 miles of the unnamed tributary from its 303(d) list of impaired waters” (ibid).

2.1.4.4 Maine: Cobbossee Lake

Another watershed that received section 319 funding from the EPA is the Cobbossee Lake watershed in central Maine. The lake had over 30 years of a history of pollution prior to success in cleaning it. It was suffering from “elevated phosphorus levels [that] promoted algae blooms, which discouraged recreation, spoiled aquatic habitat, and caused the lake to not meet water quality standards” (EPA, 2007, Maine: Section 319 Success Stories). The once beautiful lake was getting phosphorous deposited into it from “soil erosion and runoff from agricultural, residential, and commercial lands, and the gradual conversion of forested land into developed land," and that "agriculture accounted for about 60 percent of the phosphorus and developed lands accounted for about 40 percent of the phosphorus load" (ibid). This kind of NPS pollution where agriculture and development are the cause is very common.

To solve the phosphorous problems within the watershed, the EPA "funded two alum treatments that contributed to Cobbossee Lake's recovery. Alum forms an aluminum hydroxide precipitate that removes phosphorus from the water column and forms a long-lasting barrier on the lake bottom that substantially reduces phosphorus released from sediment" (EPA, 2007, Maine: Section 319 Success Stories). This treatment greatly reduced the amount of phosphorous in the water. Another way the local watershed group, the Cobbossee Watershed District, helped solve the NPS pollution problem was educating the public about 'best management practices.' Best management practices are ways to manage NPS pollution. As the EPA notes, efforts in this region resulted in, "five towns adopted ordinances requiring that new developments be designed to meet strict phosphorus allocation standards for storm water runoff" (ibid). As a result, the Cobbossee Lake now meets water quality standards each year.

2.2 The Sudbury-Assabet-Concord Watershed.

The Sudbury-Assabet-Concord (Su-As-Co) Watershed consists of three major drainage basins from each of the three major rivers: the Sudbury, the Assabet and the Concord. The watershed occupies about 377 square miles of drainage area in eastern Massachusetts. Figure 2.2 illustrates the watershed's position in Massachusetts. Nearly 365,000 residents live and work in the watershed's thirty-six towns. The Assabet and Sudbury rivers both begin from headwaters in Westborough and empty into the Concord downstream. At thirty miles long, the Assabet flows through Hudson, Maynard and Northborough to meet the Sudbury. The Sudbury flows eastward from its headwaters in the Great Cedar Swamp through Sudbury, Wayland and Lincoln. Refer to Figure 2.2.1 for a detailed map of river and lake locations in the watershed,

According to the Massachusetts Department of Environmental Protection (2004), of the 377 square miles the watershed occupies, the majority of the land (52.7%) is forested and largely undeveloped. Rural residential zoning constitutes the next largest land use, accounting for 13% of land area. Following closely is open land at 12.8% and urban with 10.5%. Wetlands and open water occupy the remaining surface area at 3.5 and 2.5 respectively. An additional 5% of land use is considered other.

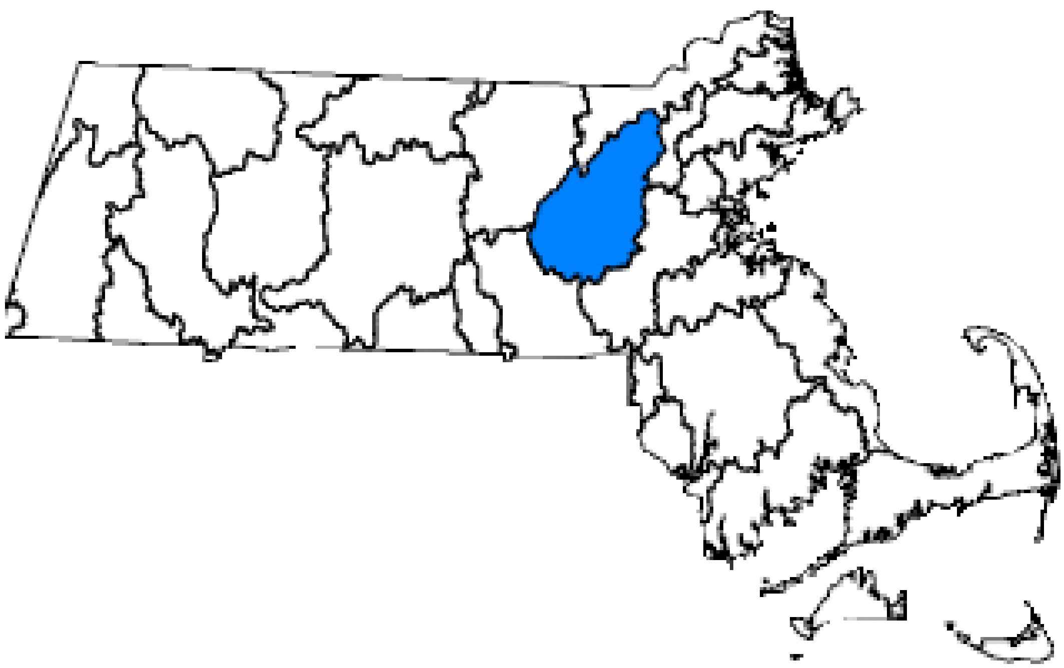

Figure 2.2: Location of the Su-As-Co Watershed in Massachusetts (O'Brien, 2005, p. 12)

2.2.1 Problems in the Su-As-Co

Currently, the watershed is classified as a mix of Class A and Class B water qualities. Class A waters are designated for public water supply use. In these clean waters reside fish that are safe to eat. They are protected as Outstanding Resource Waters in accordance with 314 Code of Massachusetts Regulations 4.03 (3). Also, Class A waters are suitable for primary and secondary recreational contact (swimming and boating). Class B waters are considered suitable as a water supply when properly treated. They too are safe for primary and secondary contact recreation and are designated as a habitat for aquatic life and wild life. Additionally, they are suitable for agricultural and industrial use. The water's quality is determined from a series of qualifications including but not limited to: dissolved oxygen concentrations, temperature, pH, solids, turbidity, oil/grease presence, taste and odor, aesthetics, toxic pollutants and nutrients. As one may expect, to be of acceptable quality the water must have dissolved oxygen concentrations, temperatures and pH levels, not to mention the other qualifications, conducive to supporting life (O'Brien-Clayton, 2005). The MASSDEP has established rigorous standards for categorizing nearly every aspect of surface water quality.

A 2005 study composed by Ambient Engineering looked more rigorously at classifications for surface water within the Su-As-Co. The report concluded that for nearly all uses (aquatic life, fish consumption, primary contact, secondary contact and aesthetics) the vast majority of assessed waters have quality that impairs their intended use. Fish consumption, for example, was deemed impaired for all samples collected. Impaired fish consumption means that unrestricted consumption is not permitted, a classification that may range from an outright ban to a weekly limit for at risk individuals. It is easy to see in Figure 2.2.1 that fish consumption impairment is virtually ubiquitous in the Sudbury and Concord Rivers. Fortunately, not all aspects of the river are as grave as fish consumption. Aquatic life use forms a good contrast, with a large portion of the water being declared "supported." Figure 2.2.2 illustrates well the prevalence of water in good condition (Ambient Engineering, 2005).

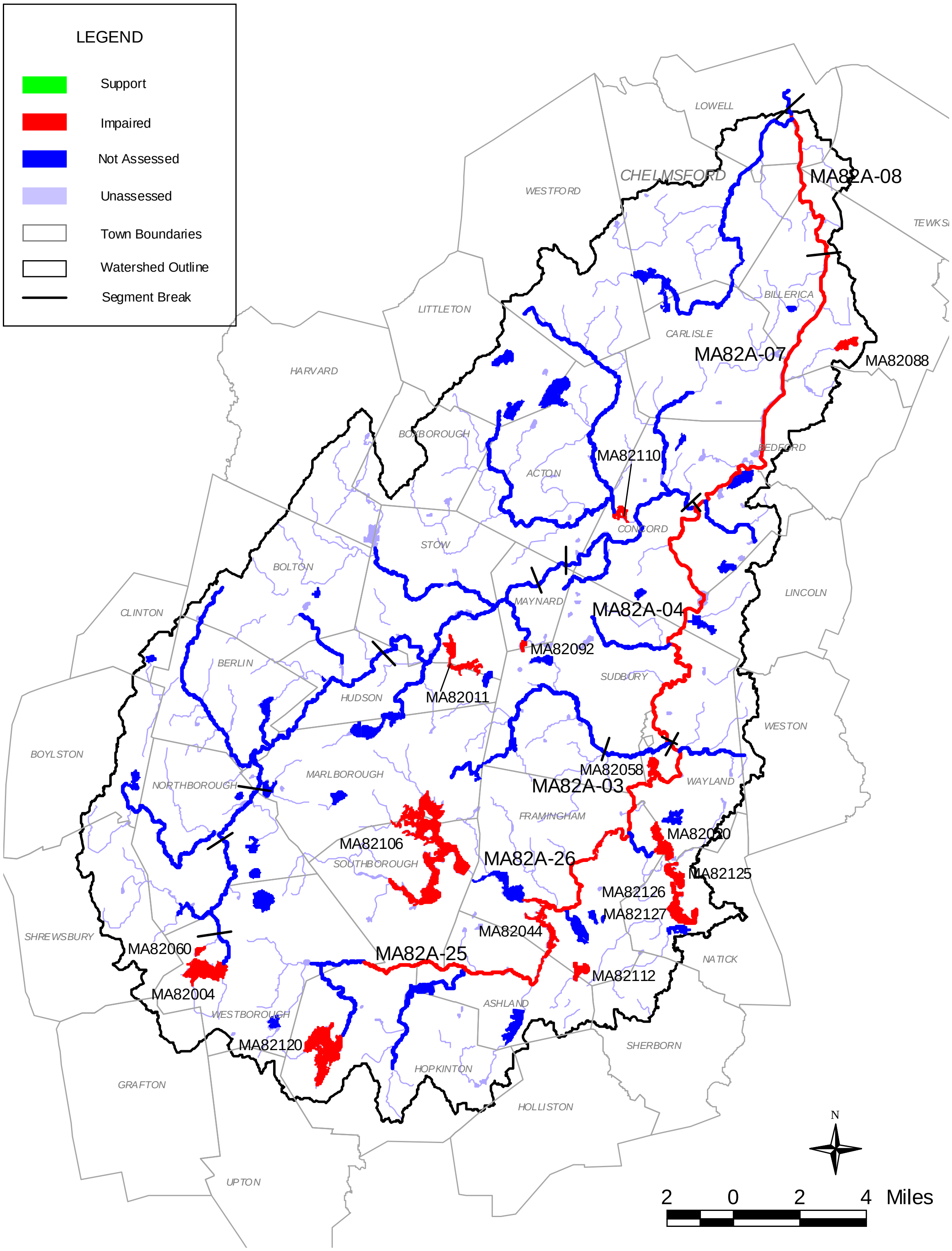

Figure 2.2.1: *Fish Consumption Use Summary (O'Brien-Clayton, 2005, p. xii)*

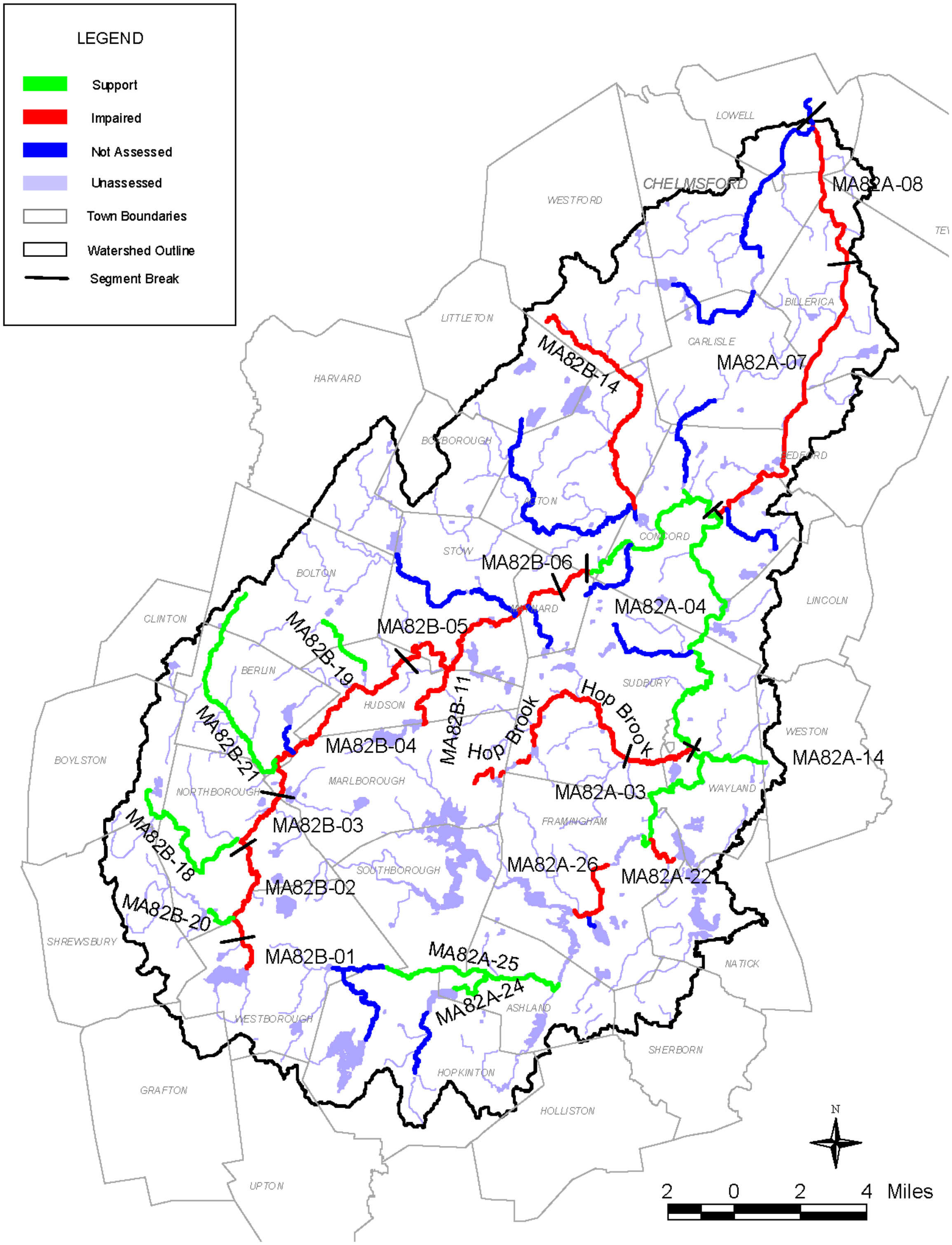

Figure 2.2.2: *Aquatic Life Use Summary (O'Brien-Clayton, 2005, p. viii)*

2.2.1.1 Nutrient Levels

The primary problem facing the Su-As-Co Watershed is elevated nutrient levels. The presence of excess nutrients, phosphorus in particular, has prompted a number of algal blooms and an overall state of eutrophication. Studies thus far have focused almost exclusively on phosphorus levels in surface water, but some data do exist for nitrogen. A 2004 Total Maximum Daily Load (TMDL) study conducted by the Mass DEP provides the bulk of phosphorus data available. The paper estimates that the TMDL for the Assabet River is 27.5 lbs/day. Citing a 2001 study, this report also notes that, "Non-point sources were observed to contribute the majority of total phosphorus and total nitrogen during 2 of 6 surveys" (Massachusetts Department of Environmental Protection, 2004, p. 20). Both surveys found that phosphorus discharge rate were higher during wet weather. This is quite understandable since wet weather greatly increases the quantity of runoff. The report predicts a maximum phosphorus discharge on wet spring days. The maximum value calculated for such a day is 1,390 lbs/day, an order of magnitude greater than the TMDL for maintaining water quality. By contrast, a low of 68.0 lbs/day is estimated for intense summer conditions. Even the lowest recorded phosphorus flow is more than double the estimated TMDL. It is important to note that of the maximum 1,390 lbs/day, only 319 lbs/day is ortho-phosphorus, or biologically available phosphorus. Dry measurements at 68 lbs/day are accompanied by an ortho-phosphorus level of 52 lbs/day (Massachusetts Department of Environmental Protection, 2004). These values are not in proportion, suggesting that the bulk of runoff phosphorus is not biologically available, and thus less of a problem for the watershed.

2.2.1.2 Heavy metals

Mercury constitutes the major heavy metal problem in the Su-As-Co. While its physical presence in water is low, it appears in dangerous quantities in fish. The United States Food and

Drug Administration recommends limiting consumption of fish with 0.5 ppm (parts per million) mercury to below fourteen ounces per week. Also, the FDA recommends that pregnant mothers, women who may become pregnant and nursing mothers should limit their fish consumption even further. As noted in the *Su-As-Co Watershed 2001 Water Quality Assessment Report,* the 1986 and 1987, mercury levels were mostly below 0.5 ppm in sampled fish (O'Brien- Clayton, 2001, p. 11). Mercury concentrations are higher than their 1987 values, thus very little of the fish in the watershed is currently edible. Elevated mercury and PCB levels have made the bulk of the fish dangerous to consume. Currently, all surface water in the Su-As-Co is an impaired state for fish consumption. This impaired classification is accompanied by a specific warning from the Massachusetts Department of Public Health that clarifies the restrictions. The recommendations range from a suggestion for no person to consume any fish caught to the suggestion that no pregnant women, nursing women or young children eat lake trout or salmon in excess of twenty-four inches in length (Ambient Engineering, 2005). Understandably, it is direct actions like fishing bans that have the largest impact on the community.

Additional studies have examined the presence of other heavy metals in the Assabet River. A 2003 US EPA study looked at concentrations of a number of heavy metals at several locations along the Assabet River (Sorenson, 2005). Concentrations of a number of toxic trace elements were considered in the context of probably effect level (PEL), probable effect concentration (PEC) and threshold effect level (TEL). PEL represents the exposure quantity at which one may expect to observe adverse effects, while PEC is the concentration above which effects are likely to occur, and the TEL is the lowest concentration that yields expected effects. In most cases, the concentrations for each quantity increase in the following order: TEL, PEL and PEC. Arsenic was discovered to exceed the established PEL of 17 ppm in four of seven survey sites. All sites were determined to have mean chromium levels far in excess of the PEC concentration. The lowest of 155 ppm is considerably larger than chromium's 111 ppm PEC value. Lead values were better than both arsenic and chromium. While all values were in excess of the designated TEL concentrations, only six exceeded the PEL and of those only two were greater than the PEC values (ibid). The aforementioned data represent the most current comprehensive study, with samples collected in 2003 and results published in 2005.

2.2.1.3 Surface Disruption

Unfortunately, analysis of the effects of surface disruption is quite sparse, as noted by Ambient Engineering (2005), "Sediment analysis information on the [Su-As-Co] Watershed is somewhat limited" (p. 3-3). Ambient Engineering references a 1998 nutrient and limnological study conducted in Lake Boon as an example of an applicable source. The Lake Boon study examines sediment as a transport mechanism for phosphorus. The Lake Boon study examines sediment for the presence of contaminants and does not look at the physical movements. Looking at growth of macrophytes, the Lake Boon study was unable to determine the cause of the measured results (Massachusetts Department of Environmental Affairs, 2001). Macrophytes are plants that root in sediment or loose underwater soils. They are useful indicators of changes in water conditions, most notably nutrient and sediment movements (United States Department of Environmental Protection, 2007b). The Lake Boon study noted that, "it is difficult to separate the effects of sediment deposition, which reduce depth and extend the littoral zone, from the effects of increased nutrients" (Massachusetts Department of Environmental Affairs, 2001, p. 7). Other studies that may shed light on sediment analysis are quite limited. Sorenson's 2003 report examined sediment samples for the presence of metals. Along with concentrations of contaminants, the study reported sediment depths. The 2005 Ambient Engineering report too noted sediment depths at points where samples were taken. Neither report drew conclusions from sediment depths regarding deposition rates or erosion rates. All three reports, however, do note that sediment is the primary motive mechanism for most pollutants, but fail to quantify such findings. The exception to the absence of quantative data regarding pollutant flow in sediment is phosphorus, where detailed evaluations of phosphorus flux from sediment are available.

2.2.1.4 Organic Waste

Evaluations thus far for organic wastes in the watershed have focused almost exclusively on industrial (i.e. point source) contaminants. Concentration danger levels for these contaminants use the same nomenclature as established for heavy metals (see sec 2.2.1.2). Sorensen (2005) and his team focused almost exclusively on non-point source organics. The team's studies focused on polycyclic aromatic hydrocarbons (PAHs), extractable petroleum hydrocarbons (EPHs) and Polychlorinated Biphenyls (PCBs). Only one of the seven Assabet sampling sites saw a mean PAH concentration that exceeds the associated PEC value. This site, however, greatly exceeded the target safety value, recorded at 89,500 ppm in contrast to a PEC of 22,800 ppm. None of the other sample sites came within even fifteen percent of being considered dangerous.

EPH levels were very low in nearly all tests. As Sorenson (2005) notes, "The highest measured total EPH concentration (438 mg/kg from the surface sample at the site P54) was at least an order of magnitude less than the maximum allowable concentration for landfill reuse of approximately 5,000 mg/kg" (p. 34). To provide context to a level of 438 mg/kg, the threshold for safe human contact is 80,000 mg/kg.

PCBs, by contrast, were abundant in most samples. While only one sample exceeded human contact demands, only two samples did not exceed the TEL value (Sorenson, 2005). In an attempt to add context to the seemingly arbitrary concentration quantities, one may note that the net effect of PAH presence in the watershed has yielded several government responses. The fish in Hocomonco Pond in Westborough are considered unsafe to eat under any circumstance, and the Massachusetts Department of Public Health recommends limiting consumption of the fish in Cochituate Lake due to the presence of PCBs (Ambient Engineering, 2005). The generally low levels of organic compounds seem to account for the lack of attention devoted to their cleanup within the Su-As-Co.

2.2.2 Watershed groups in the Su-As-Co

The Su-As-Co Watershed has had some major NPS pollution problems. In order to cope with these problems volunteers created watershed groups. Some of these were established from government grants, while some are strictly run by volunteers. All of these watershed groups have some effect on the Su-As-Co Watershed and have made major steps to improving overall water quality.

2.2.2.1 Assabet River National Wildlife Refuge

The Assabet River National Wildlife Refuge (Assabet NWR) is located in the towns of Hudson, Maynard, Stow and Sudbury. The Assabet NWR received its land in the fall of 2000 from the U.S. Army. NWR received 2200 acres and of that 3.5 square miles border the Assabet River (Assabet River NWR, 2007). Although the refuge's primary focus is for migratory bird conservation, the Assabet NWR has made improvements since their conception and even made the area suitable for human recreation in 2005. Currently the refuge and its non-profit associate, Friends of the Assabet NWR, focus much of their manpower on educating citizens on wildlife and maintaining the land, specifically the trails.

2.2.2.2 Great Meadows National Wildlife Refuge

A second NWR is the Great Meadows National Wildlife Refuge (GMNWR). Much like the Assabet NWR and other NWRs the goal of this refuge is to protect wildlife and their habitat. GMNWR borders the Sudbury and Concord Rivers for twelve miles. These twelve miles are located in Billerica, Bedford, Carlisle, Concord, Framingham, Lincoln, Sudbury, and Wayland. The current goals of the refuge are to control exotic plants, manage water level and vegetation constraints, and manage farming practices (GMNWR, 2007).

2.2.2.3 Sudbury Valley Trustees

In addition to federal land protection groups, a private group, the Sudbury Valley Trustees (SVT), is an influential leader in protecting land. SVT owns and protects, through gifts and purchases, 2150 acres of high value property in 14 towns. And, of those 2150 acres, 944 acres have had development bans placed on them (SVT, 2007). There are three major ways by which SVT tries to improve the Su-As-Co Watershed. The first is to increase the amount of land that they already own and protect. They accomplish this by presenting the advantages of owning land in order to deter development, both financially and environmentally. Secondly, SVT has multiple tours via walking, bike riding, kayaking or canoeing that increase public awareness. Lastly SVT holds informational sessions to increase knowledge of the human interactions with the environment.

2.2.2.4 Massachusetts Audubon Society

The Massachusetts Audubon Society’s (Mass Audubon) headquarters is in Lincoln, MA, part of the Su-As-Co Watershed. The Audubon Society’s mission is to preserve and restore animal’s ecosystems and their habitats, thus improving the watershed (National Audubon Society, 2005). Also, incorporated with Mass Audubon is the Drumlin Farm Wildlife Sanctuary. This 232 acre plot of land is not only a wildlife sanctuary but a full working farm located in the Su-As-Co

Watershed (Mass Audubon, 2007). Both organizations are important to keeping land in the watershed protected.

2.2.2.5 Organization for the Assabet River

Despite not actually owning land, some groups just hold events to improve water quality in the watershed. An influential watershed group in the Su-As-Co is the Organization for the Assabet River (OAR, 2005). OAR, through various methods, is trying to improve water quality, regain recreational uses of the river, restore culture and history to the area, and provide good habitats for native animals. As previously stated, high nutrient levels are a major problem in the watershed. OAR does a good job of warning the public, through their website and at events, of the dangers of lawn care products, dishwater detergent, and pet waste and their impact on water's nutrient levels. Their goal is to get the whole watershed to at least a Class B water quality level and allow for swimming and recreational uses. Obtaining this water quality level is achieved through a multitude of events that range from cleanup events, to informational sessions, even to parades.

2.2.2.6 Assabet River Stream Watch

Assabet River Stream Watch (ARSW) focuses on water level and flow rate in streams off of the Assabet River. ARSW is a branch of OAR. Using the water level and flow rate ARSW is able to decipher what fish should be living there and compare that to what fish are actually living there (ARSW, 2007). In addition to focusing on fish, ARSW also shows the dangers of abundant water uses, like watering lawns and gardens or showering too long and often, during summer dry spells, which often leads to poor water flow rates.

2.2.2.7 Sudbury River Watershed Organization

The Sudbury River Watershed Organization (SRWO, 2007) is similar to the other non-land owning groups. This organization focuses on the Sudbury River and its water quality and quantity. Through many events, SRWO gains public interest and tries to improve conditions in the watershed. SRWO's focus is on culvert pollution, dog excrement and water flow issues. Pet waste, as in dog excrements, contributes to the high nutrient levels in water.

2.2.2.8 Sudbury, Assabet, and Concord Wild and Scenic River Stewardship Council

The Sudbury, Assabet, and Concord Wild and Scenic River Stewardship Council (RSC, 2007) is a group that was created to coordinate conservation of the three rivers. The group has members from many of the previously mentioned groups. Members also include representatives from the MassDEP, U.S. Fish & Wildlife Service, and the National Park Service (NPS). In addition to sponsoring and organizing occasional clean up sessions and informational sessions RSC also serves as an official advisory committee to the National Park Service on any decisions that could affect the watershed. Also RSC puts on a major multi-day event, "Riverfest," that many of the previous organizations are involved in.

2.2.2.9 Su-As-Co Watershed Community Council

The Su-As-Co Watershed Community Council (SWCC) has a slightly different approach to the watershed. Their main goal is to obtain a community-based alliance to increase financial and environmental wellbeing. The focus is to combine efforts from federal government, state government, businesses, and divergent watershed groups to achieve one main goal, improving the watershed (SWCC, 2007). SWCC has major events in which representatives from different government agencies, different businesses and different watershed organizations all come to update everyone on their progress since the last meeting, what their goals are for next time, and how they all fit together.

2.2.3 Current efforts to improve water quality and increase public participation

One current effort that is the goal of both the government and the watershed organizations is land preservation. Government officials and environmental engineers have been correlating development and water quality for years. As for the government, wildlife refuges and parks among other things help control development. Outside of the government, groups such as SVT, a land trust, and the Audubon Society are able to protect land and deter major development.

2.2.3.1 Water quality data collection

Another way to improve the water quality is through systematic scientific monitoring. The data obtained by these methods vary from water depth and flow rate readings to water quality readings. All are important in all rivers and are problems in the Su-As-Co Watershed. Flow rates and depths are calculated by the Mass DEP, the ARSW with OAR, and the United States Geological Survey (USGS). These readings are instrumental in providing answers to whether or not groups' projects are being productive or not.

The MassDEP conducts flow rate and water quality readings sparingly, around every five years. Previously readings were taken during dry spells to suggest the worst possible conditions, but those results only showed the worst possible conditions for point source pollution (MassDEP, 2007). Major attention has been switched to non-point source pollution of late. In order to obtain more accurate readings, samples are taken during wet months, and those are far more accurate for non-point source pollution.

ARSW takes quality and flow readings at nine streams off of the Assabet River, and OAR, their parent group, takes twelve on the actual Assabet River. These surveys measure flow rate, depth, and quality. For quality the two groups test for dissolved oxygen, water temperature, pH, phosphorus, nitrogen and total suspended solids (ASRW, 2007). These data help identify the major problems facing rivers.

USGS has a tool used by most of the groups previously mentioned. It is a real time, continuously updated measure of flow rate and depth. Despite having limited numbers of check points, this is an invaluable tool. Long term data can be easily converted to a graph on their website and any sudden change in water flow or depth can be quickly caught.

2.2.3.2 Informational Sessions

There are various informational sessions put on by the watershed groups. There are basically two different types of sessions. The first is an activity type targeted at families and kids. The purpose of these events would be to increase public interest in the watershed by enhancing fun and recreational activities throughout the watershed. The second type is a workshop that is strictly educational. This may be less appealing to kids and families but would make kids far more knowledgeable about the environment. We discuss in the following paragraphs a few of the major events of each type that take place every year.

Tour guides from SVT take guests down trails, rivers, and streams to see the natural wonders throughout the watershed and share the rich history of the watershed. These tours can be done by walking, biking, kayaking, or canoeing. Most of the tours are arranged to be during the day. However, some night tours are available in order to see nature from a different point of view (SVT, 2007). OAR and SVT team up with Musketaquid Center for the Arts and Environment to organize River Solstice. This is a picnic for all members that include entertainment and a canoe ride (OAR, 2005). The largest of all of the festivals is RiverFest which is put on by RSC. This is a four day long festival that has numerous events that anyone can take part in. This festival has over 45 events that take place from a Thursday to Sunday in mid-June every year. Events include tours by biking, walking, kayaking, and canoeing (RSC, 2007).

Educational workshops are an alternative to the festivals. These workshops cover many aspects of watershed education. Some are geared toward young children and show kids how important the environment is (OAR, 2005). Some are presentations about current and new problems that have been found in the river (SWCC, 2007). Lastly, some are evaluations of previous projects and how well they were run and if they were completed in a timely manner.

Water Wise Workshops are a series of workshops aimed at young children who do not have a clear understanding of the environment. These are put on by OAR and run throughout the year. The workshops focus on the importance of keeping the environment clean and not using an abundance of water (OAR, 2005). Along with these workshops, OAR's branch group, ARSW, puts on the water conservation talk. The talk shows, pictorially, what has been consistently happening to the streams during dry spells (ARSW, 2007). Communities Connected by Water is a slideshow presentation put on by the SWCC. This is a compilation from all of the watershed groups in the Su-As-Co Watershed. The presentation shows all of the major problems and challenges that they have run into recently. This is an effort by the SWCC to enhance interaction among different groups in the watershed (SWCC, 2007). The annual River Visions Forum is another community based workshop put on by SWCC. This event is open to everyone including area business leaders, state, regional, and town government agencies, watershed group members and leaders, and interested citizens. Here, at large group members show what they have done in the past year and how their work fits into their improvement plan. Also, municipal leaders show new problems and possible new directions groups can start planning for.

2.2.3.3 Volunteer Improvements

Volunteer opportunities create a fundamental way for the public to help improve their watershed. Storm drain stenciling is a great way to remind citizens that what goes down the drain ends up in rivers. Invasive plants come into the watershed and must be removed; often times volunteers are the only available manpower to do such a job. The most obvious way to reduce pollution is to actually have volunteers pick up trash in the watershed. These are all easy ways to help improve water quality.

SRWO has multiple trips around neighborhoods to stencil storm drains. Typically volunteers will walk around neighborhoods and with a stencil and spray paint and stencil a friendly reminder on the storm drain that this drain goes directly to the river (SWRO, 2007). SVT puts on invasive plants documentation and extermination. Here volunteers explore trails all around the watershed and document and remove invasive plants that could cause major problems for other plants and for animals (SVT, 2007). The most popular way to clean rivers is to have actual river clean ups. Most of the organizations offer some sort of cleanup effort, if not multiple cleanup efforts. Among others, OAR has their "Annual Assabet River Clean Up," and RSC's RiverFest alone has multiple cleanup efforts.

The watershed groups are invaluable to the improvement of the watershed. There is no doubt that water quality in the watershed has improved greatly. There is a healthy number and type of activities, volunteering opportunities and workshops to increase education. Watershed groups of all kinds, despite still having water quality and quantity problems, seem to be a large part of the improvement process.

2.3 Summary

Watersheds at large suffer from a number of problems, but thankfully they have a number of groups working to combat the problems and even a number of successful methods that are often applicable. The four major problems facing watersheds are nutrient levels, heavy metals, surface disruption and organic wastes. Nutrients induce uncontrolled plant growth, while heavy metals and organic wastes cause direct damage to organisms in the water system. Surface disruption provides the primary mechanism by which pollutants reach and move in surface water. All four are intimately linked, exerting a great deal of influence upon one another, often compounding problems. Also, each represents a type of pollution that degrades water quality. Two groups that work to combat problems in watersheds are the Environmental Protection Agency (EPA) and the River Network. Both of these groups operate on a national level and concern themselves with guiding locally-led watershed groups. The EPA is a government agency that has produced such legislation as the Clean Water Act which regulates water and the handling of pollution. The River Network supports small watershed groups by producing educational literature, training programs, and funding. Section 319 of the Clean Water Act has proven instrumental in successfully addressing non-point source pollution. The Manatawny Creek in Pennsylvania and Cobbossee Lake in Maine are two examples of cleanup efforts that have shown improvement under Section 319. The Clean Charles River Initiative is another example of a cleanup that has been successful in demonstrating positive change.

The Sudbury-Assabet-Concord (Su-As-Co) Watershed, located in Eastern Massachusetts, is currently the target of a number of cleanup efforts. The river is plagued by elevated nutrient levels creating a state of eutrophication. Additionally, unacceptably high heavy metal and organic waste levels are impairing the watershed's ability to sustain functionality. Sediment too is proving quite problematic in the watershed. Much of the water within the watershed is deemed impaired by the State of Massachusetts. Despite efforts by interest groups and stakeholders, NPS persists as a significant barrier to achieving significant and long term water quality improvements.

3. Methodology

The goal of this project is to provide suggestions to guide non-point source (NPS) cleanup efforts and to perhaps improve cleanup efficiency and effectiveness in the Su-As-Co Watershed. Four key objectives were achieved. These objectives were:

1. Identify the most successful NPS pollution cleanup efforts in the United States and identify the best practices for NPS pollution cleanup.
2. Identify current and collaborative efforts among Su-As-Co Watershed groups and how they are affecting NPS pollution
3. Determine the current and potential role of community participation in combating NPS pollution within the Su-As-Co Watershed.
4. Determine linkages between development and water quality in the Su-As-Co Watershed.

3.1 Identify successful NPSP cleanup efforts:

One method we used to recommend solutions for reducing the amount of NPS pollution in the Su-As-Co Watershed is we identified successful NPS pollution clean-up efforts to determine which of them can be applied to the Su-As-Co Watershed. This was done by conducting interviews and researching what has been done under section 319 of the EPA's Clean Water Act that has had success around the United States. This section of the Clean Water Act outlines methods for finding a way to deal with NPS pollution and allocates funds to each state. There were several projects done around the United States that used section 319 funds to combat NPS pollution successfully. Many of the methods used can be applied to the Su-As-Co watershed.

Most of the research was done on the internet. The EPA has an entire website that is dedicated to successful watershed cleanup efforts broken down by state and further broken down by successful effort. Each of the efforts has its own site and a great amount of detail is given regarding the problem, highlights, results, and partners & funding. This research tool made it very easy to quickly access information about successful efforts across the United States

We also consulted expert sources who suggested ways to combat NPS pollution in the Su-As-Co Watershed. The most important to giving information on successful efforts was Savas Danos, general manager of the Littleton Electric Light & Water Departments in Littleton, MA. He led a project to improve water quality in Long Lake in Littleton, MA, which has had a great deal of success. Mr. Danos went into detail on methods that were used, which include several low-impact development best management practices as well as community involvement. The information given to us by Mr. Danos was very crucial to our research into successful watershed cleanup efforts.

Many states have been able to rid waterways of NPS pollution after years of problems with the guidance of the EPA. We have examined the methods that have been successful and determined which ones can be applied to the Su-As-Co Watershed. We used the information found through research, as well as interviews, to help us come up with a realistic set of recommendations to combat NPS pollution in the Su-As-Co watershed.

3.2 Collaboration among watershed organizations and community involvement

In order to assess the collaboration of watershed groups and the extent of community involvement, we asked prominent members involved with watershed management, from both, the MassDEP and local watershed groups, using face-to-face interviews (See table 3.2). We made a concerted effort to gain diverse opinions throughout the watershed. The first groups we tried to make contact with were the advocacy groups, such as the SRWO and the OAR. Unfortunately, we were unable to complete an interview with OAR. Following the advocacy groups we tried to make contact with the largest land trust in the area, SVT. After we discovered the improvements that occurred at Long Lake, we decided to interview Savas Danos from Littleton Electric Light & Water Departments. We felt it was important to gain the opinion of the portions of the state government that focuses on this watershed, so we interviewed Paul Hogan, in charge of permitting for the watershed. After meeting with Paul Hogan he referred us to Joan Kimball, which he said, “the closest that we have, in the state government, to someone that really promotes the volunteer work and the outreach.” We believed that the RSC, part of the NPS and creator of the largest festival in the watershed, would give us another view that would be more representative of the watershed as a whole. We then felt that one of the NWR’s would further diversify the information from the groups so we attempted to interview ARNWR, but efforts to contact with them were not returned. Lastly, we decided that the SWCC, as an umbrella group, would be the prime interviewee to complete the process and gain an overall opinion on different topics throughout the watershed. Time constraints of the project coupled with the small staffs that non-profits commonly have forced some interviews to be completed via either phone or email.

We developed a basic interview protocol for the groups to be interviewed that helped to identify both problems and previous solutions pertaining to the degree of collaboration among watershed groups and level of community involvement (See appendix A for interview protocols). We then researched each group to gain a better understanding of the overall goal of the group and the previous actions that they have taken to improve the watershed. After understanding the group’s goals for improving the state of the watershed we altered the basic interview protocol to better suit each interviewee.

In order to more easily analyze the data, we recorded the interviews, after getting approval from the interviewee, by using an audio recorder. The data were analyzed through a process loosely based on a version of content analysis (Berg, 1998). Each of the interviewees’ answers that were analyzed were split into one of two categories, or frames, either community participation or collaboration among watershed groups. Each response was then labeled as positive, improvement toward diminishing non-point pollution in the watershed; neutral, neither improving nor worsening non-point pollution in the watershed; or negative, worsening non-point pollution in the watershed. The data were then able to be effectively analyzed (See Appendix D for Data matrices).

Table 3.2 Table of interviewees

Organization	Position	Name
Sudbury Valley Trustees	Executive Director	Ron McAdow
Sudbury River Watershed Organization	At Large Member	Frederica Gillespie
Su-As-Co RSC	Project Coordinator	Lee Steppacher
Su-As-Co Watershed Community Council	Executive Director	Nancy Bryant
Massachusetts DEP	Permitting Coordinator	Paul Hogan
Littleton Electric Light & Water Departments	General Manager	Savas Danos
Department of Fish and Game	Riverways Director	Joan Kimball
Sudbury River Watershed Organization	At Large Member	Frederica Gillespie

3.3 Impact of development on water quality

The impact of development on water quality was assessed in four parts. First, land use changes and population changes were determined and compared. Next, water quality was assessed for key parts of the watershed and compared to changes in population and land use. An effort was then made to find influencing factors that correlate with water quality. Finally, other factors were examined for potential links to water quality.

To begin, we gathered and analyzed GIS data for the purpose of determining land use trends and the connection between land use and water quality. The state of Massachusetts provides free access to GIS data layers via the Office of Geographic and Environmental Information. The major watersheds layer provided an outline of the watershed that would provide the template for clipping each of the layers. Among the array of GIS layers used, those that contain land use data, census data, water quality information, dumping permit locations, major hydrography positions and aquifer locations were of great interest. Since land use data and census data were available per town, each town layer needed to be combined to form a unique layer, which was then cut to the shape of the watershed. The result was a collection of data layers in the shape of the Su-As-Co. Combinations of different layers were exported as images to demonstrate spatial patterns (coordination of dumping sites and land use for example). Appendix C features maps and images generated with GIS data, including detailed land use, changes in developed land use and changes in individual land use type. Each layer has encoded in it a set of data that quantifies values for each of the polygon cells. The data sets for the land use and census layers were exported into a proprietary database format, which was then converted to an Excel format for analysis.

The Excel files containing land use and census data were then analyzed in an effort to identify and quantify changes in land use and population, which is to say to gauge the extent of development. The land use data include information for 1971, 1985 and 1999, while the census data were used from 1970, 1980, 1990 and 2000. Table E.15 shows census data collected and calculations for interpolating data. It was assumed that the rate of change of population between each of the years is linear and populations per town in 1971, 1985 and 1999 were interpolated. Assuming linear behavior neglects the logarithmic nature of population growth, but we decided that an overestimation would the safest method. We predicted that the populations calculated for 1971 and 1999 would be very accurate and the predicted value for 1985 would be exaggerated, but still within acceptable bounds. Turning to the exported land use data, a visual basic script was written in Excel to facilitate sorting the 180,000+ cells by town and land use type. With interpolated census data and the land uses sorted for each of the 21 land uses and 35 towns, the data analysis could be conducted. The absolute change and percentage change in land use during each of the three periods (1971-1985, 1985-1999 and 1971-1999) was calculated. Additionally, land use per capita absolute and percentage changes were calculated. Most importantly, the ratio of percentage change of land use to percentage change of population was calculated. The ratio of the two percentages allows one to determine if land use change is outpacing population change.

GIS data were consulted to find which towns are completely within the confines of the watershed. These towns, or core communities as they are henceforth referred to, are used to simplify analysis and it is hoped to provide more accurate results. A map of the core communities can be found in figure C.9. With their bounds completely within the watershed, presumably all their legislation would be concerned with the Su-As-Co, they are subject to the same problems and there are no worries about populations existing outside the watershed skewing the per capita calculations. Furthermore, we observed that the nine towns provide a varied survey of communities in both land use and population size. The land use types were then consolidated into five categories from the 21 raw categories. From these two generalizations, each of the 24 tables was condensed from 735 cells each to 35 cells each. We determined that such generalizations do not significantly affect results since consolidations were based on predicted runoff performance.

Next, the focus was turned to assessing water quality. Our interview with Paul Hogan of the Massachusetts Department of Environmental Protection brought us the bulk of the data used to determine past water quality. In particular, Hogan provided us with four crucial documents: two water quality assessments in the Assabet and two waste water discharge reports. Unfortunately, we were able to acquire data only for the Assabet. Despite the lack of a comprehensive set of data, those which were collected are very consistent with respect to location and date. Contemporary phosphorus levels were determined from the Assabet TMDL report. The water quality focuses largely on bacteria levels and oxygen content. More recent tests add metals and a number of other tests. Since phosphorus is the main focus of both research and clean up efforts, we elected to concern ourselves with phosphorus as well. Next, phosphorus discharge levels were examined. Using the reports provided by Hogan and contemporary assessments from the Assabet TMDL, changes in amount of point source waste water discharge were examined. A very rough figure was determined for municipal waste water discharges based on flow volume and concentration. In particular, discharge characteristics of discharge effluent were from municipal waste water treatment plants from each of the years were examined. The intent of this evaluation was not to assess discharge, but merely to determine if there was an increase or decrease during the time period being considered. Statistics were generated to determine the significance of non-point source discharges compared to point source discharges.

4. Results & Analysis

This section discusses the results of our research. It is broken up into four sub-sections, one for each of our objectives. These objectives are: to identify the most successful non-point source (NPS) pollution cleanup efforts in the United States and identify the best practices for NPS pollution cleanup, identify current collaborative efforts among Su-As-Co Watershed groups and how they are affecting NPS pollution, determine the potential role of community participation in combating NPS pollution within the Su-As-Co Watershed, and determine linkages between development and water quality in the Su-As-Co Watershed. An analysis of the results is also provided to assess the logistics of applying what was found to the Su-As-Co watershed.

4.1 The most successful non-point source pollution cleanup efforts

The main problems that are caused by NPS pollution are excessive sedimentation and high nutrient levels. There is also the problem of garnering public participation and funds to help combat sedimentation and high nutrient levels. There have been many successful efforts at solving these problems, examples being Manatawny Creek and its tributary in southeastern Pennsylvania, Cobbossee Lake in central Maine, and Long Lake in Littleton, Massachusetts. Each of these three bodies of water have had success in either decreasing sedimentation, decreasing nutrients, or raising public support for future prevention, or some combination of the three.

4.1.1 Sediment removal

The problem of sedimentation is caused by storm water that runs over the ground and picks up dirt and sand on its way into a body of water. In the case of Manatawny Creek, there was a great deal of sediment build-up due to an unused dam and erosion on the creek’s banks. To solve the problem, the people working on the project removed the dam which restored flow to the river, gradually taking the sediment with it. They also reinforced the banks of the river with riparian buffers, among other things, which further reduced erosion.

*Figure 4.1.1.1: Riparian Buffer (*EPA, 2007, *Pennsylvania: Section 319 Success Stories)*

The results in dealing with sediment at Manatawny Creek "helped to reduce annual sediment loads to Manatawny Creek by an estimated 800 tons" (EPA, 2007, Pennsylvania: Section 319 Success Stories).

In the case of Long Lake, in Littleton, MA, a 1.5 acre wetland was built to intercept storm water containing sediments. The wetland is man-made and designed to hold storm water that would otherwise flow into the lake.

While the water is moving through, sediment settles to the bottom. In the case of Long Lake, storm water flowing down five streets flows into the wetland shown in Figure 4.1.1.2. A major advantage to this wetland is "dredging a lake is too expensive but draining [storm water wetlands] and bringing a back-hoe in there with a dump truck and dredging that is a day's work"(Appendix B, section 1). The wetland has no wildlife in it so there is no harm in draining and dredging it.


Figure 4.1.1.2: Man-made storm water wetland at Long Lake (Danos, 2006, p26)

The methods used in Manatawny Creek and Long Lake for sediment removal were very successful and can be used in the Su-As-Co watershed. Both projects were funded, in part, with grants coming from section 319 of the Clean Water Act. Manatawny Creek was funded by a $90,000 grant (EPA, 2007) and Long Lake was funded by an $180,000 grant (Danos, p. 2). The success these projects have had is related to the amount of funding they received, and that will also be true for bodies of water in the Su-As-Co watershed.

4.1.2 Nutrient Removal

Another major problem caused by NPS pollution is high nutrient levels that, again, come from storm water runoff. The water runs over streets and lawns, picking up fertilizers, salt, and other pollutants that are then deposited into the body of water. The project at Cobbossee Lake was primarily focused on reducing the amount of harmful nutrients that had accumulated in the lake. High levels of phosphorous caused algal blooms which reduced the clarity of the lake and depleted oxygen levels. To solve this problem, two alum treatments were performed. Alum "forms an aluminum hydroxide precipitate that removes phosphorus from the water column and forms a long-lasting barrier on the lake bottom that substantially reduces phosphorus released from sediment" (EPA, 2007, Maine: Section 319 Success Stories). After performing these alum treatments, along with erosion control, Cobbossee Lake's waters were clear and passed water quality tests.

Long Lake also had similar problems with high nutrients levels, especially because there was a storm water drainage pipe in close proximity to a public beach which caused numerous beach closings due to low water quality. This was dealt with by using several methods. First, a cascading vegetative swale was placed between the drainage pipe and the lake.

Figure 4.1.2: Cascading Vegetative Swale at Long Lake (Danos, 2006, p.46)

This vegetative swale, seen in Figure 4.1-2, holds water during high-flow events and the vegetation naturally removes nutrients from the water. The swale is cascading so when the first part of it fills, the overflow goes into another part which continues to remove nutrients from the water.

Another way nutrients are removed from storm water at Long Lake is due to residents using rain gardens in their yards to curb runoff during high-flow events. A rain garden is “a shallow, landscaped depression designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems”(Low Impact Design, 2007, p2-7) Mr. Savas Danos, GM of Littleton Electric Light and Water Departments, and his associates have worked closely with residents living near Long Lake to help them install rain gardens in their yards. The rain gardens help to reduce the amount of NPS pollution that runs off yards and has thus helped Long Lake improve its NPS pollution problem.

The nutrient removal methods used at Cobbossee Lake and Long Lake can be used in the Su-As-Co watershed. The alum treatments used at Cobbossee Lake are applicable because a major problem in the Su-As-Co is high nutrient levels. This would work best in lakes and ponds as opposed to rivers due to the flow of rivers. It also must be noted that an alum treatment will not be a permanent solution if phosphorous continues to discharge into the water. The methods used at Long Lake are applicable because they are successful methods that were done in a previously developed area, also a characteristic of the Su-As-Co and they could be used to reduce NPS pollution discharging into streams and rivers.

4.1.3 Public Participation

In each of the water cleanup efforts that have been discussed previously in this section, a key to success was participation of the community living around the water body. In the case of Manatawny Creek, public education was conducted throughout the duration of the project. Project partners "conducted public meetings on the dam removal project, participated in formal meetings with borough officials and residents to discuss riparian vegetation management, and distributed project information through print and television media" (EPA, 2007, Pennsylvania: Section 319 Success Stories). At Cobbossee Lake, people involved with the project helped "landowners adopt erosion control best-management practices (BMPs) at homes, on town roads, and on private camp roads" (EPA, 2007, Maine: Section 319 Success Stories). Finally, at Long Lake, Mr. Danos and his associates encouraged and helped residents install rain gardens in their yards.

Figure 4.1.3: A Rain Garden near Long Lake (Danos, 2006, p58)

The participation of the public is a key in any effort to clean up a body of water. This is evidenced by the correlation of public participation and the success of the water cleanup efforts discussed in this chapter. Of course, public participation in the Su-As-Co watershed will be a key ingredient in improving its water quality, as it was in the three water bodies discussed above.

4.2 Collaboration among watershed organizations

The Su-As-Co Watershed is an important source for water in Massachusetts. Because of this the state government, municipalities and watershed groups are trying to improve the state of the watershed. Discussed here are the instances in which collaboration among these groups has been noteworthy, more specifically the Watershed Initiative and the SWCC.

4.2.1 Watershed Initiative

The Watershed Initiative was a program run by the State of Massachusetts, started in 1993, to improve coordination within watersheds. The program "tried to get different disciplines within the environmental world collectively together to address problems as a group as opposed to separately" (Appendix B, Section 4). Prior to this program groups interested in wildlife, groups interested in water quality, groups interested in land conservation, etc; all worked independently. The problems with this are evident considering all these parts of the environment interact with each other.

Each watershed, for the most part and in the Su-As-Co's case, received what was called a Basin Team Leader. The leader was an individual hired by the state to work directly with a watershed and create a basin team within the watershed. The basin team was made up for the most part of individuals from environmental advocacy groups and state and municipal governments (Appendix B, Section 3). This merger of the advocacy groups and the state government was a unique way to gain a diverse view of the problems within the watershed and how to best disperse money and manpower among the watersheds to achieve the desired results.

The Watershed Initiative, being a government program, was allotted grant money to disperse among the players in the watershed community. According to Nancy Bryant, head of the SWCC, "it [The Watershed Initiative] had some grant money that would particularly try to fund work that was happening on the watershed scale, so a lot of money went to watershed organizations" (Appendix B, Section 3). Grant money is an important way to fund advocacy groups and having a basin team leader, a government employee, collaborating with advocacy groups made for a powerful plea when writing grants.

Unfortunately, a change in gubernatorial administrations mixed with financial hardships at the state level led to the dropping of this program. According to Paul Hogan, from the MassDEP, who was involved with the Watershed Initiative since its inception, "we had that [The Watershed Initiative], and it was very successful for about six to eight years…it really was a tremendous bringing together of volunteer groups, regulatory people, state, federal and local agencies. I think it was a really great thing to do" (Appendix B, Section 4). The termination of this program created a burden, not only on the collaboration of the advocacy groups with the state government, but also among advocacy groups themselves. Prior to the Initiative, some groups had displayed detrimental competition and impaired relationships (Anonymous). Two groups, SVT and OAR, consistently worked in the same area and had varying goals for the watershed. These two groups would often conflict and fight over funds. After implementing an umbrella program, the Watershed Initiative, tension was eased and these groups now work well together and participate in events with each other.

4.2.2 SWCC

The SWCC is a community council that is unique among non-profit organizations. According to Nancy Bryant, head of the SWCC, “What makes us unique is that we’re not really about advocacy; we’re really about collaboration and getting all these different players in the watershed to work together” (Appendix B, Section 3). This group was started in 1996, but really gained significance when the Watershed Initiative was cut. Through a state grant one person, Nancy Bryant, was hired to start the community council, and it is still run only by her.

What creates the persona of a community council is diversity. The SWCC represents four different interest groups, a business sector, municipal government, federal, state and regional government, and environmental groups. Each group has about fourteen representatives creating a total of about fifty-six members. Of the fifty-six members all areas, north, south, east, and west, of all three rivers are represented as well. This large range of interest groups and actual regions of the watershed greatly improves the chances that all decisions are for the greater good of the entire watershed. (Appendix B, Section 3).

The community council is very effective. What helps them to be effective is that they are composed of the diversity previously mentioned. The diversity of the group makes certain that the SWCC will be representative of all stakeholders in the watershed and an important resource to the watershed (Appendix B, Section 3). For instance, SWCC has a Su-As-Co Watershed resource library that is used by students, business leaders, advocacy groups and interested citizens and is open to anyone. SWCC also holds an annual Rivervisions conference. This conference is typically attended by 100-200 people and offers keynote speakers and presentations (Appendix B, Section 3). Nearly all of the watershed advocacy groups, some local businesses, local and state governments, and interested citizens attend in order to hear the current state of the watershed and to plan for the future.

4.3 Public Participation

Public participation is essential to the non-profit world, and the majority of watershed advocacy groups are non-profits. Significant instances in which public awareness and participation have been notably good or notably bad have been identified in the Su-As-Co Watershed. These significant instances are the annual Riverfest celebration and the general public participation toward LID, respectively.

4.3.1 Riverfest

The annual Riverfest celebration is an important event in which countless groups combine manpower and funds to create a three day festival celebrating the rivers in the Su-As-Co Watershed. “[Riverfest] occurs to build public awareness of the values of the river and hopefully they [the public] will support the protection” (Appendix B, Section 2). Riverfest, in June 2007, was held for the sixth time, and over fifty municipalities and organizations offered their services. During the weekend long festival upwards of fifty events took place, none of which, however, was dedicated to promoting or educating people about LID. “You frequently hear that if you get people on the river that will help [with public participation]” (Appendix B, Section 2). A large portion of the events in this festival allow the public to actually get on the rivers for recreational purposes (RSC, 2007). The recreational events included kayak and canoe paddling, pontoon boat tours, walking tours, and picnics. Combining events into a celebration of this magnitude is an easy way to entice the public to see the beauty of the river and an effective way to inform citizens about each event.

Another factor of water quality and quantity improvement that Riverfest strives to include is the education of the public. Events included various recreational activities that were hosted by tour guides. These tour guides varied from important members in the Su-As-Co Watershed, to directors of organizations, to students, to college professors (RSC, 2007). Their expertises ranged from, but were not limited to, wildlife, habitats, invasive species and children's education. The Su-As-Co Watershed Community also held an open house which allowed entry to their resource library. They also had displays to show the importance of storm water management. Educational events such as these helped increase awareness problems that need to be addressed in this watershed [Su-As-Co], and these efforts compared favorably to what most other watershed across the state are were doing. (Hogan, personal communication, 2/8/2008). Events such as this demonstrate the high level of public participation toward general water quality problems in the watershed.

4.3.2 Low-impact Development

LID is a beneficial idea that needs to be used by communities as a whole to be effective rather than just used by a few individuals. Ron McAdow, from SVT, said, "People are aware of it [LID]… I don't know how much new construction in the area is using it, but there is a lot of push for ecological landscaping by home owners and landscapers, in the little world I live in there's a lot of push for it, but I'm not sure that in the world beyond that there is" (Appendix B, Section 2). Savas Danos of Littleton Electric Light and Water Departments, agrees that community involvement is essential. He states that, "We're making a real big push on the use of rain barrels [a form of LID]; we have to work a lot harder to keep on educating people to build down, not up." Danos believes that in order to get public participation in LID, education is invaluable. He goes on to state that promotion and education of LID is done "…through articles in the paper, public presentations, as well as brochures and pamphlets through the Clean Lakes Committee, or directly through the water department” (Appendix B, Section 1). Educating the public about this process is essential to the success of LID and informing the public must be done more effectively.

Low impact development (LID) has been discussed by many people working in the Su-As-Co Watershed. Unfortunately, as prominent members in the Su-As-Co Watershed have stated, LID has been underutilized and the inconsistent use has hampered improvement efforts. Due to the lack of support towards LID, public participation is weak. Some stakeholders (including one person interviewed for this project), have expressed skepticism that LID has been effective, and have expressed concern that many developments with large homes are being built without any attempt of incorporating LID. Current efforts aimed at combating runoff pollution have been good, specifically education on the problems that lawn watering, various detergents, and pet waste can cause. However, LID is another way to lessen NPS pollution that hasn’t been given the proper support.

4.4 Linkages between land use and water quality in the Su-As-Co Watershed.

To analyze linkages between land use and water quality, land use was first compared to population growth in an effort to assess how land use changes compare to population changes. Changes in water quality were then determined from water quality assessment reports and compared to land use changes to see if there are any correlations. In addition, the locations and significance of point sources were assessed to determine if point sources demonstrate a connection to water quality. These results are used to assess the steps communities in the Su-As-Co watershed might take to address water quality problems in the future.

4.4.1 Land Use and Population

GIS Maps provide valuable information on historical land use trends. Appendix E has detailed tables, while Figures C.4, C.5 and C.6 feature detailed land use maps for 1971, 1985 and 1999 respectively. Figure 4.4.1.1 shows growth trends of land use, while Figure 4.4.1.2 depicts areas of developed since 1971. Overall, the data in this figure demonstrates that there is a very strong shift toward developed land use.

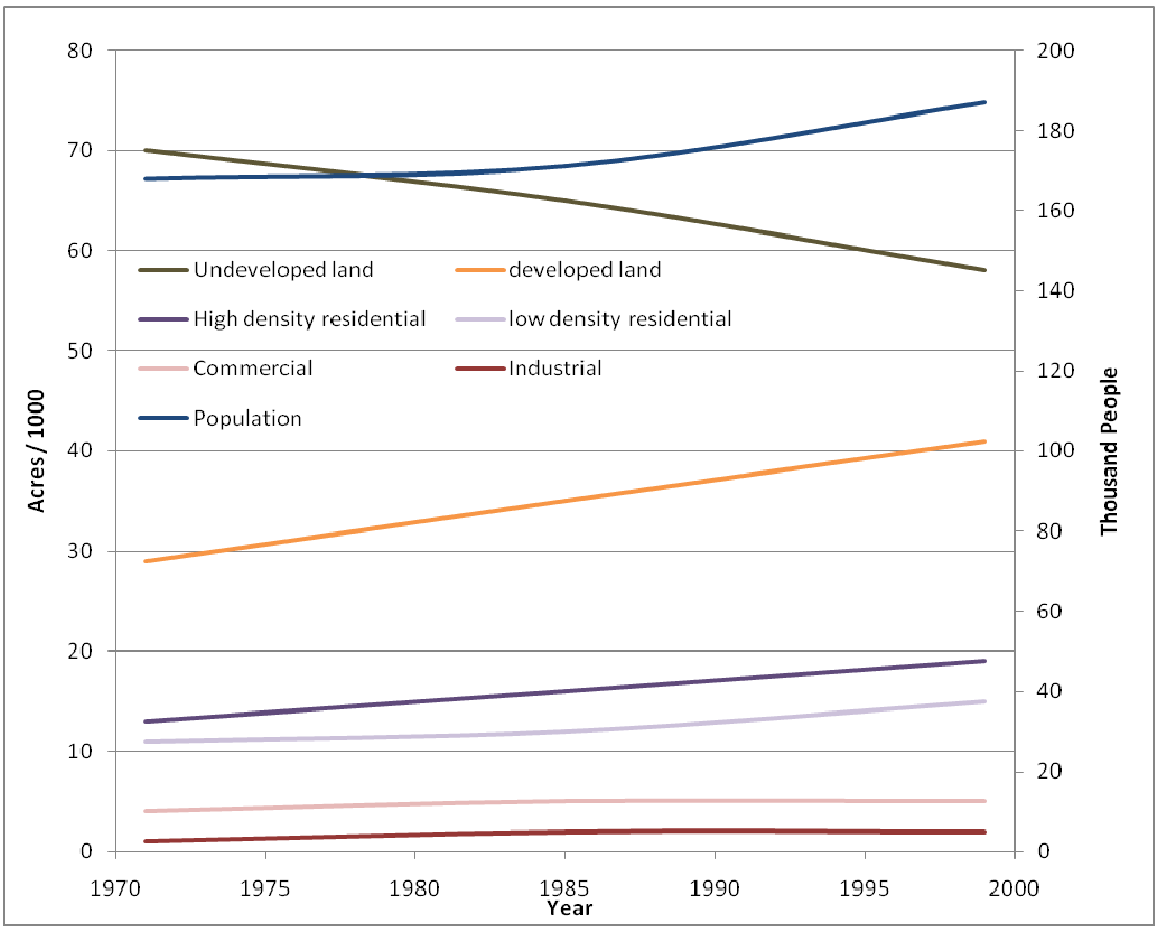

Figure 4.4.1.1: Changes in developed land use through the selected years.

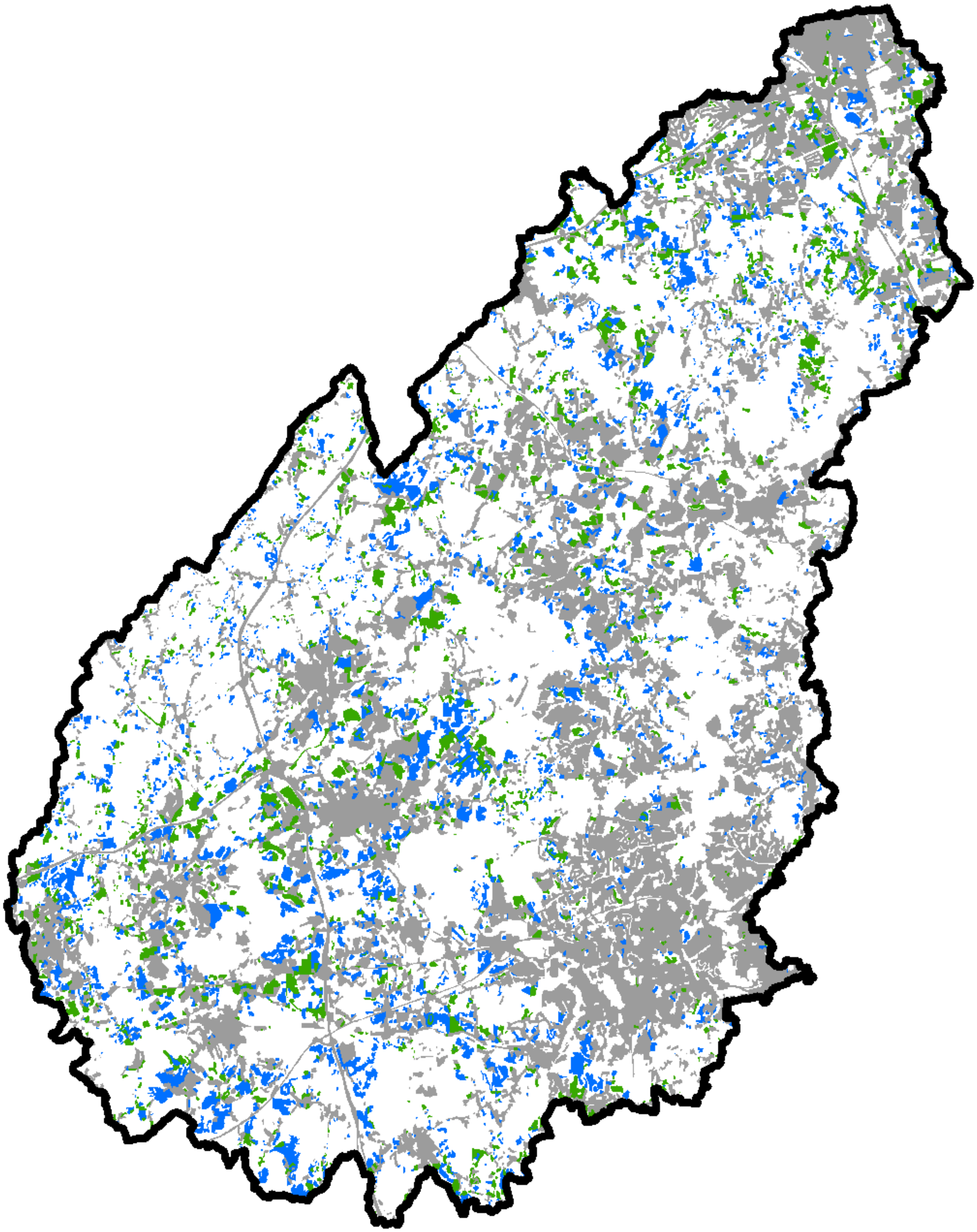

Figure 4.4.1.2: Developed land use change from 1971 (gray) to 1985 (gray and green) to 1999 (gray and green and blue).

As depicted in Figure 4.4.1.1, there is emphasis on low density residential and industrial development, the growth rates of which both outpace population growth rates. It is reasonable to assume that such land use changes will increase the amount of runoff. Low density residential, in particular, creates a great deal more runoff than the forestland it replaced. Low density residential is the fastest growing land because it demands the most land per person and thus does not demand large population changes for large land use changes. Industrial land use, too, is often low density, which explains the observation that such land use outpaces population growth. As shown in Figure 4.4.1.2, growth rates between 1971 and 1985 are lower than those between 1985 and 1999. This trend of increasing rates of growth is expected to continue.

The results also indicate that land use changes outpace population growth rates in each of the core communities in the Su-As-Co Watershed. Using a ratio of land use percentage change to population percentage change, it is possible to compare growth/consumption rates of land use in contrast to population growth. Table 4.4.1 features the growth rate percentage ratios for each of the major land use categories in each of the core Su-As-Co communities. In Table 4.4.1, a positive number indicates an expansion of a particular type of land use, while a negative number indicates a reduction of land use type. A ratio equal to 1 or -1 indicates that the rate of growth or decrease is equal to the rate of population growth, while a value between 1 and -1 indicates that the rate of growth or decline is slower than the population growth rate. A number smaller than -1 or larger than 1 indicates growth or reduction rates that outpace population growth rates. Most communities exhibit a rate of developing undeveloped land that far outpaces the population growth. Framingham and Marlborough between 1971 and 1985 exhibit particularly high rates of land development, with Framingham's low density residential development far outpacing any other growth. The "Pop w average" represents a population rated average for rates of change calculated by multiplying the mean of the percent change ratio by the average population.

Table 4.4.1: Percent Change Land Use / Percent Change Population

1971-1985	UND	HDR	LDR	COM	IND
Acton	-7.50	8.95	11.73	12.72	30.83
Carlisle	-0.40	INF	1.37	-0.75	0.78
Framingham	-18.00	7.42	67.67	1.49	6.66
Hudson	9.55	-7.93	-17.37	-15.54	-43.32
Marlborough	-13.95	9.09	37.77	25.60	38.65
Maynard	-0.85	1.44	1.00	-0.84	2.61
Southborough	-0.84	0.56	4.46	4.12	0.51
Stow	-1.47	11.88	2.60	8.21	13.12
Sudbury	-1.30	25.48	-17.86	3.07	1.55
Pop w. average	-9.53	8.06	31.32	5.62	9.14
1985-1999	UND	HDR	LDR	COM	IND
Acton	-1.11	1.12	1.85	-0.55	1.85
Carlisle	-0.55	7.18	1.42	-1.77	-1.46
Framingham	-3.10	1.14	6.41	0.32	5.73
Hudson	-5.37	1.95	9.67	6.91	8.50
Marlborough	-1.81	1.78	2.91	0.61	2.58
Maynard	-2.49	2.39	8.64	0.91	6.32
Southborough	-0.71	0.82	1.87	0.18	1.71
Stow	-0.49	1.33	2.33	-2.91	2.01
Sudbury	-0.68	1.92	0.24	-0.39	0.07
Pop w. average	-2.42	1.61	4.83	0.77	4.16
1971-1999	UND	HDR	LDR	COM	IND
Acton	-2.03	1.95	2.78	1.16	4.61
Carlisle	-0.52	3.10	1.34	-1.38	-0.01
Framingham	-4.81	1.77	11.59	0.44	5.73
Hudson	-11.61	5.37	17.07	13.55	22.14
Marlborough	-3.22	2.30	4.99	2.76	4.88
Maynard	-1.46	1.71	3.35	-0.26	3.52
Southborough	-0.78	0.79	2.05	0.84	1.53
Stow	-0.86	4.33	2.29	1.51	4.86
Sudbury	-0.86	5.33	-3.32	0.34	0.37
Pop w. average	-3.91	2.62	7.13	2.19	6.07

UND = undeveloped land (cropland, pasture, forest, wetland, open land, water, woody perennial)

HDR = High density residential (smaller than ½ acre lots and multifamily)

LDR = Low density Residential (larger than ½ acre lots)

COM = Commercial and urban open land uses

IND = Industrial land use

The "Pop w. average" represents a population rated average for rates of change calculated by multiplying the mean of the percent change ratio by the average population.

See Appendix E for detailed tables.

4.4.2 Land Use and Water Quality

Maps in Figures 4.4.2.1 and 4.4.2.2 illustrate the correlation of land use with local water quality quite well. Areas with large clusters of commercial or industrial land, Framingham for example, tend to have impaired surface water and aquifers in close proximity. Analysis of other factors, however, reveals that it is the proximity of dumping sites that correlates more accurately with water quality changes. The apparent correlation of water quality and land use coincides because dumping sites are picked in accordance with local land use. Figure 4.4.2.1 demonstrates the proximity of reported spill sites and discharge sites to aquifers that are not considered suitable as municipal water supplies. Furthermore, as shown in Figure 4.4.2.2, dumping sites correlate with impaired surface water quality. Figure 4.4.2.2 also depicts the correlation between dumping sites and commercial and industrial land use. Quite understandably, individuals do not want dumping sites near residential areas, especially where wells provide drinking water. Insufficient data prevents any conclusions of causality to be drawn between reported spills and nearby water quality.

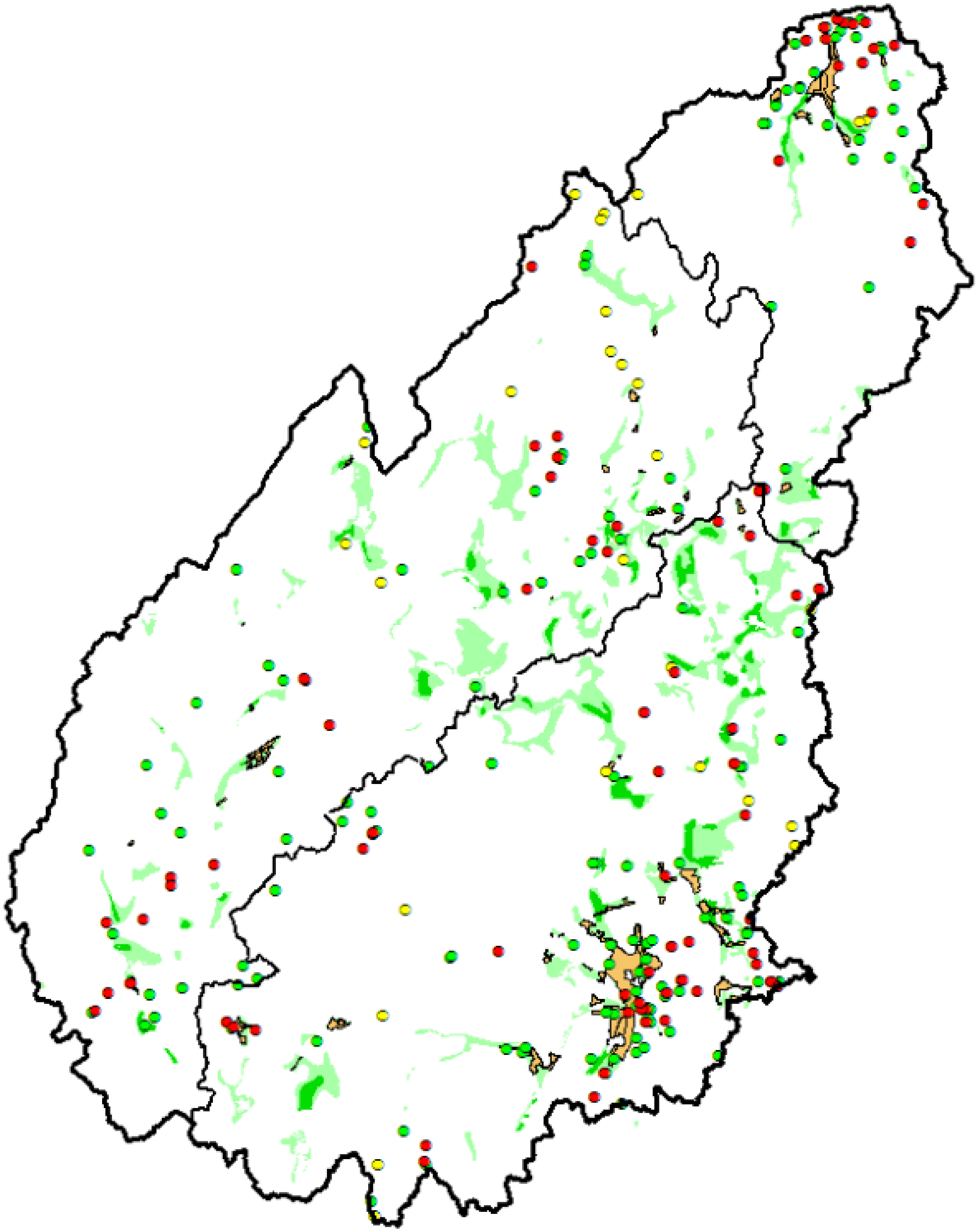

Figure 4.4.2.1: Su-As-Co with groundwater discharge (Yellow dots) and reported spill sites (red and green dots) and Aquifers. The green aquifers are those which are used for drinking water, while those that are yellow are considered unusable for consumption.

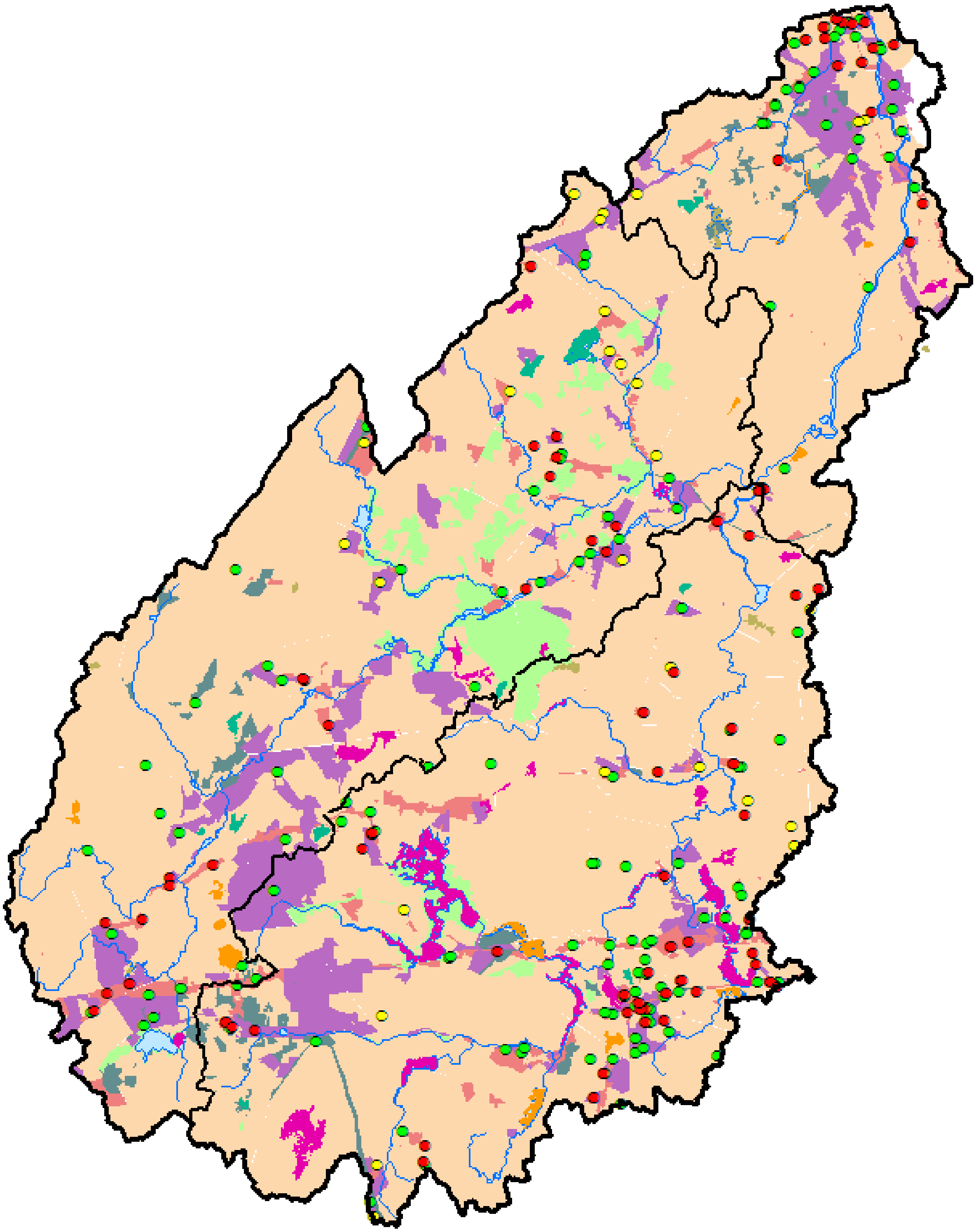

Figure 4.4.2.2: Dumping sites, general land use and water quality. Groundwater discharge (Yellow dots) and reported spill sites (red and green dots) shown with residential/undeveloped (tan), preserves (light green), commercial land (purple), Industrial land (red), water (blue) and impaired water bodies (pink, orange and dark green).

With land use analyzed, water quality was characterized to see if there exists a connection between land use and changes in water quality. It is challenging to gauge changes in water quality for the entire watershed. The limited availability of past data also presents challenges in gauging changes through time. Never-the-less, a report for the entire watershed is published about every five years, reports from 1969, 1985/1986 and 2001 provided a constant base for comparison. Unfortunately, only data for the Assabet were available for 1969. Thus only Assabet data were considered for 1985 and 2001. Changes in median phosphorus concentrations follow the same pattern. Allen Street in Northborough is a common sampling site in all three sampling years. Phosphorus was chosen for the availability of data and concern expressed by nearly all who were interviewed.

Table 4.4.2 shows that mean concentrations of phosphorus increase from 1969 to 1986 and then decrease from 1986 to 2001. The concentration of phosphorus actually decreases through time at the Allen Street sampling site. Additionally, one may observe that (with the exception of 1986, the Allen Street concentrations are considerably higher than the average values. Figure 4.4.2.3, which includes a bar chart showing population and developed land use per year compared to water quality per year, clearly demonstrates that there is a direct correlation between population and developed land use in all areas surveyed. The chart shows that the Allen Street concentrations decrease with time, while the mean concentration fluctuates. Most importantly, Figure 4.4.2.3 demonstrates that there is no direct correlation between phosphorus concentration and developed land use. Point six in Figure 4.4.2.4 depicts the location of the Allen Street sampling site in the context of the Assabet Watershed.

Table 4.4.2: Phosphorus concentrations and change by selected years

Date	Mean ppm	Median ppm	Allen St. ppm
10/23/1969	0.88	0.7	2.0
10/17/1986	1.80	1.7	1.6
Fall 2001	0.31	0.28	0.6
Time Period	Change mean	Change median	Change Allen St.
1969-1986	0.92	1.0	-0.4
1986-2001	-1.49	-1.42	-1.0
1969-2001	-0.57	-0.42	-1.4
Sources: Massachusetts Department of Environmental Quality Engineering Division of Water Pollution Control Technical Services Division, 1987; Cooper, 1971 and Herzfelder, 2005			

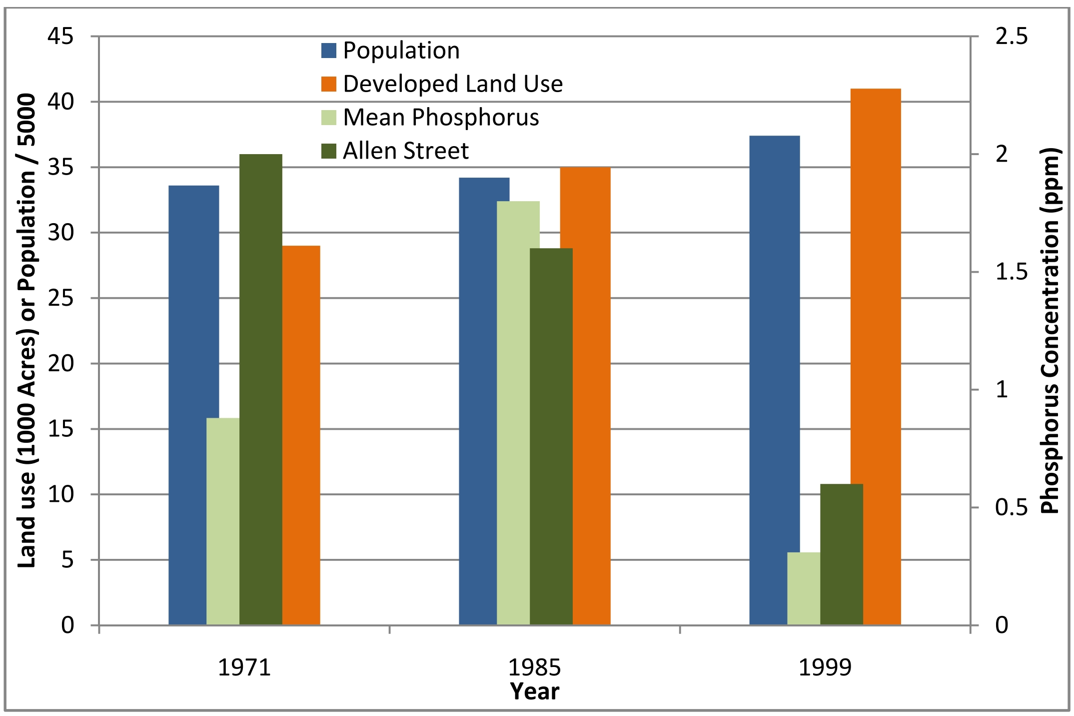

Figure 4.4.2.3: A graph contrasting trends in population (per 5000 people) and land development (percentage) to those in average phosphorus concentrations (ppm) and phosphorus concentrations (ppm) at the Allen Street sampling site.

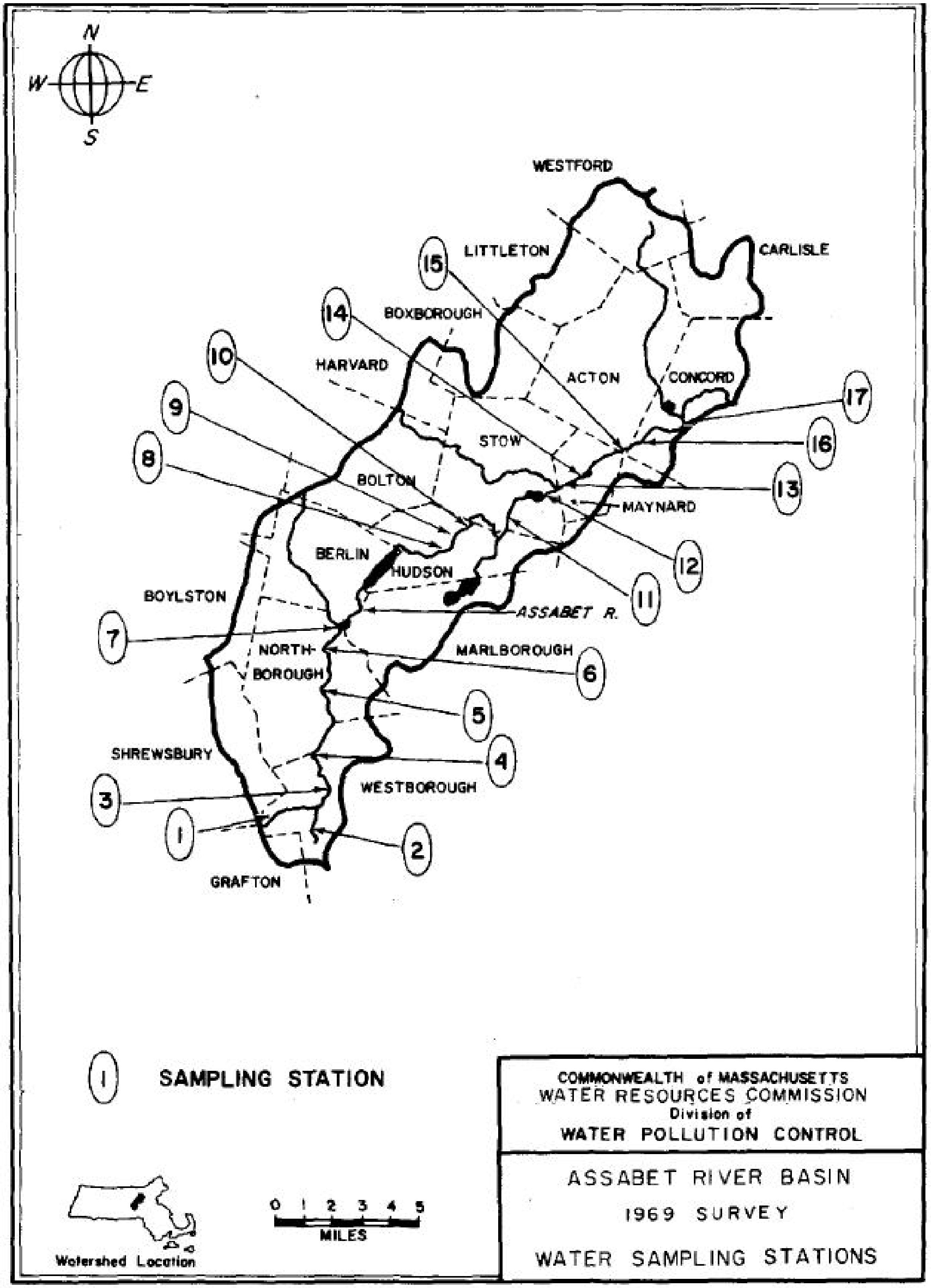

Figure 4.4.2.4: Assabet sampling locations, with the Allen Street site displayed at point 6 (Cooper, 1971, P.11).

4.4.3 Point Sources

We believe that changes in municipal wastewater treatment plant discharge regulations account for observed changes in phosphorus concentration. As noted by Massachusetts Department of Environmental Protection (2004), the reduction in public wastewater treatment effluent phosphorus content would significantly reduce the phosphorus content in water. In addition to point sources associated with wastewater disposal facilities, the remaining phosphorus loads entering the river comes largely from sediment flux and runoff. The TMDL report predicts a minimum phosphorus level of 0.007 ppm in the absence of wastewater treatment plants given the current sediment content of phosphorus. Effluent concentrations from each year support this conclusion as well. Phosphorus discharge from municipal treatment plants has decreased in concentration since 1969. Figure 4.4.3 shows the locations of wastewater treatment plants in the Assabet. Comparing the1969 and 1985 discharge reports for Shrewsbury, one may see that even though the concentration of phosphorus decreases slightly from 8.8 ppm to 8.2 ppm, the rate of flow increases from 1.3 million gallons per day to 1.7 million gallons per day. Similar trends are evident at other discharge plants as well. More important, however, is the increase in the number of discharge points. The 1969 document reports six discharge locations, while its 1985 counterpart reports thirteen. Contemporary discharge rates for phosphorus content are almost universally below one part per million. Concord, Maynard and Hudson each have discharge limits 0.2 ppm, 0.1 ppm and 0.1 ppm respectively (Hanley, 1986, pp. 70, 62 and 30). These findings are explained by the fact that waste water discharge plants must reduce effluent phosphorus concentrations to 0.1 ppm in by 2009 in accordance with new permit conditions (Massachusetts Department of Environmental Affairs, 2004). When one considers that as 97% of phosphorus (48% in rainy or high runoff conditions) is from point sources, it is clear that waste-water discharge characteristics are currently the primary driving force for phosphorus content in watersheds (ENSR, 2001).

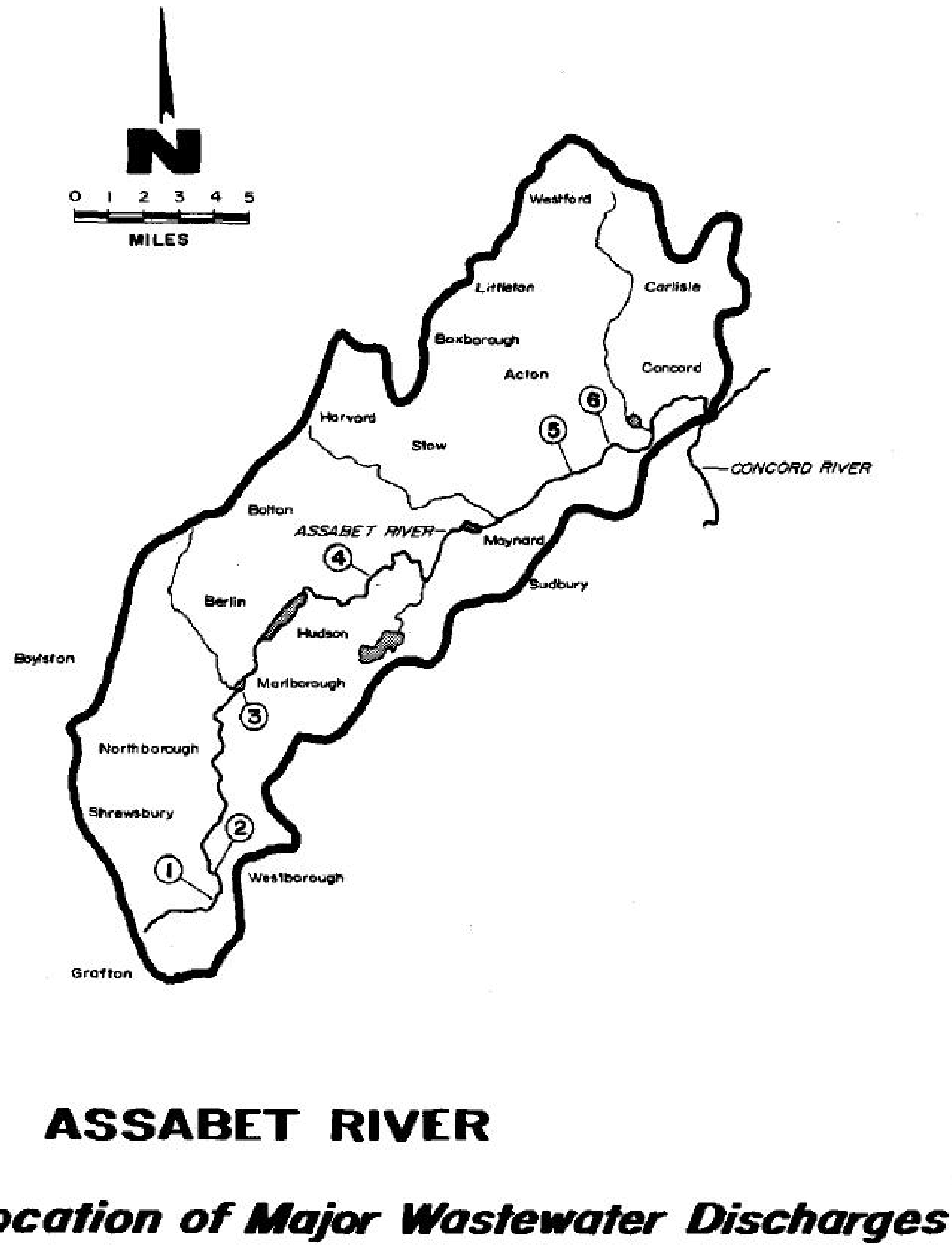

Figure 4.4.3: Waste water discharge locations. "1. Westboro S.T.P., 2. Shrewsbury S.T.P., 3. Marlborough Westerly S.T.P., 4. Hudson S.T.P., 5. Maynard S.T.P., 6. MA Correctional Institution Concord Reformatory S.T.P." (Cooperman, 1971, p.12)

4.4.4 Further Considerations

While it would appear that runoff has increased, any increase in phosphorus content due to runoff is currently much smaller than municipal waste-water treatment. Considering that at the very least 88% of ortho-phosphorus is from point sources, non-point sources are currently but negligible in comparison (ibid). Though a minimum 88% of ortho-phosphorus comes from point sources (a figure determined during high runoff conditions), the amount of total phosphorus contributed by point sources during wet weather conditions drops to 48%. While ortho-phosphorus is what plays a key role in eutrophication, total phosphorus contributes greatly to sediment phosphorus content. The 2001 Assabet TMDL report notes that of the estimated 29 lbs/day of phosphorus contributed from non-point sources, 28 lbs comes from sediment flux. Indeed, the report suggests measures such as dredging, dam removal and encapsulation to combat the problems of phosphorus in sediment. Even with such a large quantity of phosphorus coming from sediment flux, the waste water treatment plants from Westborough and Hudson alone contribute an average of 46.1 and 32.2 pounds of phosphorus per day respectively to the watershed. Planned reductions in effluent phosphorus content and sediment flux reductions may make runoff sources represent a more significant portion of phosphorus entering the watershed.

Population growth and development of land correlate to water quality mainly by their effects on point sources within the watershed. Low density residential growth has been shown to contribute a high level of phosphorus to watersheds, but far less than industrial land use. For example, the Lake Boon TMDL (Massachusetts Department of Environmental Affairs, 2001) attributes 23% of phosphorus loads to the 18% of the watershed that residential land use consists of. By contrast, industrial land use accounts for 3% of land use and 24% of phosphorus loads. It is important to note that these figures for Lake Boon are based on a relatively stagnant body of water with very few point sources (ibid). The rapid flow of the Assabet, Sudbury and Concord rivers typically ensures that pollutants do not stay in one place for very long, save those in sediment. Additionally, point source contributions in the Assabet far exceed those in Lake Boon. Long Lake, too, demonstrates the dominance of runoff sources of phosphorus when considering virtually stagnant bodies of water. It is recognized that rivers such as the Assabet often include impoundments and slow-moving reaches that may be affected by runoff sources of phosphorus as well as other sources. As such, lakes may thus provide a model for rivers that have lower point source contributions, but it is unknown what factor flow characteristics play in this conjecture. These flow characteristics are not included within the scope of this project, and are recommended for future study.

4.5 Summary

The effects of point and non-point sources have been addressed with respect to the management of phosphorus, since this constituent is recognized as an important parameter affecting water quality in the Su-As-Co watershed. Furthermore, the sources of phosphorus have been assessed in the context of population growth and developed land use increases.

With regard to external cases of phosphorus management, we have observed that the use of low impact development in Littleton has proven quite successful. Dam removal in Manatawny Creek worked well in reducing sediment, while alum treatments in Cobbossee Lake did manage to reduce phosphorus levels within the sediment. It is important to note that public participation played an important role in each of the three projects. From interviews we found that umbrella groups are an important and effective structure in watershed management. Additionally, community outreach programs like Riverfest have proven effective and public participation plays an important role in programs like LID. Finally, data suggest that very little ortho-phosphorus comes from runoff sources. Point sources represent the vast majority of phosphorus, while nearly all non-point phosphorus comes from sediment flux. The dominance of sediment flux as a non-point source contributor of phosphorus makes approaches like dam removal, sediment removal and alum treatments especially applicable. Additionally, the prevalence of low density residential development make LID quite compatible with land use trends in the Su-As-Co watershed.

5. Conclusions and Recommendations

There are several things that our results suggest can be done to improve water quality in the Su-As-Co watershed. One of them is the use of low-impact development. Low impact development has been proven to work in Long Lake in Littleton, Massachusetts and was also used at Manatawny Creek in Pennsylvania. Another is alum treatments which were very successful in removing phosphorous from Cobbossee Lake. Dam removal could be used to improve flow and reduce the amount of stagnant water in the watershed. This was done with great success at Manatawny Creek. The establishment and stability of umbrella groups within the watershed have made collaboration easier and more frequent. Large events and workshops are run in unison and done consistently. The extent of community participation, for the most part, in the Su-As-Co has been great compared to other watersheds in the state. LID, however, has not seen the amount of community support and implementation it needs to become successful. Furthermore, since runoff sources of pollutants will eventually be significant, they should be assessed and controlled as soon as possible.

One method that would help improve water quality in the Su-As-Co watershed is alum treatments. Though they may be opposed by some people, they can be very successful. This was done at Cobbossee Lake with a great deal of success. Our results show that phosphorous is a major cause of poor water quality in the Su-As-Co watershed. If enough alum treatments are done in the Su-As-Co watershed, the phosphorous levels can be drastically reduced to healthy levels. There are, however, a few stipulations regarding the use of alum. One is its use is only feasible in lakes and ponds, and not rivers, due to the nature of river's flow which would reduce the treatment's effectiveness. Another is alum would only be a temporary solution if phosphorous continues be deposited into the watershed. Phosphorous intake must be curbed before alum can be completely effective. The major issue with alum treatments, however, is the cost. Treating all of the high-phosphorous bodies in the Su-As-Co watershed would cost a great deal of money, as would dredging out the precipitate that is created in the treatment's resulting chemical reaction. Watershed groups and activists would have to request section 319 funding. They could cite the success at Cobbossee Lake which itself was partially funded with section 319 funds. Alum treatments could be a huge part of successfully improving water quality in the Su-As-Co watershed with the proper funding.

Another method that could be used to improve water quality in the Su-As-Co watershed is dam removal. This method was done at Manatawny Creek in Pennsylvania and was successful in improving water quality. Dam removal would help improve flow in rivers, which would move the excess sediment and decrease the high water temperatures caused by stagnant flows. It would also increase a river's TMDL due to the increased flow. It could, at least initially, cause a problem if the sediments were contaminated with nutrients but in the long run the river would be better off with increased flow. Dam removal would require additional efforts to reinforce river banks, as was done at Manatawny Creek. This is because the increased flow would cause erosion where the banks had previously been at stagnant flows. Reinforcement of banks would require the help of residents if their property is adjacent to a river. It would require them to construct some kind of riparian buffer which would hold the soil together and keep it from being washed away by the river. Dam removal is a cost-effective way to improve water quality because it does not require any sophisticated equipment or complicated methods. A disadvantage of dam removal would be its interrupting of the ecosystem that's has been established around the dam. This interruption could not be avoided and would have to be dealt with on a case-by-case basis. There exist plans to assess the removal of each dam in the Assabet, in accordance with the 2001 TMDL report. Overall, such assessments in the Assabet, coupled with evaluations of dredging and encapsulation represent important progress. We feel that applying such assessments to the Sudbury and Concord watersheds would prove be important steps in determining how to proceed. Dam removal should be done in the Su-As-Co watershed wherever possible due to its cost-effectiveness and great potential to improve water quality.

The existence of umbrella watershed organizations has been essential to improving the Su-As-Co Watershed. Prior to umbrella groups, such as the Watershed Initiative and the Su-As-Co Watershed Community Council, detrimental competition and uncooperative relationships had plagued watershed cleanup efforts, namely between SVT and OAR (Anonymous personal contact). These two groups, among others, have played major roles in combating NPS pollution in the watershed through advocacy and outreach collaboration events previously mentioned. The concept of an umbrella group, specifically a community council, looking over the entire watershed representing diverse views is something that should not be overlooked and should be continued. According to Nancy Bryant, due to lack of funding that has been occurring in watershed groups (Appendix B, Section 3) an even more influential umbrella group would be a state-run program, such as the previous Watershed Initiative.

The amount of community participation in the Su-As-Co Watershed has been high compared to others in the state. More recently, a major portion of community participation in the watershed as a whole has been geared toward curtailing NPS pollution. Such community involvement has been evident through the SWCC's Storm Water Matters Program and the many events found in Riverfest. These, as with the majority of community advocacy and education efforts, have neglected an emphasis on LID. Prominent members among the state government and watershed groups in the Su-As-Co agree that LID has not been implemented as well as it should be. Dedication to LID from watershed groups has begun (Appendix B, section 3) but is still limited. A bigger emphasis by watershed groups should be put on educating citizens about the advantages of LID and the ease of implementing some of the solutions. All levels of government should at least consider passing bylaws to promote the previously mentioned LID practices.

As is shown clearly by the results of the GIS analysis, land use changes correlate with population growth. Yet, changes in phosphorus content exist independent to changes in land use and population growth. As discussed in the results section, phosphorus levels in the river are determined almost exclusively by point sources. Studies suggest that the vast majority of non-point sources of phosphorus come from the release of phosphorus from sediment. Runoff sources of phosphorus currently constitute a very small minority of non-point source phosphorus contributions, let alone total phosphorus contributions. Despite the fact that runoff sources are currently negligible, addressing runoff sources of phosphorus is still important. Current plans call for an eventual 90% reduction in sediment flux and a reduction in point source effluent phosphorus concentrations to below 0.1 ppm as a means to address non-point and point sources of phosphorus (ENSR, 2001). Once sediment flux and point source concentrations are reduced to their target levels, runoff sources will represent nearly one third of non-point sources of phosphorus. At that point, remedial action to address land use and runoff will be more important. There is little reason not to address the problem before it becomes significant since low density residential land use is likely to increase.

Finally, the low impact development methods used at Long Lake, such as the cascaded vegetative swales, the man-made storm water wetland, and rain gardens, are all used to control the flow of untreated storm water into the lake. The prevalence of low density residential land use and the high degree of compatibility between low impact development and low density residential land use make low impact development a rather reasonable solution for curtailing nutrients such as phosphorus in runoff. Similar methods to control storm water flow could be used throughout the Su-As-Co watershed. Since Long Lake is at the bottom of a hill, the methods used there were designed to catch water flowing from the hill. Other areas in the Su-As-Co could creatively use its geography to treat storm water before it runs into a body of water. If the water is on flat ground, some kind or irrigation system could be used to control the flow of water into something like a vegetative swale or a storm water wetland. Public participation is very important to the success of LID. At Long Lake the residents constructed rain gardens in their yards with the leadership of Savas Danos. In other areas around the Su-As-Co watershed the residents in a neighborhood could agree on a leader who could supervise the construction of things like rain gardens. The use of LID has shown its effectiveness in improving water quality and should be expanded and used throughout the Su-As-Co watershed.

Public participation thus far has been excellent in addressing runoff pollution. Indeed, nearly all current community outreach programs focus on curtailing runoff sources of phosphorus. Programs to reduce or eliminate the use of phosphorus-based soap and reduce lawn and garden fertilizer use are prime examples of programs that combat only runoff pollutants. Ron McAdow from SVT focused his discussion of community programs on some that are similar to the soap and fertilizer efforts. Efforts in LID, too, focus to a great extent on limiting runoff sources. Savas Danos of the Littleton Electric Light and Water Departments noted that the focus was runoff control, observing that rain gardens and permeable parking surface are chief among examples of LID reducing pollution from runoff. Yet, such focus may seem somewhat off target when one considers that nearly 99% of phosphorus contributions come from other sources (ENSR 2001). However, such efforts may actually be in the right place, since the bulk of municipal efforts are focused on point source reduction and sediment management. Though non-point runoff of sources of phosphorous currently represents a very small percentage of the total, projected reductions in point sources of phosphorus discharge rates and sediment flux will mean that current runoff sources will soon represent more than 1% of phosphorus contributions. Once runoff is a larger source of pollutants in contrast to other sources, the level of attention to NPS pollution from activist groups will become well deserved.

In conclusion, through analysis of our research and results, we have come up with several recommendations to improve water quality in the Su-As-Co watershed. These recommendations are: to expand the use of low-impact development to curb polluted runoff from entering water bodies, to use alum treatments on lakes and ponds to reduce phosphorous, to remove unnecessary dams from rivers to increase flow and TMDL's, to increase the influence of umbrella watershed groups to better coordinate and unite individual watershed groups, and to increase the level of community participation so the public better understands how their actions can affect water quality and how their efforts can help improve water quality. If these recommendations are followed and executed, the water quality in the Su-As-Co watershed can be drastically improved and the watershed can be used as a model for other clean up efforts to reduce and control the negative effects of non-point source pollution.

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Appendix A: Interview Protocols

Section 1: Low-impact Development

Questions before the face to face meeting, we will be sure to reiterate the questions in person.

- Will you allow us to record your interview?
- Should we keep your responses anonymous?

To begin the interview we will all introduce ourselves personally and then as the "Water Quality Management in the Sudbury-Assabet-Concord Watershed Interactive Qualifying Project Group from Worcester Polytechnic Institute." After a brief chat for warm up we will ask the following questions:

- How does low-impact development differ from normal development?
- What, if any, low-impact development methods are designed specifically to improve water quality? In the Su-As-Co watershed?
- Have you seen water quality improvements in response to low-impact development? How and to what extent?
- How does your organization/company promote outreach (educational, training programs, brochures)?
- Does your orgainzation/company have any partnerships or collaborations with watershed groups in the Su-As-Co?
- Do you find that contractors are adopting low impact development practices? If so, to what extent?
- Do you find that individuals are electing to use low-impact development practices? If so, to what extent?
- Can you refer us to any examples of low-impact development that we could visit?

- Have you done any work in the Su-As-Co Watershed? If so, What?
- Do you have any information on how it has affected the water quality in the Su-As-Co Watershed?
- Is there anything else that you would like to discuss or mention that seems pertinent to our project?

After this interview has been completed we will make sure to thank them and ask if we are able to contact them at a later time for more information.

Section 2: Watershed Groups

Questions before the face to face meeting, we will be sure to reiterate the questions in person.

- Will you allow us to record your interview?
- Should we keep your responses anonymous?

To begin the interview we will all introduce ourselves personally and then as the "Water Quality Management in the Sudbury-Assabet-Concord Watershed Interactive Qualifying Project Group from Worcester Polytechnic Institute." After a brief chat for warm up we will ask the following questions:

- What is your organization's connection to the watershed?
- What does your group think the major problems facing the watershed are?
- What are you doing to address these major problems?
- Has your group incorporated successful water quality improvement methods from other watersheds? If so, what?
- Where are the biggest sources and types of water pollution in the watershed? Has this changed over time? What may have caused the changes?
- Ideally, what do you think the best ways are to improve water quality?
- Are there any locations that have seen drastic changes in water quality and why?
- Have you noticed a correlation between residential and commercial development and water quality?
- How are you trying to involve the public in your organization's activities? And for what goals? And in what ways?

- What have you found to be the best ways to improve community participation? Is there evidence that this has improved watershed water quality? If so, how?
- Are you working together with other watershed groups and if so: in what ways? Which organizations? Have you encountered any problems?
- In general how well do you think watershed groups work together, could you please provide examples?
- What have the state and municipal governments done in the watershed to help improve water quality? What else could local and state governments do?
- Is there anything else that you would like to discuss or mention that seems pertinent to our project?

After this interview has been completed we will make sure to thank them and ask if we are able to contact them at a later time for more information.

Appendix B: Interview Transcripts

Section 1: Savas Danos

Interview with Savas Danos Thursday November 15, 2007 – Transcribed by Shaun Tirrell

Savas: This is a map of Littleton and this map has a lot in it. Its an overlay of a zoning district. First thing it has is these colors here are the underlying zoning and then we have aquifer and water resource districts which pertain to our wells which are up here. Now so anything from here going towards me, or going north and east is in the Merrimack River watershed. So most of our commercialized properties and all of our water sources and ground water supplies are all in the beaverbrook watershed which drains into the Merrimack river. The watershed that you folks are concentrated on which is mostly in Acton and Concord is the Su-As-Co and that begins here at long lake, one of its tributaries. Long Lake discharges into Fort Pond which discharges into Nagog Brook which ends up in the Concord River. So this is the watershed divide between the Merrimack River, or what's called the sub-basin, the Stonybrook basin, and the Nashoba brook which is a sub-basin of the Su-As-Co. Now the work that you folks saw in the PowerPoint presentation was work that revolved around Long Lake. So it is one of the first bodies of water at the head-waters of the Su-As-Co watershed. So that's Su-As-Co, that's Stonybrook. They're both sub-basins of eventually the Merrimack. Su-As-Co goes to the Merrimack through the Concord River, right? You should check that out. I think it does. Anything around here goes into the Merrimack. So that's a little bit of background.

Rick: Do you know somewhere where we can get GIS data?

Savas: Yea, …

Rick: We've been working with the state layers that are available.

Savas: I have all this on GIS so if you wish I can send you a lot of those watershed maps, all those types of GIS, I have your e-mail, I'll just e-mail those to you, OK? If you go to… you should be able, if you go in the state GIS and find one that talks about watersheds and river basins.

Rick: Yes.

Savas: We concentrate our efforts from a water perspective on … water, which is here. Now why did we use Long Lake? We use long lake because what made this an interesting project and it got a lot of press and a lot of publication; you have seen some of them.

Someone:…

Savas: You have that which is really a function of the PowerPoint presentation. That's really the first publication that came out at the infancy of the project. The issue is, this will give you the first few questions, and we were taking an established neighborhood, that being the Long Lake neighborhood in Littleton and were able to implement that installation of best management practices, LIDs. BMPs, best management practices means the best way to have storm water management and LIDs are low-impact developments. The real term is distributed LIDs. Typical engineering for storm water management is to get the water off of the travel ways because of concerns for safety. The conventional method is, obviously, hooded catch basins with discharge pipes maybe into a swale then discharges into rivers, lakes and wetlands. In the case of many of the communities developed out here around 495, there are no sewage systems which is good and bad, and as a result of that the nearest receiving waters has always been the location where storm water ends up. It is the cheapest way, you know, 'you have a parking lot here, you have a wetland where you are, and lets just capture the water and put it into the wetland and its not our problem anymore'. Well over time, obviously, from a water quality perspective, that kind of flash flow into the wetlands and or into streams and lakes results in first and foremost sedimentation. Just stuff coming off the ground naturally as well as winter salt, sand which is really nasty in terms of the amount of sedimentation it causes, and nutrients: phosphorous and nitrogen specifically from fertilization, anthropogenic drop out from the sky of phosphorous and nitrogen and that's just washing into streams and rivers. And then you get the old problems with streams and rivers with phosphorous. That's the overall problem with not having a real strong storm management policy. Back in the '60s when EPA first came into existence and our rivers were dying, they concentrated their efforts on point source pollution, that being outfalls from municipal sewage treatment facilities and or private treatment facilities which were under-designed. This huge [amount of] money to update and upgrade municipal sewage treatment so they could remove the contaminants in streams specifically the nutrients and bacterial contaminants, and private industry did the same thing. The lakes and rivers, like the Merrimack River, where I grew up, in Haverhill, went from almost a dead water body to a very active fishery and recreational water body because of, really, the huge amount of money from the EPA for point-source pollution abatement.

The big issue we have now is non-point source even though storm drains and discharges from storm water runoff are at a point, there are so many and its so spread out, any one street could have many of them going into a water body that they term non-point because they're all being collected. What we can't do, the government is not going to help, is collect all these things in one place and then treat it, because of geography and hydrology and topography, you just can't take a street flowing this way and tie it to a street flowing that way and then treat it, you could but the cost would be astronomical. One of the ways of dealing with this it to let nature do its natural job; on a piece of undeveloped property, water falls on the property during high-flow periods and meanders a surface flow and eventually interacts with the flora, the plant life and some of it gets sucked up and if there's grass and trees and things and bushes, it finds its way of being controlled before the water gets into river. As a result of urbanization, the intent of urban development was to capture the storm water flow, contain it, and then control discharge it into rivers and lakes. It was more an issue of taking it off the pavement and containing it, holding it back long enough so it doesn't create flooding but then just letting it go. There is no treatment in that train. What LIDs do is intercept that storm water flow as often as possible and slow it down which allows things to drop out, try to encourage it to infiltrate back into the ground, I'll explain what that's for, and pass it on its way again, water you can't control. If you have cascading, as you saw in my PowerPoint presentation, cascading wetland, it allows water to be contained in the first basin, some of the water will infiltrate into the ground, some of the nutrients will be taken out by the plants and then as the water keeps on flowing, if it's a big enough storm, it cascades into the second basin, that happens again, it cascades to the third basin, it happens again, then the water is allowed to discharge into, in this case, a lake. At Long Lake, getting back to our situation with the Su-As-Co, Long Lake has 19 outfalls into the lake, all developed in the '50s and '60s; steep streets, pipes with catch basins that discharge right into the lake. Anything coming down those streets was being slowed down by just filling up the catch basins then overflowing and going right down into the lake. These (LIDs) start to intercept that flow, one of the things we've done by intercepting the flow is we're able at time to get 90% of phosphorous and nitrogen. Phosphorous in the environment is by far the most important nutrient towards proliferation of algae and pond scum and the eutrophication of lakes and streams. Have you taken any course in hydrology or environmental sciences?

All: Shaking heads no.

Savas: Ok, quickly, just like we need food and water to nurture ourselves, in a lake ecosystem or river ecosystem, what happens is nutrients in the water allows algae to grow, small plants, the algae are then eaten by small fish which are eaten by big fish, the big fish die off. The algae die off, sink to the bottom, bacteria break them down, use oxygen and the cycle begins again. When a lake loses oxygen it's because there has been a lot of food down with the bacteria breaking it down and they use all the oxygen because the lake is stratified and the lake has problems. The number one parameter that affects the proliferation of plant life in a lake in the northern hemisphere is phosphorous. Phosphorous is in fertilization, all sorts of discharges. We talked about nitrogen which is another important component. Nitrogen doesn't have as much of an impact, its what's called a limited factor in lakes because it's a nutrient in ground water but not in lakes. If we could intercept, through the use of best management practices, LIDs, intercept the storm water flow off of people's property and parking lots and streets, have it go through vegetative wetlands and vegetative sites and disconnect it, initially, from the river flow have it cascade or go into a vegetative swale, then when the overflows discharge into a storm water system then before it discharges into a river, have it go through a fore bay that allows more crap to drop out before it discharges into a stream. We've intercepted that storm water flow two or three times, and in doing so, it gives nature a chance to first allow the sediments to fall out, and allow nutrients to be taken out by the plant life you planted. And under the right conditions, like today, because this is flash, a little rain then it stops, allowing the water to seep into the ground before what is left over discharges into the river. The seepage is a real important parameter because in New England we have what are called flashy streams; the stream basin you're studying is very flashy. And what happens is when it rains it pours and all the rain gets into the lakes and it causes it to rise real fast and then the lake discharges it into the river and as the summer goes on it keeps on going down and gets very dry in the late summer. Part of that is due to the flashy nature of our rivers around here. Also it's probably due to, because of all the pavement, the water is not seeping into the ground and becoming ground water, its just discharging into rivers directly. So by having these distributed LIDs, which stop the water let it fall out, stop the water let it fall out, that water that is seeping into the ground ends up in the ground water table and then the ground water table slowly discharges that water back into the river. During the summer time, you have what is called a higher days flow. If you have a huge parking lot that nurtures the ground water that then discharges into surface water, that parking lot will make the river come up real fast and then in the summer time when there is no rain, it goes down real low. If that parking lot is allowing some of the water to go into the ground, that ground water feeds during the low flow periods so it has more flow. That is really the two main concepts in the use of LIDs as best management practices: attenuation of storm water, meaning taking nutrients and sediments out, and then returning that storm water flow back into the ground whenever possible to become base ground water flow back into the river basin. Its really a simple concept. Everything that I sent you all relates to taking an existing neighborhood with the normal catch basins and parking lots and all that and intercepting the stuff and re-routing the water into these structures before it goes into the lake. What has that done? Since we began this program around the lake we did the first five basins right around here, near the town beach, there are no more closures due to bacterial problems; during the summer time it's a swimming beach. Before and after a summer storm you get all the crap flowing into the lake directly it closes the beach; there are two outfalls right next to the beach. Now those out falls are gone, those out falls are going through vegetative swales in advance of the water going into the lake because the water has to go into the lake, there is no place else to put the water. All of that's gone away now because all that water is being retained and being treated by the LIDs before its being discharged into the lake. There has been an improvement in the water quality of the lake as well because the amount of nutrients going into the lake is dropping. We've got quite a ways to go, we've only done the first five pipes and there is still 12 to go. So, I'm just rambling.

Adam: How long has it been since the lake was closed from swimming?

Savas: The last vegetative swale that we put in that stopped the lake from being shut down was in 2005 was when we opened the last one. If you look at pictures of the lake, I gave you pictures of it, we can go down there as well, the swimming beach is here and there are catch basin out falls over here and here and the first year we took care of those and the second year we took care of those, and so now we don't have any direct discharge of storm water into the lake and there have been no closings since then.

Adam: Was it consistently closing before?

Savas: It was closing a few times a year after heavy rain storms, not consistently and there are two reasons why. The out falls, they're not always flowing most of the summer time. You need about three inches of rain to make them flow and they only test the beach once every two weeks so if the town tests the beach on a Thursday and it doesn't start raining until Friday or Saturday, and they don't come back until two weeks later, the problem is all gone, the out of sight out of mind mentality. Now, if the beach were to be tested soon after a rain storm, it more the likely would be closed a lot more often but these typical small beaches with limited budgets and local boards of health, they just can't do it often enough. They're not just looking for those kinds of events; they're looking more at overall quality. They really don't know what causes it, people causing the problems in the water or storm water flow, or geese. This is a case where there is definitely an influence from the storm water but no one was responsible for going out and measuring the impact all the time. The frequency of the beach closings was not that frequent … because they just tested on a certain day every other week no matter what was going on.

How does low-impact development differ from normal development? Ok, low impact development is, as engineers you're not going to like this, not using the most advance engineering science, its using some of the more natural methodologies, as I said. A typical storm water collection system has a design that is based on the amount of water you're trying to get off a parking lot, as an example. You have deep sumps that hold the water because the normal storm water management system's job, for the most part, is to minimize flooding. So they're retaining the water … and then after you get sediment fall out, … the water is then allowed to discharge into the water lake. Low-impact developments use distributed low impact developments not only attempt to detain the water to prevent flooding, but also as it is being detained, that things are going on in the detention area to not only encourage the water to go into the ground and also encourage the natural flora, plants that you plant, to take out the nutrients. Now, there is advanced low impact development which is a cross between normal and low impact where you have an area that you can't put retention basin, because the basins take a lot of room. So what you do is do it underground through mechanical means that might have what's called vortices or a vortex mixer that basically, through the water flow creates a vortex, that allows it to drop out and it has filters and it filters and then it discharges. You use those and it is pretty expensive. You use those in areas where you need to have storm water management in both quality and quantity but you don't have enough room to do it naturally. Low-impact development uses natural means; infiltration into ground water and nutrient uptake by plants as the focus on how you clean up storm water.

The second one (question from the interview protocol), from the PowerPoint presentation it is clear answers that question and I can show you those if you want to go for a ride. Again, it an issue of water quality improved by elimination of nutrients, the nutrients in storm water from flowing over lawns and flowing over roadways is attenuated by the plants and the slowing down of flow and sediment drops out. That's how you'd get improved water quality, item two.

Item three (from protocol), yes; if you look at the PowerPoint presentation, the last few slides, it gives before and after of phosphorous and nitrogen and suspended solids and these are up to 90% removal of phosphorous, nitrogen, and suspended solids in the Long Lake experiment which is part of the Su-As-Co.

How does your organization promote outreach? Ah, I think I sent you examples of that, I have another one. We are a water department but we recognize the importance of conservation and the importance of water quality. This is the latest, I'll give you a few of the brochures, and this is our latest brochure that we did this fall, has to do with conservation. One of the things in it is a rain barrel, I don't know if these are real low-impact but these rain barrels are a very simple way of slowing down storm water flow. One of the basic parameters in the use of low-impact development for improving storm water quality is to try to minimize the amount of water in the storm water train so the natural processes can treat it. Roof drains, roofs, are a big source of water that enters the storm water train. As I said earlier, if you intercept the storm water train, any part you intercept it as a way of treating it and preventing it from discharging right away. A low cost low impact method is using rain barrels. By having rain barrels on the side of your house where you have down spouts, the first half inch of rain could be captured and that rain does not enter the storm water train at that time. Then, a week or a few days later when you need to water your plants, you use the rain to water your plants. Its not that much but if everyone does it in a watershed or everyone does it in an area, there is a significant amount of water that is not going to be part of the storm water train the first day. By watering your plants with it, the water that doesn't get takes up by the plants, it infiltrates into the ground and adds to the ground water table. A way of doing that more actively is re-route a sub-system of cisterns. Rain barrels are a very simple way of doing it, the next would be a cistern where you take an area, and we're doing it with IBM uptown, where all the roof water on this building is going to go into the ground into these big caverns. Roof run-off is pretty clean to start with because other then what are called anthropogenic inputs which are the quality or air and the components of air, there is nothing else in it. If you can put that water into the ground and bypass those storm water trains, all that water from the roof is not getting involved in the storm water train to create flooding or to over burden your existing structures. By using a sub-system of cisterns in areas where the ground can absorb the water fairly easily, and they can be the size of this room with holes in them and rock around them. The rain water from the roof goes into the cistern, the cistern then goes into the ground and that water never sees the storm water flow. It completely bypasses it and goes right into the ground water flow, because its clean water now, and then that becomes part of the ground water flow that either we use as water for our wells to drink maybe two or three months later, or it ends up discharging into a stream. We have promoted a lot of this stuff through our bylaws, through our brochures,..., we promote it actively in our *Watts and Drops* which is the Littleton Water Department's newsletter. The two major ways that we promote storm water management and water quality improvements in the Su-As-Co are through articles in the paper, public presentations, as well as brochures and pamphlets through the Clean Lakes Committee, or directly through the water department.

A partnership collaborative … we have in Littleton something called the Clean Lake Committee. The Clean Lakes Committee basically has oversight over all the streams and lakes in town and they're almost like a subset of both the Nashua/Merrimack Watershed Association and the Su-As-Co Watershed Association. We concentrate our efforts on improving the water quality in our surface waters and we do that using rehab grants and we get money through cell tower income which allows us to go out and pay for these improvements to be made. Some improvements are made by people through education others we do paying people to do that work, contractors do work from a public grant. The Clean Lakes Committee in the town of Littleton, we get our money not from taxes we have several cell towers, most of the cell towers in this town are on water department property we have agreed to share those revenues with different committees in town … which helps buy open space to protect things like orchards and farm land and some of that money is given to the Clean Lakes Committee where we use that money to go out and do contracts to put in these low impact development best management practices. If I'm talking to fast or anything don't be afraid to stop me and ask questions.

Do you find that contractors are adopting low impact development practices? That's a great question. Contractors will do anything in order to get their permits… low impact developments are not very costly so the question really is promoting this at boards which this is still a product of boards because they think, and I'll explain why, promoting it with boards and also engineers, consultant engineers who design these systems, I'll give you an example: In the town of Tewksbury, the requirement of the planning board with normal storm water management is that they require for all sub-divisions, you know, a little cul-de-sac, they require what are called granite curbing, you've seen it, so the plows don't dig up the hot top or the edges, they require granite curbing which is very expensive, and that's just a requirement. Well they worked with our consultant where they put in that whole subdivision, a cul-de-sac, and maybe ten houses. They agreed that, and they were able to show, this consultant, that they were able to do this entire subdivision using low-impact developments by having the water sheet flow into cascading swales and then from there, at the very end of the road, that water that's left would enter the street storm water system. There were no catch basins and drains in the road. Catch basins and digging it up to put drainage costs a lot of money, they thought, even though they agrees with the idea, they still thought this was a cheaper alternative, which it was, then going with conventional. In order to promote this, you couldn't have the granite curbing because you want, rather then the road capturing the water to discharge into catch basins, they want to slope the road so the water just ran off and landed in the swale that they created, you know with dams in it. They still put in the granite curbing but rather then it being curbing, they made them lay it flat because they thought that the developer would be getting away with something if they didn't have the granite curbing so that not the subdivision has a granite line which, the white granite all the way around, but it serves absolutely no purpose, the town wouldn't let him get away without putting in granite curbing so they put it in the ground instead. That's the kind of thing we face as engineers, engineers want to build things, want to build structures. This stuff is almost the opposite; it is more genteel in that you're building things that have vegetation so that, built properly, you really don't see any bricks and boards, its still they need to be stabilized with things like weirs or gates to stop damage and overflow devices but its very subtle. Its changing a storm water engineer's, a civil engineer's, mentality from capture it hold it back and get rid of it to use it and nurture it is a learning curve, its happening but it happens slower at that level. I think the engineering community, the consultant engineers, who are the ones who make it more difficult because … what they have to do is become good land use planners because rater then building a building all the way up like this, you build it real close to the parking lot well if there is a storm water swale her you don't have to … build the building smaller. But if you build a swale here that makes the building smaller and if you need 5000 square feet of office space you can't afford 1050 so screw a swale, just put it into catch basins. I think contractors are not the problem as much as I think the design community that has to catch on.

Do you find that individuals are electing to use low-impact development practices? Oh yea. We're making a real big push on the use of rain barrels; we have to work a lot harder to keep on educating people to build down, not up. Typically when people put in flower beds or put in perennial gardens, they dig a big mound up, they put them all around, and think about when you do that, so when it rains some of the rain goes in, most of the rain washes off and all the mulch in the garden gets washed off and you have to come out the next day and fix it. But if you were to build this down you would create whats called a rain garden, which I gave you that as well, and the water would pool in the rain garden and feed the plants then seep back into the ground. We are promoting that build down not up; mostly on slopes, to intercept it. Rather then having mounds for your flowers, have them built this way and put the flowers in there so the water flows through it. You see people that create those little waterfalls, you know those artificial water falls, this way, I guess, because water would stay in, and that's another important point. You're not building these to create ponds, that is a different story all together. You want these to empty in about six to eight hours because they could become a breeding ground for mosquitoes, you don't want them to be wet, they can be damp at the bottom but they don't generally stay wet. If it rains every other day for a week, sure but typically in summer time, the rain gets into them, they fill up, if they overflow then the overflow discharges. But if they don't overflow then that rain over about eight to ten hour percolates into the ground and that's what you're looking for. So we are promoting it and people are catching on.

Can you refer us to an example of LID? Yea, if you guys want, if you have time, I can drive you down to Long Lake and I can show you the ones in those pictures you've seen, I can show you a whole bunch of that stuff so we can do that if you want to do that.

Have you done any work in the Su-As-Co watershed? Yea, everything that I have given you on long lake is Su-As-Co.

…-talking to someone else-

Do you have any information on how [your work] has affected water quality? Yes, again, in the PowerPoint presentation there are two or three slides at the end that gives you actual water quality information data, you can use that.

Is there any that you would like to discuss? Well geez what have I been doing for the last hour?

Yea, so it is kind of interesting going forward. I was speaking about dealing with storm water. The other non-point sources and ways of dealing with non-point sources in the Su-As-Co and improving water quality, both water quality and water quantity which is a big thing. One of the things you guys want to look at is in Acton and many towns, and Maynard; they have waste water plants used for treating waster water before discharge into the river. One of the things you want to check out is those towns' either sewer departments or DPWs; talk to those people about, over the last ten years, what have they done to the waste water treatment to improve the quality of the river. That is a point of consideration to look into as well. There have been, again, when the EPA treatment of waste water was growing, it was normal to remove bacteria from the water and some nutrient removal. Now, a lot of communities are recognizing that treatment of waste water to reduce waste water contamination, they're going back and adding treatment systems to help remove nutrients as well. I think you might find, in talking to the communities along the Su-As-Co who have municipal waste water plants you could ask that question. Back in the '60s and '70s you built these plants to deal with bacterial contamination of rivers. How is that going? Then you ask what are you doing to help mitigate or reduce the amount of nutrient contamination into the rivers? That will be a nice part of your story as well.

Those are the two main things, the third thing, obviously, is industrial. Maybe when you're speaking to those waste water plant operators or directors or whatever they call themselves. You might want to ask the question: does your municipal waste water plant take industrial waste as well? You could ask for examples of companies whose waste they take and what have they done to it for pre-treatment to make it clean, if not, do you know examples of industries that have their own waste water facilities for industrial waste water and who to talk to?

So the three main things that are part of the water quality impacts to a river, like the rivers through the Su-As-Co are point sources, first and foremost municipal sewer systems which I was talking about, industrial discharges and non-point sources, the biggest non-point source here with urbanization is what we've been talking about for the last hour: the management of storm water, better ways of managing storm water. That's the story that it's you job to get the answers to or, at least, not that you can get all the answers to it, but get some of the answers to it.

That help?

All: Yes

Savas: I don't want to overwhelm you, the good news is that you have potentially a huge project here and I'm not sure about your time and your abilities. If you aren't able to fully deal with the three major contaminant streams into a river, storm water, industrial and municipal contamination, you might want to talk about all three but then concentrate on one so the initial work might 'what is more interesting to us' and then concentrate on that one. … Or you might have the time for each one of you takes one of the waste streams and deals with it because one of the important things is if there are any good before and after stories. This is the kind of waste water stream, storm water, storm water would be impossible; all you can talk about with storm water is what people are planning on doing. With waste water you can say this was the general quality of the waste water back in the 60s and 70s when there was very little treatment, and this is the treatment as of 1990 and this is the treatment that is expected by the year 2010. That is a good story. Industrial as well, some of the big companies are gone, there used to be a …plant down in downtown Maynard, a leather plant in downtown Maynard, and they had a direct discharge and we found that … the water used to be blue because they were using dyes in the leather, that's how I got into this business as a kid in Haverhill, that's all gone now. Some of the improvements to water quality in the river are simply because freakin' factories … its not that people are making improvements it's just the factories used to line all the rivers up and down these coasts, specifically New England aren't there any more, they're shopping malls now. That's another story too.

Savas then invites us to go look at some of the LIDs he and his people are working on.

In the car now:

Savas: The problem is… a lot of people use just one pond or pool to drop off storm water and then it overflows and discharges into a river. The concepts I have talking about are not having just one big one but having a whole bunch of small ones which works much more effectively. They're easier to maintain, they also nicer rather then having this huge, what looks like, a mud hole sometimes during the year.

Shaun: At the Burlington Mall, they diverted a stream around the parking lot and it empties into this bug pond that always overflows during storms.

Savas: Part of the reason it's overflowing is because the water is not being retained, the water is all being washed off of the parking lot, its huge, and the natural systems can't handle that during storms.

Rick: Are most of these designs more compatible with lower-density residential areas?

Savas: Yes, they are. That is a great question. The only way these work in a higher-density area, because of lack of room, it you have to do them underground. For example, the idea of cisterns and what are called mechanical storm water management tanks. They're built below the ground. I'll give you an example of were they use these: You have been to a street, like in Boston, where the trees have a grate over them and there is gravel underneath the grate?

Rick: Yes.

Savas: What the idea is, that is a smell BMP. When it rains, the rain falls into that grate and it stores water so the plant can use it and then the overflow discharges. Those are like mini ones because you couldn't have grass around that because there are apartments and structures and sidewalks and things like that. The case of cities and more urban areas, it becomes much more problematic after the fact. The way of dealing with it before the fact in urban areas is, one good place to do it, is intercepting roof drainage of buildings and getting that into the ground and out of the storm water train. That alone in a congested area has a huge impact in slowing down the storm water flow and the quality of the flow.

Rick: The systems seem to not do much to address bio-accumulation of heavy metals and organics and stuff. Are there ways to address that, or is it in the works?

Savas: You do get heavy metal attenuation if it absorbs up in the sediments and then there is nutrient uptake. Heavy metal … things that wash off of cars, that can be attenuated by the grass and stuff and then it given them a chance to volatilize off rather then get into the water stream. At low levels, it works very nicely. If you had swale, a high level now, the amount of heavy metals now naturally occurring just from urbanization is completely in volatiles, for example, you don't have lead in gasoline anymore and tires and things like that so those things aren't parts of the natural storm water contaminant flow are being reduced significantly. The key to volatiles are don't let the get into the ground, keep them on the surface so the initial storm water flow into these retention basins keeps them on the surface which gives them a chance to volatilize off. You also have what is called a … the sun gets through them and helps break them down as well, so there is some degradation of those things.

Rick: So it seems then that it wouldn't work in a higher density area or in commercial application.

Savas: That's correct. What you do in those areas is use the structures I was talking about, the mechanical structures which have filters that have mechanisms in those high pollutant load areas to include those types of filters, charcoal filters, those kinds of things and it can help reduce that if it is a potential problem, great question.

We're going down to a boat launch which is on the very edge of the town beach. Everything from here going that way, and there are all of these streets. All of this water right now flows along the street edges, unfortunately with the rain you can't see, but there are catch basins here and it goes underground to get over this hill, there are catch basins down here, all these streets around here. At one time these catch basins took a b-line right for that rock, it went underneath that rock, and discharged into the lake. This is the town beach, all of that roadway, the three or four roads that are with us, used to discharge right there. Now, we have intercepted all those storm water drains … all that storm water now flows out that pipe and into this vegetation … into this swale. When this swale fills up, it overflows into here and … then discharges into the lake. This is able to hold about half an inch of rain fall at a time. So the first half inch of rain of a storm is detained, the plants are nurtured, it goes into the ground, and discharges into the lake. Now think about this, a catch basin, in the summer… this first rush of stuff is nasty stuff, that first rush ends up in the lake, that first rush ends up in this thing and is trapped and is filtered and is nurtured…

We did two other things and we didn't talk about this and its porous pavement; these are two kinds of porous pavement systems. These are rock pavement system; this used to be all paved so during a high flow period, water would just rush along here into that lake and take all the crap with it. Now that water finds its way through the pores here, or … there are cups trapped in the rocks and these have been here for two years now and all the dirt and crap the would have gone into the lake has been trapped by these cups. Now the water that bypasses the storm drains is now being trapped by that and its infiltrating … water that doesn't get into the swale and at least prevents it from going directly into the lake … so we stop storm water flow from going directly into the lake, so what we have done here is intercept that storm water flow and do something with it to prevent it from going directly into that lake. I'm going to take you over to a rain garden, a few rain gardens that are on private property on the other side.

This is one of the first water bodies whose discharge ends up in the Su-As-Co river basin. So the work I have been showing you all pertains directly to your area.

Rick: How does the cost of building one of these compare with just paving it or whatever it was before.

Savas: This is more expensive paving because of the cup system; I'd say they add about 30% to the job. You can't use these everywhere but parking lots near sensitive areas or maybe roads that are near sensitive areas, they have their value. The thing about that, the pavers say, the crushed gravel paving system, you really can't use in New England where you plow, we have to close it down in the winter time, because if you have to plow that stuff, you could be digging that stuff up. You can use what it called porous pavement which allows water to just run right through it, but we haven't experimented with that.

Now the next one I'm going to show you, we'll go by a rain garden, I'll show you a big thing, we've intercepted five drains to create what is called, just a large wetland area. It's basically not really a low impact BMP, but it is a BMP. All these streets drain here; there are five streets, all would discharge into a stream and then discharge into the lake. The town owns this property that I'm going to show you right now and we intercepted these drains and created a large wetland to basically stop the contaminated flow, we call id our vegetated wetland… That water was discharged from all these streets, three pipes, one from this street, one from that street and one from the next street were being discharged right into the lake. We intercepted those trains, created this stream which discharges water into this fore bed so the water can discharge here when it starts raining hard. This fore bed is pretty deep, it allows the water to slow down, and it then allows the sediment to fall out of it, then it discharges. We have a weir structure there, this water discharges into the weir structure over there; you see all the algae and the plant life there? Well that's what you want to happen. By that happening there it means all the nutrients and the crap the would have ended up in the lake is all being absorbed by the bacteria and the algae there and then after that fills up, that water discharges into the lake. What we do is we drain this, like in the fall, and all the crap that has accumulated, we get rid of it; we dry it out and it becomes mulch and organic material. All of this organic material would have been in the lake doing its nasties is not being allowed to go in the lake. We create a plural lake, if you will, to prevent that from happening.

Adam: So this is man made?

Savas: Yea, this is all man made, it used to be a forest, this whole this is mane made, its part of the program.

That pond prevents all that crappy looking water from ending up doing the same damage in the lake … Dredging a lake is too expensive but draining those kind of structures and bringing a back-ho in there with a dump truck and dredging that, there is nothing to it, a day's work. … That's what its all about, letting the nutrients proliferate and grow algae and plant life there rather then having it done in the lake.

Another thing I'm going to show you is a few rain gardens; I'll show you a really nice one. These rain gardens take flow off people's property and intercept it. This is a little one and it doesn't look like much right now at this time of year. During heavy rain there is water that flows over this property line. This little rain garden here, this depression, it needs to be cleaned out, traps the water and infiltrates into the ground and then it allows it to pass. I'll show you a big on, we have these all over the place here. This one is a pretty cool one. This isn't a good time of year right now because they're not built up all pretty right now.

This is a pretty substantial one, this is a rain garden. If you look at the presentation, there is three feet of rock underneath this. It drains from this gentleman's property and all the water flow from the woods here which normally would go into the road way and down into the catch basin behind us. A lot of it is trapped, and he says it hardly ever fills up because there is so much gravel in this thing. All of this water comes here and just feeds the plants and gets sucked into the ground. It is sucked in the ground so it doesn't go directly into the lake. You really have to come back in the summer time, they look pretty, and they aren't useful now because they're off season but in the summer time they're great. There is a picture in that PowerPoint presentation that shows this being used and then there is a picture right after it that shows a Corona bottle lit up with palm trees, he makes a palm tree display with Corona bottles in the winter time its pretty neat. There is another rain garden there. They are all over the place; we're putting a lot more of them in.

You notice that, as we go up these roads, before we start intercepting this flow and what we are going to start doing now is intercepting gutter flow and putting it into those swales. Before we did this, all this rain which is flying down these roads, we need to do a lot more work, we need to put in a lot more rain gardens we are hoping people put the in themselves. We have been intercepting the flow so the water that flows off these properties is intercepted and doesn't just go down the street. Again, it's a bad time of year for these because of all the leaves and plants have stopped growing.

Adam: Are those expensive for people to put in?

Savas: No, they really aren't. Depending on where the area is you can dig them out yourself, these we did with a back-ho, but you can dig them yourself. The plants are just perennial plants that are resistant to being moist. What we hope that people do here is share the plants, cut them up and share them with their neighbors. … That's all it takes; people want to put some day lilies in their front yard, well just don't plant them in the front yard, plant them so they intercept the flow. That's a way a residential person can help, again, intercept the flow of storm water and do something with it.

That's my story. These are not these great engineering marvels, its pretty simple shit, you know? Clearly I'm throwing a lot at you, … if you have any questions, feel free to e-mail me, call me, it doesn't matter. If you want me to review anything in your presentation, I'd be happy to do it for you. Not only my section.

…

One of the problems we have in our society too, which is making this problem worse, is the idea that everyone has to have a green lawn. When I was first in this business, only the rich people had sprinkler systems, no one had sprinkler systems in. If you went away for say 4th of July weekend, which many people do, you couldn't sprinkle your lawn anymore because they were hand sprinklers, and when you got back your lawn was burnt and you forgot about it, you know, it will come back in the spring. Now with all the shows on TV about gardening during vacation, Home Depot, Lowes, you could put sprinkler systems in your self. Now people have a sprinkler system because they want their lawn to be nice and that is creating a huge burden on the water industry because of the fact that, a lot of towns, Burlington for one, they have a lot of trouble in summer time meeting water demands because of sprinklers. … If you have a big lawn, its hard not to take care of it, so one of the arguments are, you put in a rain garden, and put in perennials that don't need to be watered as often, and you plant a lot of bigger trees, or keep your bigger trees which provide shade so you don't have to water as much.

Some of the real big impacts to water quality were the gas stations. Back in the '80s there were a whole host of laws passed and regulations and technologies that you don't really hear or see gas stations having ruptured tanks any longer. All the old tanks from 20-3o years ago, the steel tanks, have been replaced everywhere. The impact created by gas stations in terms of ground water impacts and leaking of contaminants, many of those problems have gone away due to modernization of gas stations.

… We say good bye and end the interview.

Section 2: Ron McAdow

Interview with Ron McAdow Thursday November 15, 2007 – Transcribed by Adam Lirette

Adam Lirette: What is your organization's connection with the watershed?

Ron McAdow: The watershed is our service area. SVT has defined it's area of services to 36 towns that are all or partly inside the Concord River Watershed, sometimes called Su-As-Co.

Adam Lirette: What does your group think are the major problems facing the watershed are?

Ron McAdow: Do you mean with respect to water resources?

Adam Lirette: The problems with water quantity and quality

Ron McAdow: The question you asked is what do we see for the watershed, I just want to make a disclaimer that we're not specifically a water resource organization, we're a land trust. But you're asking me about water right?
Adam Lirette: Yeah

Ron McAdow: I am certainly in touch with people who are involved with water resources so it's not like I don't know anything about it, but it's not our organization's primary focus. Who have you talked to all ready, have you spoken with OAR?

Adam Lirette: Yeah, but we haven't had a chance to interview them

Ron McAdow: The three rivers in the system have different but related issues. The Assabet River has a long history of pollution from industry, but more recently from all the waste water treatment plants that empty into it. That situation has improved a great deal over the years as the wastewater treatment plants improve. But they still have too many nutrients, mostly phosphorous, that they put into the Assabet River. The advocacy groups like OAR have pressed for the state and the federal government to enforce clean water standards that are legal standards. They have succeeded at that. In the future towns along the Assabet will have to do something about that. The short answer to your question is the Assabet River has nutrient pollution. Both rivers have potential problems with the level of flow. You said water quality but the water research people talk about quality and quantity. They're not quite separable. To the extent that people waste water by irrigating their lawns with it and it evaporates and doesn't return to the ground and back into the rivers and streams. That causes low flow situations which has numerous bad consequences. That is a problem for the Sudbury and the Assabet. The Sudbury has this unique history of being a superfund sight. Does that mean anything to you guys?

Group: No…

Ron McAdow: A superfund is a federal government designation of places, usually by industry but it could be by government too, that has had a lot of toxins dumped into the soil and water. The Sudbury River has one right beside it in Ashland. It's called the Nayanza sight. It doesn't anymore, but it dumped a huge amount of mercury chemicals into the soil sometimes directly into the river. That has stopped and the government has spent a lot of money cleaning up the sight in Ashland where that had taken place. But, meanwhile they already brought the horses out of the barn in the sense that mercury has seeped into the river and it is heavily in the sediments of the river. That means that the invertebrates' living- it then travels up the food chain to the fish. The invertebrates eat it, then the fish eat the invertebrates and the fish end up with too much mercury in their flesh to be healthy to eat especially if you're pregnant. It would be great if we thought that there was some way to get mercury out of the sediment in the river, but no one really knows a way to do that. That would cost the whole national budget. So that's a probably a permanent, difficult problem to solve. It doesn't mean that the water itself is polluted however, it's perfectly safe to swim in the Sudbury River, you're just not supposed to eat the fish.

Adam Lirette: Does your group have any public outreach programs? If so, what?

Ron McAdow: We participate in, if you look over your shoulder there, that's a sign you may have seen. Parts of the three rivers were designated for inclusion in wild and scenic river system. The federal government has a program that gives protection to rivers if they're designated at national wild and scenic rivers. There is a long multi-year process for a river to be considered for designation. If it's accepted then the national park service administers a program that helps protect the resources that made the river nationally significant. The lower parts of the Assabet and the Sudbury and the upper part of the Concord, the five resources were found. There is a wild and scenic river stewardship committee that usually meets here. It's not ours but we are represented on it as other organizations are. They usually meet in the conference room downstairs. It's true that the RSC does reach out to the public. The outreach results in a big event called Riverfest. There are many local areas and we cannot create all these river celebrations. But, by having the publicity – There are many different local organizations that are doing in one way or another some kind of river based event and they are publicized together and coordinated together by the RSC. So, that is to build public awareness of the values of the river and hopefully they'll support the protection. We also initiated a project called the boaters trail on the Sudbury River. It's a self guided trail where you have information available at various point along the river. That project started here and has been carried on by the RSC

Adam Lirette: How has the public involvement with the watershed been?

Ron McAdow: I think it's good. People care about it but, I'd say its disappointing how much of the public doesn't understand that lawn watering is an egregious waste of natural resources and it's connect to everything else. So, that part is a little frustrating. But, other than that most people in this area would say that they care about natural resources and water resources.

Rich Pampuro: Are there certain areas of conservation that you focus on that attract larger numbers of people?

Ron McAdow: Well, my wife is the president of the board of OAR and it's her contention that people are more apt to support land issues than water issues. People volunteer for both of them. We have reservations that people can go and visit and they enjoy having this conservation land. But, of course they like to have nice rivers that they can paddle on. I don't know, I think its all part of the cycle. I do find it easier to extract dollars for land protection than for water. In one way that's logical because when we protect a piece of land, if we do it right, it stays protected and if we didn't do it then it might get taped over and out of reach for conservation. Whereas water resources in one way, we can always fix that.

Adam Lirette: Are there any locations that have seen drastic changes in water quality and why?

Ron McAdow: No, the Assabet River, over the next five years, will be improved. Now, if you canoeing in August you're apt to run into thick mats of duckweed. That's going to change because the dumping of nutrients by wastewater plants will decrease. Even that won't be too drastic because again the sediments act like a sponge of not only the mercury but the nutrients those they will keep spitting out nutrients. The other rivers, the other issues, there has been no dramatic changes. But, if you look at it over the long haul, I wrote this book, so I have given slideshows about our rivers… And very often elderly people would come up to me and tell me they used to swim and turn blue because of the die. The mills used to dump the die into the rivers and so the rivers themselves would flow bright colors and obviously be polluted. And the sewage which didn't used to be treated, towns like Hudson and Maynard, they would just flush the toilets right into the river. But, they were a much smaller population. That was gross. So we stopped that and other kinds of pollution. People used to think of rivers as ways to get rid of stuff. But as for much of my adult life that hasn't been the case. People have regarded the rivers as something to be respected and taken care of. That takes a lot of years for that to become as real as we had hoped.

Adam Lirette: Have you noticed a correlation between residential and commercial development and water quality?

Ron McAdow: No, I couldn't say that. There has been slow steady development pressure in this area and obviously development reduces impermeable surfaces. I am not aware of any direct correlation in our area. Undoubtedly there is, but there are so many factors that get mixed in like agriculture is no sweetheart either nor are golf courses. So, if you had a residential or commercial development that was using good practices for capturing storm water. There's a lot more attention on that now. (he then talks about Nancy Bryant from SWCC and how they do a lot with storm water)

Adam Lirette: what groups do you work with?

Ron McAdow: RSC, OAR and the SWCC. And a woman named Freddie Gilepski has a new organization called the Sudbury River Watershed Organization which is just getting off the ground.

Adam Lirette: Can you go into detail about what exactly you do with them outside of Riverfest?

Ron McAdow: There's a huge development for right down the road here on route 27. It's called Wayland Town Center. It would be a development with a mixture of residential and commercial. It is however redeveloping an industrial site that was used by Raytheon that is now closed. So we had the chance to comment on the development plans. The conservationists then suggested using native plants to reduce invasive species, use LID to capture storm water. We don't directly comment on these things, but we have a chance to give input to the RSC. So things that come before them, we have a chance to weigh in. Another group you should add in is the Hop Brook Protection Association. Hop Brook runs right across the Sudbury and it's a major tributary of the Sudbury River. It receives nutrient pollution from the Marlboro easterly treatment plant. So, when its license was up for renewal we joined in commenting on that. We are sort of lobbying the government t o make them pay more attention to an issue. We don't do very much advocacy, in terms of lobbying or trying to get people to do this or that. We stay out of the for the most part or just through the RSC.

Adam Lirette: Have you seen LID become a significant component to improve water quality?

Ron McAdow: People are aware of it, and we're trying to do that in the town center. I don't know how much new construction in the area is using it but there is a lot of push for ecological landscaping by home owners and landscapers. In the little world I live in there's a lot of push for it, but I'm not sure that in world beyond that there is. In our site here we try to create it as a model of ecological landscaping. We have a rain garden and we have some barrels for our runoff. So I couldn't give you a very well informed idea. But if you want to know about trends, that's a very new phrase. Another organization somewhat related to this is and has done work with LID is the 495 Metro West Partnership. Which is basically an economic development organization but it does some conservation too.

Adam Lirette: Has the government's role in the restoration of the watershed been helpful?

Ron McAdow: Oh yeah, it's absolutely critical. These are what we call in economics public goods, it's the commons, the rivers. If the government can stop us from abusing it people would be using it to death. So, the government's role is absolutely critical.

Adam Lirette: Have they been doing a good job with it or do you think that they could be doing more?

Ron McAdow: Well, it's all relative. The water resources people- I was in a meeting yesterday where the commissioner of the department of environmental protection was going on and on about all they were doing with water protection. But the leading advocates can think of more things that they ought to do. But I think they do a very good job. They function at a political level where they have to please everyone and still have to enforce the laws and still do it within the budget so I wouldn't be real hard on them. The Massachusetts Water Management Act is the big thing you guys might want to inform yourself on. It is new and it's about how much the safe yield is of an aquifer. Nobody quite knows how to do this. The town of Sudbury is only supposed to withdraw a certain amount of water from its well every year, like 65 gallons per person per day. I think they go higher than that and it's not clear that itself is a safe yield and all these things and how they are supposed to be controlled, because they themselves are a government. It's all very sticky and something we will be trying to figure out for a long time. However the whole issue would be fine if we'd stop watering our lawn. It's almost on, and I realize I have said this before, but every time I hear people talk it comes back to the same thing. It's not about showers, it's not about washing clothes, it's about watering lawns. If people wouldn't do that the impact on the ecosystem would be much smaller. Here at Walbach Farm if we use water, like many houses in this area, it goes out into a septic tank and then out into the ground and then it goes down into the ground again. That's true for the water in a septic tank. If we have an irrigation system and try to make the grass bright green, which we do not, that water wouldn't get to the ground. It would evaporate or be transpired by the grass or evaporated from the grass. Virtually none of the water used in irrigation gets back into the ground and that's why that's different. On the other hand some towns, this gets complicated, take their water and they don't even put it in the rivers. The Hudson wastewater treatment plant, it collects the sewage from the little urban center and dumps it in the river in a fairly clean state. What they try to do is try to figure out how to take that water and put it into the ground instead of dumping it into the river because that is much healthier. But, that's not so easy to do because you can't just inject a huge quantity of water into the ground.

Here he begins to describe the watershed in the Boston area

Adam Lirette: In general how well do you think watershed groups work together, could you please provide examples? Do you think there has been any competition?

Ron McAdow: There is a little low level competition for funds, but basically they work well together. We joined forces together to write up a list of goals for the watershed, which some had to do with water. I think they work together well.

Rick Pampuro: Do you find that there are certain types of things that you do that create more community participation?

Ron McAdow: Well we have events that make it possible for public to get out on the rivers. The rivers are so hidden, they're not visible. So the people who have lived in town for years are quite amazed how beautiful it is to go down the river and how much nature you see from the river. That, I think, is one thing you frequently hear is that if you get people on the river that will help.

Ron McAdow speaks here about land conservation

Section 3: Nancy Bryant

Interview with Nancy Bryant Thursday November 15, 2007 – Transcribed by Adam Lirette

Adam Lirette: Can you give me a description of your organization's role in the watershed
Nancy Bryant: We have been around for about eleven years now, I think we're going into our eleventh year and we are, as you know the Su-As-Co Watershed Community Council. The council is very unique among no-profits. Amongst environmental non profits nationwide we're relatively unique there aren't too many models like ours. What makes us unique is that we're not really about advocacy we're really about collaboration and getting all these different players in the watershed to work together for the common good. So we've been talking common good now in this watershed for a while, and I guess, I don't know if you saw the president's speech [State of the Union] but he's been talking about the common good. And we've been doing that for a long time here. Our purpose is really to try to get, on environmental issues, as I'm sure you are well aware, there's so many sides of the coin, anything from the economics to try to do something that will benefit the environment, to the variety of players and their different points of view on the issues and in many cases no exact right and wrong. So, our goal is to try to bring all these different diverse constituencies who have vested interests in the watershed to bring to the table together to talk about the issues in the watershed and to find common ground and go forward. To try to work with each other and not fight. There is definitely a place for advocacy, a place for legal battles, and a place for the fighting. These advocacy groups will push issues which is helpful and good. Our role is the whole environmental outlook in this watershed and to try to bring all the players to work with one another, to seek that common ground and go forward together on the issues in this vicinity. Our organization is formed such that we have equal representation of particularly four interest groups. We have steering committees who are standing representatives from across the watershed. They are regionally diverse and also the four different interest groups that they represent are as follows 25% represents the business sector and their interests, 25% represent the municipal government, 25% represent federal, state, and regional government, and 25% represent environmental groups, most of which are advocacy groups. That grouping adds up to about 14 of each group, about 56 members. Again, an equal number from each of the groups, or at least close to it. Those individuals are again also representative of the diversity of watershed region, north, south, east, and west, the three different rivers. It's an unusual model. A little history, back when this whole exploration of forming the community council started, eleven years ago, back in the heyday of the watershed initiative, you heard of that?

Adam Lirette: Yeah I have

Nancy Bryant: It was a state program initiated under Judy Cox, secretary of the Executive Office of Environmental Affairs at the time. Her goal was to manage environmental issues by watershed. Well, those that can be, air doesn't really work, but land and water issues really do. That state program was very strong here in Massachusetts for a time until Governor Romney came into the administration and just axed the program on his own accord. I used to serve under what was called the watershed initiative steering committee. It was a group of individuals representing the diversity of stakeholders across Massachusetts, to help govern the Watershed Initiative and make into a better and better program. This steering committee wasn't even consulted when the whole program went down. But anyways, that program has been gone since the beginning of the Romney Administration, so the last five years. But, prior to, when this program was in its heyday, it had some grant money that would particularly try to fund work that was happening on the watershed scale, so a lot of money went to watershed organizations. In the Su-As-Co, as you have found, is pretty much a suburban area and many of the towns are quite affluent and the knowledge of environmental issues is pretty strong. We have a fair amount of protected landscape and a population that is by and large pretty knowledgeable. As a result we have a lot of environmental groups in the watershed, such as SVT, Hop Brook Protection, we used to have Framingham Advocates (FA), we used to have the Su-As-Co Watershed Association, and that was looking at things watershed wide. It started back in the day when Boston was looking at taking water from the Sudbury River.

She goes into detail here about how Boston was considering taking water from the Sudbury River and then decided on the Quabbin Reservoir.

We also have OAR, so all these different groups were active and aligned in the watershed. Under the Watershed Initiative there was grant money but these groups came together and formed what was called the Su-As-Co Watershed Coalition but also the participation by the Metropolitan Area Planning Council (MACP), which most of the towns in the watershed are under, I think 101 towns it covers. MACP was there sort of broker to the deal, to try to bring some of these organizations, who had some varied histories with each others, some of them were competing against each other for funds or members. MACP was there to try to say hey, let's all work together. So, MACP or Hop Brook, SVT, FA, and who did I forget….OAR and Su-As-Co Watershed Association. Those groups came together and formed the Su-As-Co Watershed Coalition and applied for money under this new coalition. They put together a plan that had a bunch of different ideas, things that needed to be done. One of which was to explore the idea which was, before related under the Watershed Initiative, that there should be a community council in every watershed. I can't take credit for the whole idea; the idea really came from the Watershed Initiative, the state program. But, we can take credit for having received the grant and then explored with the watershed community, does this seem like a good idea, does putting together a community council seem like something we should do here in the Su-As-Co? Under their grant program they had enough funding to initially hire a person; I was hired, to carry out this grant that they got from the state, after the Watershed Initiative. I fulfilled the other components of that grants and the one thing that kept going was this whole idea of a watershed community council and whether or not we should go on and proceed with that. So in our first year we had a conference that we called Rivervisions and that was back in 1999 I believe. In that conference we forwarded this idea with the watershed community, it had about 150 at the conference, many of them very knowledgeable about aspects of the watershed, whether it was habitat or water quality or the various issues in the watershed. We identified some of the prime issues that are going on here and everyone thought that we should have an overall arching organization that represents all the different things in this watershed and brings together all the different players to work with each other. We should follow this community council model and apply it here in this watershed and make it work. We were really the only group in the state of Massachusetts who really took the ideology of the watershed Initiative model of community council and really made it happen. There were other groups that had semi watershed community councils. I say semi watershed because they didn't represent all the interests, maybe one odd issue and a couple sides of the issue in that particular watershed. But, they didn't really try to embrace the diversity of all the issues and the diversity of all the players. And, keep the footing equal amongst those players. In a community council anyway it's considered that every player is equal. To this day we are really the only community council that happened in this state. As we went along, after we developed, the state continued with its watershed initiative program and started to hire what we call Basin Team Leaders. And these were government employees, mostly one per watershed. Some of the watersheds got grouped together. We had one state employee who was dedicated to our watershed and he created a "Basin Team", and this is another entity that was pretty much environmental advocacy groups and state government together. We as the SWCC worked very closely with our watershed team leader. He believed very much in the model that we were developing and we believed very strongly in the basin team model and the help that the state government could be and the wonders of having the communication be so clear between the council and this team leader and the team leader and the other environmental groups. There was wonderful communication at the state level. We were making it work here in this watershed. The whole model of a community council has gone through, on the state level, the doubters on to the watershed initiative basically saying, "Well if we have basin teams, do we need a community council after all?" Some of the environmental advocacy groups doubting the necessity of a community council by saying if you're not advocating, then does it really work? In order to get progress made, don't you have to advocate? So eleven years later the community council still exists, the basin teams are gone because reliant on the state government and Governor Romney took them away. So all the basin team leaders got put back in the state government and no longer work with groups in each watershed, which is a very big loss. That program went away because it was on the whim of the state government and the state government can change by who's in charge. The community council is still here today and we still have the environmental groups participating on the community council. We have, I think, our biggest challenge is not to get participation, we have good participation, our reputation is quite well known, many people in this watershed call me Su-As-Co, but the hardship we have found as a community council, without this state program around, giving more for funding and with a recession and an economy that has just been up and down and with a government that really hasn't focused as much on environmental issues as I wish they would, funding is a real difficulty. In the early days of this, funding was easy, it was a new idea bringing in a community council, there was a watershed initiative, the state was really pushing management of watershed issues and collaboration was considered as the way to be or way to go. I thought geez; I though grant writing was supposed to be hard, I was getting grants left and right. Basically it was pretty easy to get money for this, but as with, I think, a lot of environmental issues, the tides change and watersheds are no longer considered the hot item, particularly when the state dropped the watershed initiative. The business funding we used to get, the support we used to get, some of them, would say "if the state doesn't think it's important enough to keep the watershed program then I don't know. In the mean time education isn't funded enough, our business is now only going to support education issues and social issues and we're not going to do the environment issues." Foundations also follow the tide of what's the hot issue of the moment and with watersheds not being thought of as hot anymore then foundations are thing. "Well that's kind of old stuff now; tell us about new things and the new work you're doing." We felt collaboration is indeed important, and not to say that advocacy isn't. There's also a place for collaboration and trying to bring all these players together. Education is a big component.

She here explains how she used to be in negotiation training and how she applies this to get groups to comply with each other.

Our hardest question is how to sustain our self because the work we do, being so neutrally based as we are and so education based as we are, we really are almost a quasi-government organization and as such it sure would helpful if the government supported the work we do, gave us some funding, but they don't. So, as a result our sustainability for how we keep this program running is very difficult. But, the benefits of having a community council here have been fantastic and probably I should stop there because some of your questions will lead me here.

Here she asks for a copy of interview because it was a good description of the group

Adam Lirette: Before the watershed initiative, was the competition between the groups in the watershed?

Nancy Bryant: Yeah, well there is still some of that. Some of that is just the non-profit world, the reality of things. Ron McAdow's predecessor Steve Johnson at SVT always used to say to me, "you need to look at it as the pie is always bigger; there is plenty of money out there to sustain all of these groups and what we do because it's so important. Instead of thinking there is only so much money and we have to compete with this organization or that organization for the limited amount of money." Johnson always said. "What we've got to do is get the message out there more broadly so more people realize the importance of the environment and keep making the pie bigger, there's enough for everybody." He was somewhat rare in his vision that way. I still believe him, but, the reality in the day to day work is that there is only so many businesses who actually give money to environmental issues and you find that both organizations or three or four are all writing to the same businesses for the same money, so in essence, we end up somewhat competing. I think that's true of non-profits who work on social issues too or health issues or any kind of issues. There has been information in the press about how, a couple months ago, there was a story in the Boston Globe about how many different non-profits are out there and there is a foundation for them and that some of these non-profits should blend together because they could conserve interest rather than each having their own overhead. They should work together. That just all part of the non-profit world. There will be some competition

Adam Lirette: Has the competition been detrimental?

Nancy Bryant: Again, I am a much bigger believer in collaborating and working together than competing. Competition seems to be by design in our business and the economy of the US. Competition is what makes businesses thrive and get better. There is that view of it, my personal view is that working together can make a lot better progress than sometimes, head butting. I guess, there is always room for healthy competition. In every foundation, everybody is competitive for grants. They're all reviewing grants, not everybody gets grants so there is competition. I think grant makers think that that makes the grants that much better; because they have to compete so they stay on their toes. There is some reality to that of course. The down side to competition is when it creates impaired relationships and that can sometimes be the inevitable result. I think there are good sides and bad sides.

Adam Lirette: Despite not doing much advocacy can you answer some questions on public participation?

Nancy Bryant: Again, if you ask us our view on “X,” often times as an entity, what I say by advocacy, if you go on our website you can see our motto of promoting blue waters and a green economy. So, that’s what we’re trying to accomplish here. We are three rivers but one community. We’re all in this together. So, the one thing is that the council often is unable to take a position on a typical issue because we are trying to represent everybody’s interest. That is sometimes seen as a downside by some and an upside by others, because that means that we’re trusted by all sides so at least we can inform and educate and in a way that people will believe is unbiased. If you believe that more informed people and better educated people will come together and make better decisions on these issues then that’s an important role to play, to be a trusted educator, but when it comes to taking some positions on some things in this watershed we are hampered in doing that because we work by consensus. So, go ahead and ask me and I’ll answer what I can.

Adam Lirette: Do you have any specific ways to improve community participation?

Nancy Bryant: What do you mean by community participation?

Adam Lirette: Anything from clean up events to workshops on conserving water or improving water quality.

Nancy Bryant: With education, we do a lot of that actually. The various ways we do public participation are… let me reel of a few. Our steering committee, those are all representatives across the watershed of various sectors of diverse interest groups. We hold our meetings, about five a year, and every meeting we have a guest speaker come and speak about a particular topic. Our hope is that all these different people attending these meetings will then go out to their constituents and then educate them. Again, these happen five times a year. We have our annual Rivervision conference, which is huge for public outreach. Typically between 100 and 200 people attend. We’ve done tens and tens of workshops at these events and had guest speakers and key note speakers, open and welcome to the public. Our steering committee meetings are never closed, the public could come. Not that we advertise them in the newspaper per say. But, Rivervisions, the conference, is definitely big time, advertised, put the word out there, get as many people to come as possible. I, in my job do a lot of public speaking. So I am out there putting the message out on various issues in this watershed and speaking to a lot of different groups. Anything form students at a school to a land trust series that has guest speakers to a rotary club to Walden Woods, which does educational projects for teachers who are doing summer workshops. Those teachers then go back and talk to their kids. So, I do an awful lot of public speaking and getting the word out to various groups. Then we have what is called our Storm Water Community Assistance program, which really spreads outreach hugely. I also go to a ton of meetings and speak out at the meetings so I play a role as a resource to this watershed too. People can call me and ask me for so and so’s name or how do I find more information on this, let me check my database here is a ton of names of people you can call. We also put out a calendar with the various meetings that are happening in the watershed. That calendar is up on the website. There is a bunch of stuff that I need to update but the website is a resource as well. The calendar, I try to keep that up to date on a monthly basis with meetings. Mostly what I call talking head meetings, we don't put nature hikes or recreational trips down the rivers in there. But, we put more discussion in the calendar. People can check it and see when conferences and meetings are. I get so much information coming in here so I can disperse it out. Our Storm Water Community Assistance program is, briefly, to help communities comply with the storm water phase 2 program. I assume, since you are talking about NPS here in this watershed you know about storm water phase 2. It's now it's in the fifth year of the permit, a five year permit. Back when the towns had to write the notice of intent they've got their control measures to comply with. Control Measure one being outreach and education and control Measure two being public participation and involvement. Those two controls member, we just saw, here's the chance for the SWCC with a despaired membership and pretty collaborative nature and unbiased viewpoint, educational purpose as being a really good entity to help towns comply with control measures one and two. Most towns don't have people in their DPW or in their conservation commission who don't have the knowledge, creativity or time or all three mixed together to go ahead and create educational materials to tell their populous about their storm water, to get all the people who are compliant with how to manage storm water so that NPSP is lessened. They're required to do this now in a permit. We started a wonderful opportunity a couple years before the permit became finalized. We thought, hey this is a really good place where we can help the town and help them improve water quality by educating people and we can get some money to help pay for our existence. So, we charge towns an annual subscription fee and we create some tools that they can utilize to educate their people and involve their residence and businesses and all the players who make a difference with the storm water on what storm water is all about and how it can be less polluted. In the very beginning, what we did was, include the notice of intent plans from the first five years for those two control measures and show those to the communities. We have followed through with that plan by subsequently producing the tools for control measure one and two on an annual basis and selling those tools to communities. And, stop me I wont describe them all if you have all ready look at the website and seen them. The website has them all and if you go there and click on storm water matters then you'll see our storm water…their called programs for storm water matters we have a logo that shows that when it rains it goes down a storm drain and the drain actually goes into a fresh water body and effects water quality. This affects the fish that are there and we hope that logo tells the story of why storm water matters in a quick example consider that like the arrows in the recycle logo to get people to realize and when they see them on our storm water matters logo, they think oh yes, storm water, storm water, what role do I play in this? How am I treating my lawn, or where am I washing my car, am I keeping my car up to date with leaking oil, if I'm a business am I sweeping the sidewalk in front of my place, if I'm a restaurant what am I doing with all that grease, on and on and on. It takes all people to realize storm drains, by and large, throughout this watershed, as in most places, goes into a freshwater body nearby and none of it gets treated. Therefore you have so many stories about the kind of stuff people dump down storm drains and you hope with all environmental education that much of the environmental problems are due to ignorance. If you educate them the ignorance goes away and then people better their practices and NPSP become less. If you look at the website you can see all the various tools that we have created, everything from lesson plans for sixth graders that utilize maps of their own towns and aerial photo maps, and kids can see their own house and how close they are to the water and the direction the water is flowing. Anything from that to our large storm water management display that towns have put up in their town hall, post offices, schools or town meetings so that people realize where the water goes. Then, a flyer that has been sent out to residents and businesses. A PowerPoint program so that town personnel can go and give presentations themselves to people about why storm water is important and that presentation can be elevated to a higher level of when it comes to talking to your conservation commissioner and trying to get them to put together an erosion control bylaw. Or, normal person's level about what storm water is all about. The PowerPoint is very amenable for its use, and on and on. We've created four years of tools so far and this year were doing a massive outreach campaign that will have posters and post cards and information to go on cable stations and flash kinds of stuff that people will see, using EPA philosophy of just hit the public one issue at a time. Don't tell them everything they can do with storm water just hit them with one particular issue. So, we're doing a little of that. Actually, one of the posters will actually be about LID. A lot of the towns are trying to pass LID bylaws right now, it's getting talked about more and more. It's trying to get the public to understand that there are these things you can do, rain barrels and stuff that can make a real difference. So, with that storm water matters program, that is a huge avenue by which we advocate, educate, particularly for cleaner watershed controls and NPSP.

Adam Lirette: I have had some mixed reviews on LID, I am wondering, what is your opinion on it?

Nancy Bryant: Number one, it's a hard thing to think, review or talk about because people's definitions about it are different from each other. Are you aware of the work being done at UNH and their storm water center? (No) If you click on UHS's website, I'm sure somehow you can find their storm water center. They are doing fabulous, real technical data research on how LID makes a difference. It's great, and there's tour of it up there, they charge $50 to do a tour but it's a half day all morning you can see it, of course they don't do it in the winter, but in the spring, summer and fall they have opportunities that you can go and take this tour and they show you around and what they're doing. They've got, for instance, pervious pavement and impervious pavement and they're literally recording data, it's a huge parking lot, and they are recording the results of what kind of pollution they get from each and managing it. It's kind of a scientific study that they're doing. They're also doing the same thing with pervious concrete. They've got a parking lot that is made of concrete that is pervious; it's a little more difficult to put down than pervious pavement but both of them take a skilled person that knows how to do it. Part of it is that people complain about LID if it's not done right. If the technology gets better and people learn how to do it better what they have found, at UNH, with pervious pavement, is great. We are standing there and we dumped a bucket and just went away (laughing), it was great it didn't stay there on the pavement it just seeped its way down in. But they had not vacuumed that pavement since they installed it five to eight years ago. It was still more porous. Even if the sand had gotten into the pores of the pavement, it was still far more porous than the regular paved surface. Now, they're finding with porous pavement that there is one form that they even used on stretches of I-95, some degree of porous pavement, because it gets the water off the pavement so that cars don't have the opportunity to hydroplane. So, there is even safety behind it as well as environmental benefits. They have tested there a couple of… vegetated wetlands, a wetlands, they have chat tails and going to another species and then another in very small spaces. They literally have taken non point water off of the parking lot, they have this huge parking lot area for UNH, so they have lots of area to take great NPSP from and they run that through the vegetated wetlands and see what the results are at the other end. How much petro chemicals are removed, how much sediments are removed, how well does this grow, how hard is this to maintain, here is the danger on that. The water that they put through there is pre tested and post tested so they can really find out how well things are being treated by these systems. They have various types of techniques in storm drains, a simple hood in a storm drain, there are various kinds of storm drains technologies that are used that they are testing. I would have to look back for other kinds. Anyways to me, that's a really good place to find out how well does LID work, what kinds of LID work and I find that there's great promise with the technologies put they have to be put in correctly, they have to be maintained correctly and when it comes to us participation, the town of Maynard is putting together their LID bylaw, you also get into the politics of how you institutive this, how you require this part of development. Are the requirements to severe or are they reasonable? Do some of these technologies, once put in, actually pay back after a certain amount of time? In most of the cases they find that most of the technologies do pay back. We find later that, in the environmental field, there certainly were a lot of things we thought were great, but once implemented and gone further with, we realize it was a mistake. A huge one was putting the waste water treatment plant out on Deere Island for Boston. Instead of recharging all that water, all the water is salinated. Some day in the future that will probably be all undone, but at the time there were too far along before the realized a local one would be a better idea. But, by and large, I would say that LID has great potential and I'm glad there are places like Unh that are doing really good research on it so that the right kinds of LID technologies can be implemented. I think pervious pavement and I think some of these vegetative swales and vegetative wetlands technologies have terrific promise. That's my take on LID

Adam Lirette: During the Romney Administration and post Romney, has the government been doing a good job with the limited funds that they have?

Nancy Bryant: You're in a Romney Administration, granted we were faced with a fiscal crisis as a state and everybody was pulled back for budgets, but I think the environmental budget for the DEP and the some of the other agencies, department conservation, recreation all the agencies like that took a harder hit than many other kinds of agencies. We've got a long way to go and recovering from that hardship. I have so much respect for the Paul Hogans and people that work at DEP. We are fortunate as a state to have some of the staff that we have in these environmental agencies. They have been there a long time; they don't make the kind of salaries they could probably make at a consulting company instead; they are dedicated staff, they have been through very depressing times, particularly under the Romney Administration when a lot of the staff was laid off or let go. I just have a lot respect for the staffing here in the state. All those environmental basin team leaders under the watershed initiative, they were just an incredible groups of individuals and it was a huge mistake to have lost them and pin pointed them back to one daily… when they have all this knowledge of all the players in a watershed and have some much knowledge and we so helpful. Basically we have a long way to go to recover; I know that Patrick Administration has put a lot more money back into the environment, that's good. They are putting a lot more money into land protection again, that's good. Unfortunately the whole watershed arena and water quality issues are still… they get remembered on the Charles River, because that's noticeable in Boston. But, a lot of the other rivers here in MA tend to get forgotten. What I was saying earlier about foundations and businesses going from hot topic to hot topic with their funding and know there is a lot of talk about sustainability and going green and energy.

So energy is now the new hot button and it's a good thing because my belief is that things go round and round and we've been on the downside in terms of water being an issue like it was back in the says with the Watershed Initiative but that' going to come around again. Because of climate change we experiencing lots of flooding and lot more severe storms. We are also experiencing, in the Su-As-Co and else where, a lot of towns are having a lot of trouble meeting the demands of their water supply. Water supply will become a hotter and hotter topic. Wastewater treatment is going to become a hotter and hotter topic. Back in the days of the 60's and 70's there was a lot of federal funding for creating wastewater treatment plants. It's been 30 years and these places need upgrades but there is no longer federal dollars to do that. And municipals are very hard pressed. And at some point or another, just like bridges are becoming realized, infrastructural no one pays attention to them enough, our treatment plants are going to become like that too. They have all ready, to a large degree here in this watershed, with some of the issues on the Assabet and Hop Brook, in terms of trying to get enough treatment for phosphorous. But, also water supply is going to become an issue as is the new mentality with the populous with going green. That is a good thing; it will bring good things to the environment. If all of us who work with these issues can just hang in there and keep ourselves around, I do believe that the issue of water supply and wastewater treatment and storm water are going to become huge issues within the next five to ten years, without question. We'll get a lot more attention again. Things go round and round and that's just the unfortunate part, the attention isn't consistent enough so that things like wastewater treatment plans and their infrastructure gets poorer and now they need a huge amount of funds

She continues to talk about the hardships facing municipalities with their lack of funding.

Section 4: Paul Hogan

Interview with Paul Hogan, Thursday December 10, 2007 – Transcribed by Adam Lirette

Adam Lirette: What is your organization's connection with the watershed?

Paul Hogan: I've been with the department, doing this stuff for 34 years and 11 months as of today, so I guess I've been around a while. But, I do mostly now, permitting for wastewater treatment facilities. Now in the Su-As-Co you have seven or eight treatment facilities as you saw in that slide show, which are being improved. In the past I have done water quality management planning for watersheds. My first watershed was the Su-As-Co. I tried to find past reports from the past, but the micro feed everything, so I can send you a copy later as a PDF. So, I have been involved with the Su-As-Co in particular but also the entire state of Massachusetts. Now I do permitting with the USE EPA with all the wastewater treatment facilities across the state. In the Su-As-Co there are seven municipal treatment plants and I can talk to you more about them as we go on.

Adam Lirette: What does your department think the major problems facing the watershed are?

Paul Hogan: One of the things I suggest that you do is to go onto our department website and we have water quality assessment reports on there. We go out and do river surveys. [Here, he recommends that we look for a job helping out with this as it is interesting and high paying] The water quality assessment report is our review of the water and has all the data we collected. It has water chemistry and oxygen, bacteria, and nutrient levels, and in the past we did metals. We don't do metals any more because of the techniques necessary to test for them. We do biological work and review toxicity testing. It's certainly all the water quality stuff from top to bottom and we have done it periodically for the past 35 years. So those assessments are online. The Assabet, which is one of the three rivers, is one of the first reports we did. It was mandated by the EPA because we are not meeting standards on that system. It requires us to do what is called a total maximum daily load, A TMDL. You will see that terminology. There's also a report on the website that talks about the Assabet in particular the TMDL and what's required at the treatment facilities and what's required through sediment work to reduce the nutrients levels, particularly phosphorous. So bottom line is that in all three watersheds, it's our strong opinion that nutrient enrichment and resulting algae and plant growth and variations of oxygen is really the major problem. So if you have looked at those PowerPoint slides, they all talk about the facilities that are undergoing current upgrades to remove phosphorous up to 95% of what it is now. Now phosphorus comes from human waste and phosphorous cleaning agents. There is no phosphorous in laundry detergents any more, but there is in dish washing detergent. There is still a fear of phosphorous coming from those sources. The important thing in a water system is that you only need a very little amount of phosphorous. So these are all pretty much phosphorous enriched. So you get, particularly in the summer time…do you study much about plant growth and algae? They get pretty green and slimy. So, that is the biggest problem in the watershed. The other side of the coin is water quantity. Do we have enough and are we being smart with water, particularly in withdrawals from water supply? Many systems have ground water, so you take it out of the ground water; export it out of the system, your local tributary streams. This is what we call base flow and it will be significantly reduced, so you don't have enough flow for biological life in these systems. Secondly, probably, management of storm water and the really strong push in the past 25 years. Now, the Su-As-Co is basically is up I-495, toward Route 2. Marlboro, Concord, Westborough…So, if you look at the watershed map you can see it's very highly populated. One of the things you should do is look at the characteristics of population over a certain time period. With population comes need for housing, with housing comes less impervious surfaces. With more houses, generally people live in houses and you need more water. People have waste and you need more waste water. It really puts a demand on water. Another thing that was within the watershed is really that balance of water supply and disposal of wastewater. Those are the major things that we see there.

Adam Lirette: Has the state incorporated successful water quality improvement methods from other watersheds? If so, what?

Paul Hogan: If you go back to the Clean Water Act in 1972, just as I came into this stuff, you had systems where it was untreated sewage and industrial waste going into river systems. You wouldn't believe it, if you ever saw pictures; you'd say "How the hell did you let that happen?" So, we have made great strides in reducing a lot of the gross loads into the river systems, where we now have healthy populations in most river systems. That is the biggest improvement. So, it's not one watershed verse another and it's been statewide and nationally that much of that has come from construction in operation and upgrade of waste treatment systems, where waste water is collected and treated at a facility. You should go visit one in Westborough probably fifteen minutes away on route 9. I'm sure they would be happy to talk to you about what goes on.

Adam Lirette: Where are the biggest sources and types of water pollution in the watershed? Has this changed over time? What may have caused the changes?

Paul Hogan: The watershed is about 400 square miles and you have seven municipal treatment systems. Unfortunately they are perfectly spaced so you get Westborough right at the head water of the Assabet giving you a very large treatment facility going into a river from here to there, so now it's mostly wastewater. And you go six or eight miles into Marlboro and another six or eight miles you go into Hudson and another eight or ten miles you're in Maynard. In the eastern part of Marlboro there is a facility that goes into a very small brook, called Hop Brook. It is a national historic - have any of you guys heard of that?

Group: No

Paul Hogan: It's in Sudbury. It's an old mill type system. You have the town Concord right down from the north bridge. So, you have a repeating sequence of wastewater inputs. So, with that comes waste into those systems. The other thing is that many of the rivers in the state have old damns that were built in the 17 and 1800's that for water power. If you look, go out and take a trip around the watershed, you will see from the Assabet there is probably eight or ten damns and the Concord there is three or four and in the Sudbury probably 10-15. Most of those were built two or three hundred years ago. You have a natural river system and you put a damn in and you suddenly flood it. That now becomes a sink for sediment; it really changes the ecology of the system. It's now more of a wetland area good for wild life but, hurtful for promoting algal growth and plant growth. Massachusetts has a lot of these old historic damns, hundreds of them. Just another thing in the sequence.

Adam Lirette: Are there any locations that have seen drastic changes in water quality and why?

Here Paul Hogan goes into depth about other watersheds that have gone though major changes. Boston Harbor is an example of a watershed that has gone through drastic changes. It went from nearly not being able to look at the water, but able to actually put businesses on the water. Another example is the Nashua River watershed. Paul tells us that he used to go up to the Nashua River watershed to test and said that depending on the ink that the local paper company used most recently. He then goes on to inform us about Marion Stoddart and her efforts in the Nashua. He explains that she used the public's help really well.

Adam Lirette: Have you seen and drastic changes in the Su-As-Co Watershed?

Paul Hogan: I think so, significantly. Because, back again, 35 years ago we had very bad oxygen problems. We had what you call high organic loads. The waste wasn't treated very well. All of the waste treatment facilities have been significantly upgraded over the past 35 years. So, the levels are much better. What has happened is we have shifted the problem from just gross awful water with sewage to algae problems because there is so much phosphorous. Before phosphorus didn't matter because there was no oxygen, there was so much waste it was unable to grow. So, it has shifted the dynamics and it is significantly better now, but there are still problems.
Adam Lirette: So, in the Su-As-Co, the water quality has, as a whole, improved drastically?
Paul Hogan: It's improved, I think significantly, but it still has that remaining nutrient enrichment problem. It went from no oxygen, awful problems, untreated wastewater going in, just putrid water. We have removed a lot of the organic waste and now we have a more biological system.

Paul now talks to us about another watershed in southeastern Massachusetts and its metal problems. Despite the water being clear and looking clean the pH was three or four and killed nearly all biological life. They made drastic changes in that water shed and removed many companies that deposited waste into the river system.

Paul Hogan: If you can't take a drive around try somehow to get a sense of the river as opposed to looking at it on a map. Go to a few spots, it's really a beautiful area. I don't know if you fish, hunt, just like wildlife, or canoeing. There are some really nice areas. Right at the headwaters of the Assabet there is a big flood impoundment built in 1970, in Westborough. They have tremendous hearings that nest there and you see gigantic swooping hearings around there. There's also beautiful bass fish in there. But, it's a very nutrient enriched system. So, I think there has been improvement in usage but, again we have a lot of work to do. There's a lot of money, if you noticed on the slides, we're talking millions and millions of dollars put into it.

Adam Lirette: Have you noticed a correlation between residential and commercial development and water quality?

Paul Hogan: The biggest thing is the fact that if you put in, everybody uses the term Wal-Mart, but I'll use a box store. If you cement the parking lot you can't get the water back into the ground naturally filtrated. The emphasis has been to try, at sites like that, to "treat the water" before it leaves and erodes away a stream or something of that nature. Put in some time of prevention basin, overlaying swale or something like that. But, there is a definite impact in residential and commercial development. Again, what I said before, a lot of use, more waste water and a less impervious surface. Downtown Worcester, when it rains, a lot of the water is going down a sewer and into the river, not a lot of filtration.

Adam Lirette: Does your department have any public outreach programs? If so, what?

Paul Hogan: Depending upon the program, about five years ago, when we really started concentrating on addressing storm water, we did a tremendous amount of outreach to the public, to consultants, and to cities and towns. So we have made it a concerted effort, we have worked closely with watershed groups over the many, many years. Nancy Bryant, have you contacted her?

Group: Yeah, we have

Paul Hogan: I've worked with her a lot of the past ten years, that's [SWCC] an example of a watershed group. They are self sustaining, they have to raise their own money, they have to get money from grants, companies, volunteers and donations. They keep regulatory agencies and municipalities on their toes so to speak. If people didn't care about the quality of the river systems, then who's going to talk about it? I think that's a tremendous aspect of it, very important. The downside of it, at times, is that progress takes a long time in this business. You guys have probably seen that. It's not like "oh, you can fix it like this, right?" It takes money, it takes planning, it takes recognition of what the problem is and most of the public volunteer groups, volunteer. So, they have other things to do in their lives and they have somewhat a sustained dedication for life. If you're a red sox fan, you're a red sox fan for life, so let's put that aside. If you're really passionate about volunteering for something, you maybe do it for five or ten years and then you're worn out. But, without them I don't think we'd be where we are. When you find out about Marion Stoddart, she's the type of person who refuses to say no. She's that tremendous, tremendous example of one person who said, "I'm not going to take what's going on." She started back in the late 60's and early 70's. One of the things we did do about six or eight years ago. We set up what is called the Watershed Initiative. We tried to get different disciplines within the environmental world collectively together to address problems as a group as opposed to separately. Prior to that we would say here are the wildlife guys they take care of the fish and stock fish. But, they don't do much with water quality. Water quality guys don't do anything with the people who take care of conservation or land development. So, we put this initiative together and said lets all get together. Water quality is important to fish, land development is important to water quality, etc. So we had that and it was very successful for about six to eight years. Then there was a change in administrations and it was done. I was involved from day one with that. It really was a tremendous bringing together of volunteer groups, regulatory people, state, federal and local agencies. I think it was a really great thing to do. It just got bounced by the new administration when Romney came in. Things like that happen, unfortunately.

Adam Lirette: Are you working together with any watershed groups and if so: in what ways? Which organizations? Have you encountered any problems?

Paul Hogan: I've worked with them since I started; recently I have worked with the Blackstone River Coalition. They're doing work on the Blackstone, as far as making the Blackstone meet standards by 2015. They have a really strong group of people, a coalition based in Worcester. You might want to look them up as well, just for ideas. Donna Williams is the person… she's actually a Mass Audubon employee. There is, within, the Division of Fish and Game of Massachusetts, a group called Riverways. It's really a river advocacy group. They're in Boston, but they go all over the state. They're really the closest that we have, in the state government, to someone that really promotes the volunteer work and the outreach. It's Riverways, Mass Fish and Wildlife, Joan Kimball. It is well worth giving her a call, she knows me very well.

Adam Lirette: In general how well do you think watershed groups work together, could you please provide examples?

Paul Hogan: I think it's a good relationship because we're all after the same thing. We have our old, as people say, irregulates. I was quoted in the paper a couple weeks ago as an "old irregulte" because one town didn't like what I was telling them. But that aside, our goal is environmental improvement, water quality improvement, sustainable environment… People who have a passion for it are just tremendous. There are night meetings, weekends… that Su-As-Co meeting conference was on a Saturday. Now you have 100 people who spend, on a Saturday, going to discuss what's happening in the Su-As-Co. We get a lot of things done at the conference. Things such as, we had a panel, carbon foot print. Some women gave a talk on how organizations are trying to become carbon neutral. There was a gentleman there that was saying don't worry about water quality and nutrients, it's all the invasive species that are killing the river systems. I gave a talk on the upgraded treatment facilities. In Ashland there is a superfund sight called Naianza. Mercury has been discharged for about 30-40 years. From that portion of the Sudbury all the way down there are warnings about mercury contamination in fish. If you paddle down the Sudbury, which is a beautiful river, to get past the invasive species and water chestnut and you see these signs, "don't eat the fish" and "mercury contamination" it's really looks bad. There's a lot of stuff going on besides water quality, so maybe you could try to get Nancy to try getting the slideshows used at the conference to put them on their website.

Adam Lirette: Would you say there is Competition among the groups?

Paul Hogan: I don't think so. The two that are really active are the Su-As-Co Watershed Community Council and OAR. Maybe they compete for a little funding, but they have the same goal. One of the things that they try to do is to get support from individuals who care and from organizations who have more money. These people aren't well paid. The Nashua River Watershed Organization has a staff of about 20 full time people and that started many, many years ago with Marion Stoddart. But they have a lot of big corporations give money. They have hundreds and hundreds of members who donate money yearly. So, I don't see that. Sometimes there are grants that they both apply for from the federal government or from organizations and it's a pretty tough thing to do and they are pretty aggressive. Unfortunately you do need money to survive. Those who have full time employees need money. You guys are going to school, you want to get a job and make some money. I think from the perspective I wouldn't say there is competition, maybe they go after the same grant. The Nashua just got a grant for, I think $500,000 from the EPA, but maybe someone else applied for it. But I don't think there is any really harmful competition.

Adam Lirette: So, nothing detrimental?

Paul Hogan: No, I don't think so.

Adam Lirette: Is there any attempt to put LID into policy?

Paul Hogan: The Executive Office of Energy and Environmental Affairs in Boston, there is a person there, you can go on their website and look it up. Andrea Cooper, she's the LID spokesperson for the state. I am, to date, somewhat of a skeptic on how effective it has been. The idea is to have less impact on the environment. I live in Holden, the next town over. All I see is big houses built in every part of town. I don't see any attempt of LID in my community. I think it's a nice idea but, a nice idea that isn't widespread.

Here he asks us about our hometowns and if we've seen an LID, which none of us have seen.

Adam Lirette: How has the state's funding for water improvement changed?

Paul Hogan: For wastewater treatment facilities, the funds, going back 35 years, there were grants for communities to build sewers and treatment plants. It would be up to a 90% grant. You guys know the difference between grants and loans? You like grants, but maybe you have to take loans right?

Adam Lirette: We know about loans…

Paul Hogan: But some of the schools say they're going to give out just grants; WPI isn't up to that yet?

Group: Not that we know of.

Paul Hogan: They used to give grants for all this and they'd give millions and millions of dollars, billions across the country. About 15 years ago they stopped giving grants. The grants came from the EPA to the states and they were dispersed and now it's a low interest loan. It used to be a zero percent loan and you'd give to, say Dover, 10 million dollars to build a treatment plant and they'd pay it back over a time period with no interest. That is now a 2% loan and we give out about $300 million dollars a year to treatment facilities. So, Burlington would apply for a loan for their sewer rehabilitation pump stations at waste treatment plants. They get it, they pay it back over a certain time period and the money goes back into this trust fund. They have approximately the same amount of money that is loaned out to the communities for water treatment plants. It's not the grant program anymore so the community is not free.

Richard Pampuro: Why did they shift from grants to loans?

Paul Hogan: You know it was just a shift in policy. They didn’t want to continue to give up millions and millions of dollars. I don’t know what administration it was it in, maybe Reagan. For a community it was much better to get a grant, as you guys know.

Richard Pampuro: Do you have any wastewater discharge records I could look at?

Paul Hogan: On the Assabet, 5 or 6 years ago, when we knew that the facilities on the river had to get upgraded. We got the four major communities together and formed a cooperative to look at planning for their sewer needs, treatment needs, etc. That will be in your TMDL reports. That’s something you should look at.

Adam Lirette: As for LID, is there no pressure form the government for people and businesses to pursue it?

Paul Hogan: I’ll be honest; I’m not that involved with it. Look first on the EOEA website. I’ll send you a list of web connections so that you have those and you probably can search faster than I can through those. I’ll send you Riverways, Andrea Cooper and more. They probably have discussions that maybe there are bills or legislation filed in communities, but I just don’t know that. I hope that my skepticism proves wrong, but I haven’t really seen it work as it is talked about.

Richard Pampuro: I noticed in the Assabet TMDLs they specifically NPS phosphorous for a large portion of the report. But, most of the older reports don’t address that, for the most part. Do you know when they started looking at NPS?

Paul Hogan: If you look at the old reports that we did in the 70s, we talked about the NPS. We weren’t in the dark; we knew that most of the problems were point source related, so we talked a little about NPS, storm water, run off… When we did our mathematical modeling we had a NPS portion. The reports that I send you, you will see that we establish a NPS program in the 80s. We recognized that we might be able to do something about it. We were just so overwhelmed with trying to get the big problems resolved. We just couldn’t address NPS in any real detail. It’s a tough thing to do because if you have an input, a pipe, and a treatment facility it’s a finite thing you can handle. If you have a watershed and non-point it’s basically an entire water shed. It’s much more difficult but there are ways to do it by land use planning and a lot of other things like less fertilizer used, etc. NPS is also the stuff that’s in sediment. The stuff that has been there for decades and hundreds of years. It has been recognized. I will see if I can dig up more history on NPS. We did a thing called the mega-manual about 15 years ago. That really looked at NPS controls. We have a program called 319 where we give grants out to look at NPS control systems. We have recognized it and we have put money into it. In the Assabet 80% of the load comes from those four facilities, so that’s where were putting most of the effort.

Section 5: Joan Kimball

Questionnaire

- What is your occupational connection to the watershed?

State agency; serve on Sudbury Assabet and Concord River Wild and Scenic Committee; our program provides technical assistance to groups in the watershed.

- Does your department have any public outreach programs? If so, what?

We work with the public in many ways—creating Stream Teams that we train in what a river needs to be healthy, how to conduct assessments and find problems, assets and we facilitate them in involving municipal officials and developing action plans. We also, when appropriate and when we can, help implement the plans. We have formed, in cooperation with watershed associations, X Stream Teams in the Sudbury Assabet and Concord Rivers over the past ten years include ***Assabet*** *River: Maynard, Northborough, Acton Marlborough;* ***Sudbury River*** *: stream team on Hop Brook, Sudbury River in Framingham, Upper Sudbury (that turned into the Sudbury River Watershed Organization) and on the* ***Concord River*** *a Stream Team on the Mill River and one in Billerica.*

- What have you found to be the best ways to improve community participation? Is there evidence that this has improved watershed water quality? If so, how?

We find doing experiential work—assessing streams with a view to improvement, monitoring, and working together. The Organization for the Assabet River has done a truly phenomenal job of combining science and advocacy and their work is making changes. Some of the Stream Teams, such as the Hop Brook Stream Team and the Acton Stream Team have made significant progress with identifying nonpoint source pollution and working to have it remedied. The Hop Brook Protection Association and OAR have both worked to ensure more stringent water quality permits; which may or may not be controversial.

- Are you working together with any watershed groups and if so: in what ways? Which organizations? Have you encountered any problems?

Organization for the Assabet River: right now Riverways is providing technical assistance on dam removal.

Sudbury River Watershed Organization: Right now Riverways is providing technical assistance for both flow monitoring and water quality monitoring

Sudbury River Wild and Scenic River Stewardship Council: represent the Commonwealth
SuAs Co Community Council: Last week Riverways provided staff to be on a panel at a workshop Riverways reviewing dam removal protocols.

Currently provide Stream Team assistance as requested. We are actively working with the Marlborough Stream Teams.

We have outstanding relationships with all the groups in the Sudbury, Assabet and Concord Rivers. I used to serve on the EOEA watershed team before Governor Romney disbanded it.

Appendix C: GIS Pictures

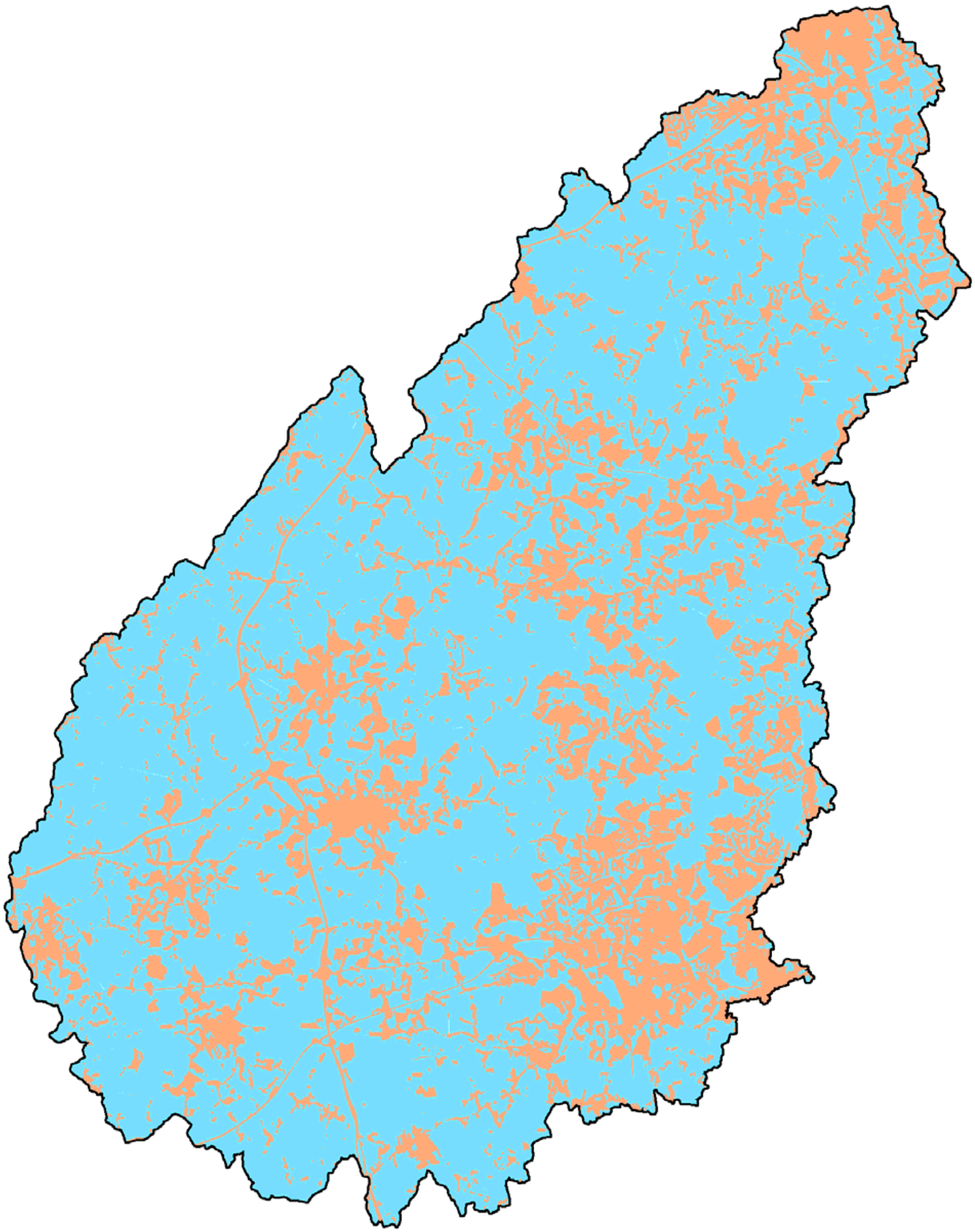

Figure C.1: Developed land (orange) and undeveloped land (blue) in 1971.

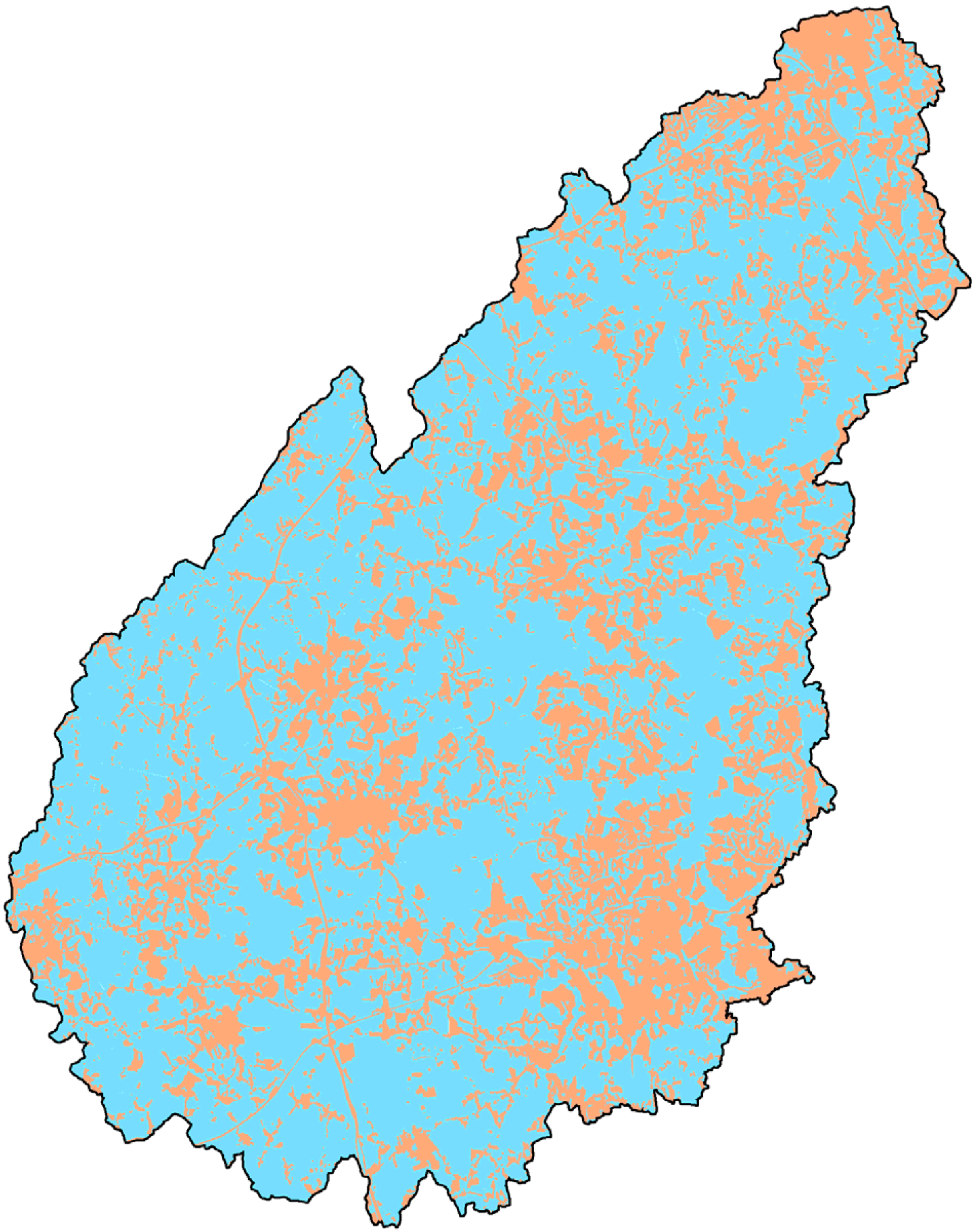

Figure C.2: Developed land (orange) and undeveloped land (blue) in 1985.

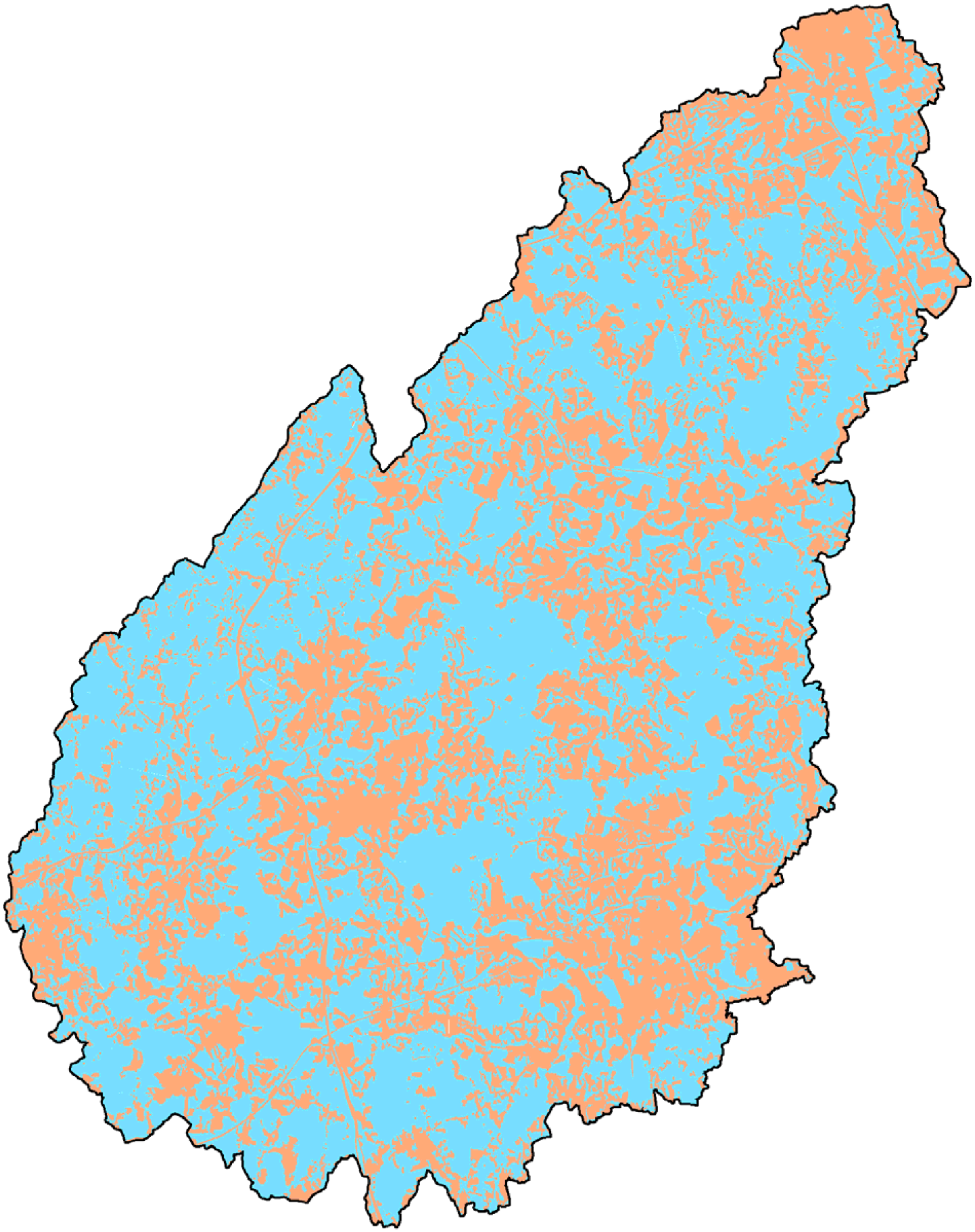

Figure C.3: Developed land (orange) and undeveloped land (blue) in 1999.

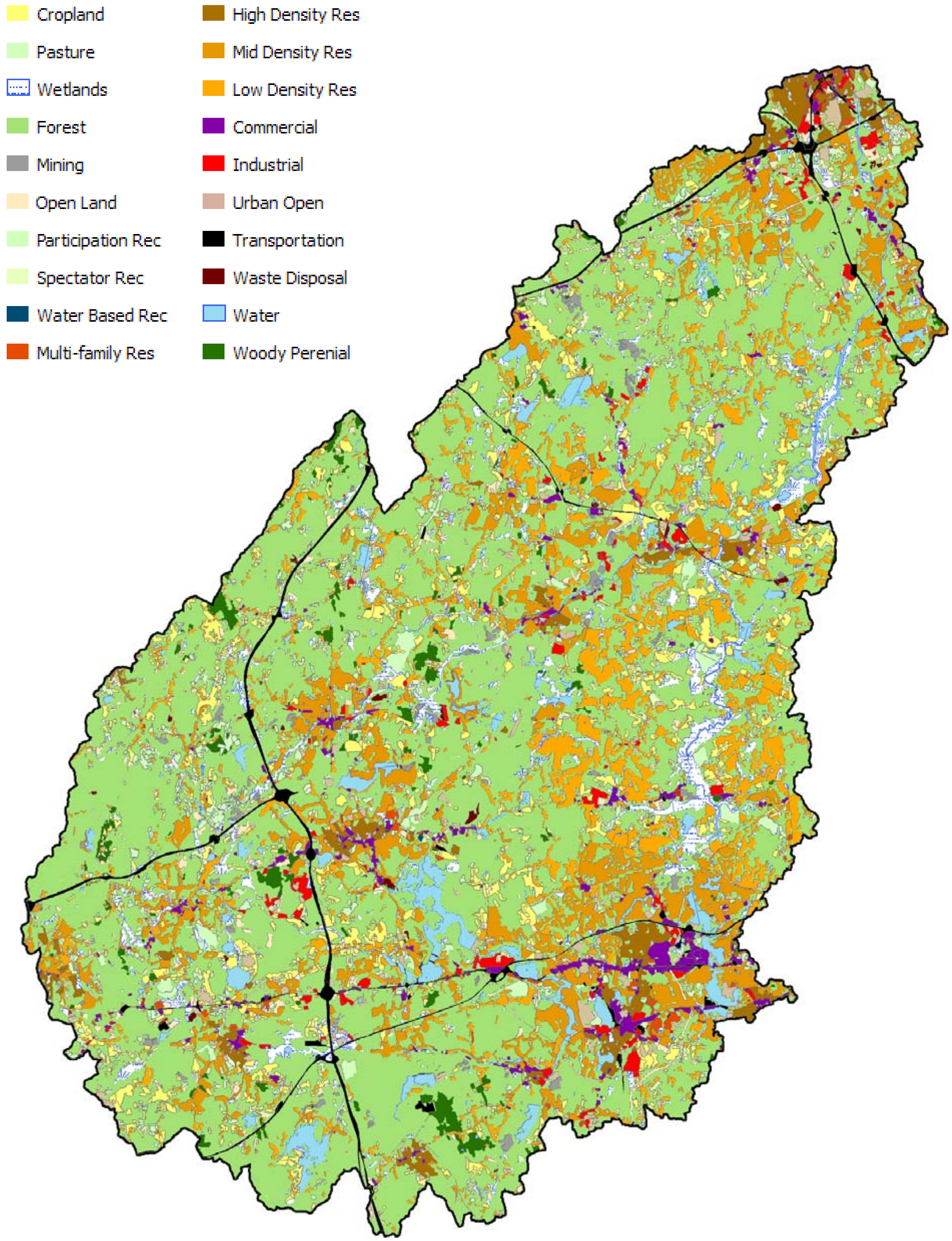

Figure C.4: Land use in 1971.

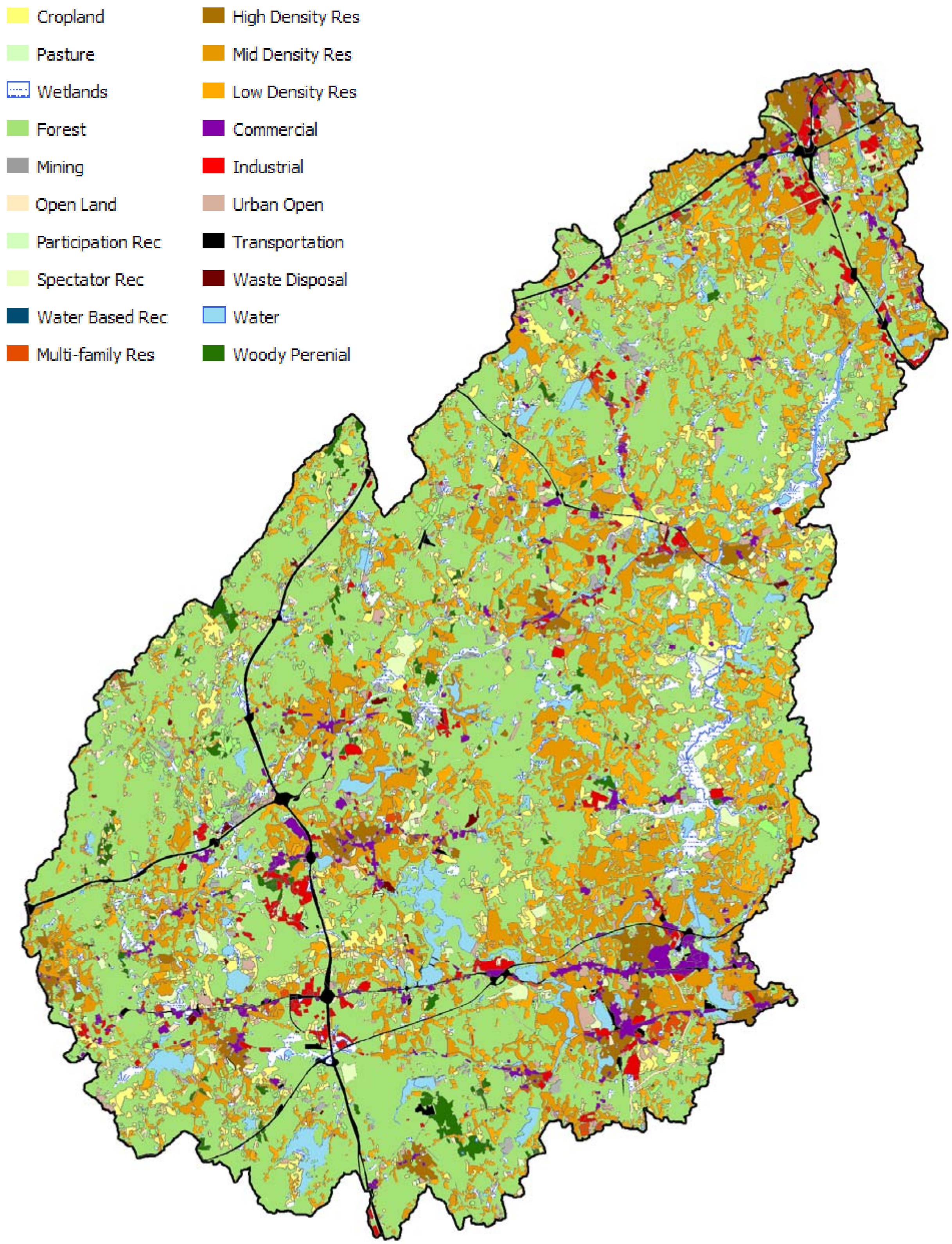

Figure C.5: Land Use in 1985.

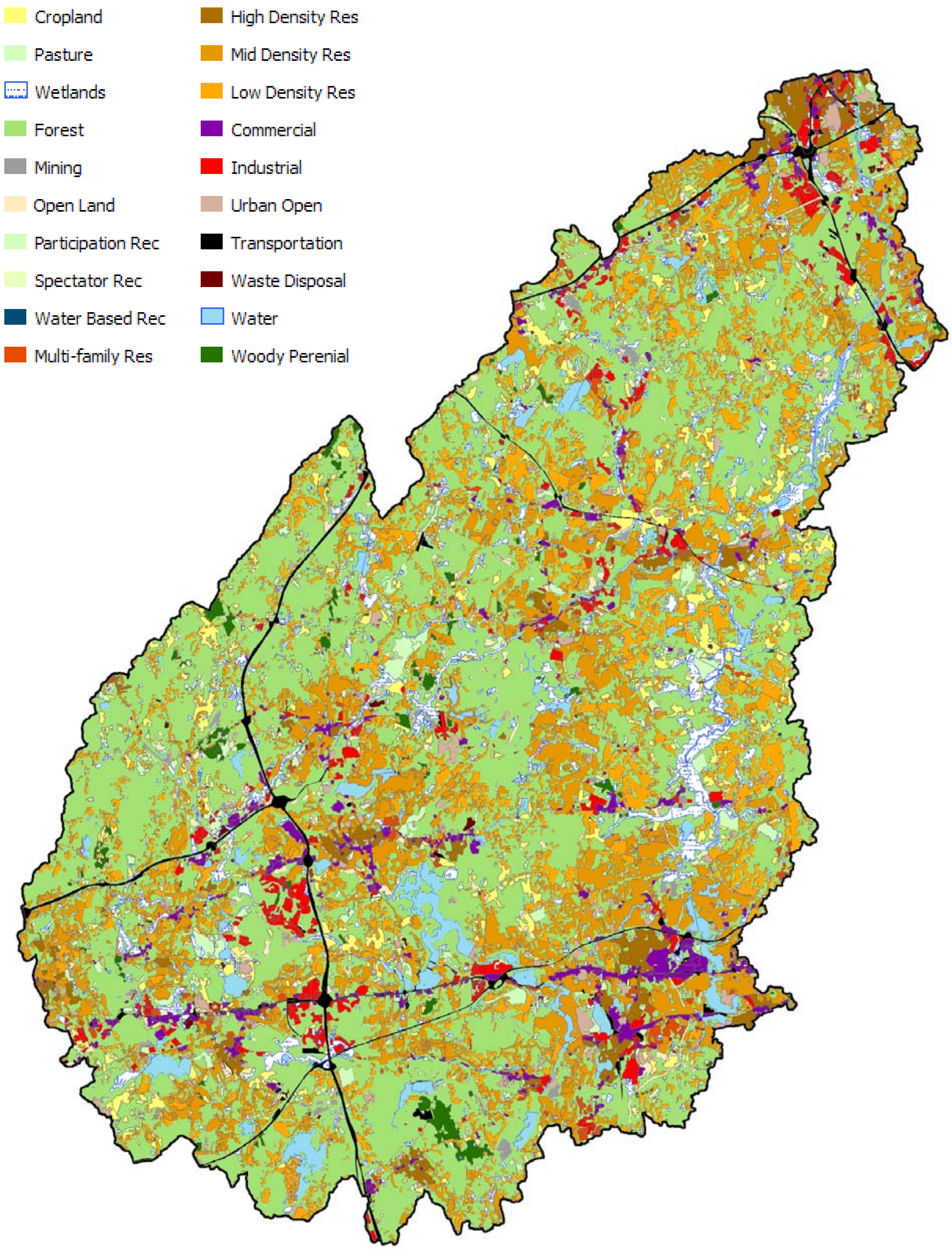

Figure C.6: Land use in 1999.

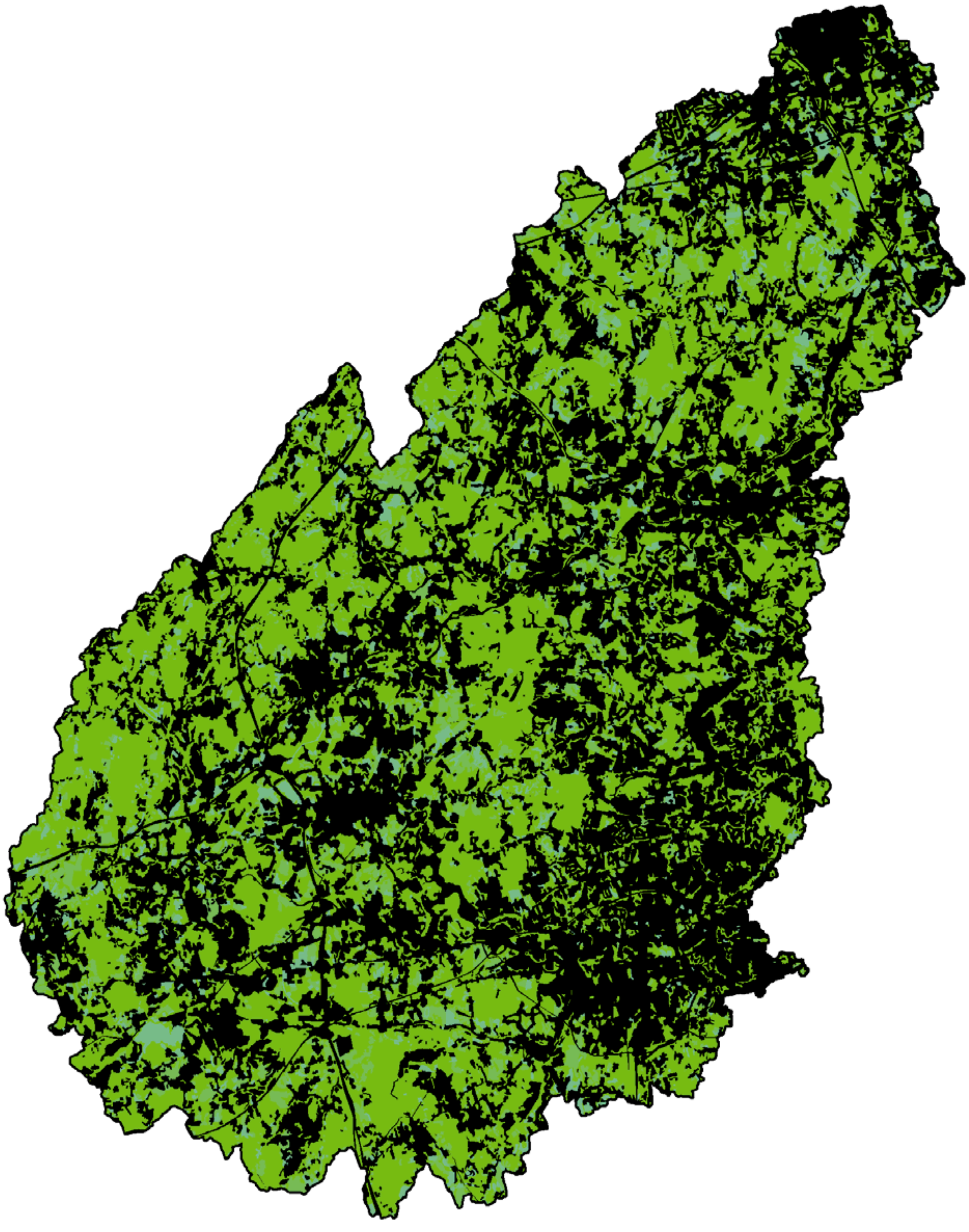

Figure C.7: Forest land use

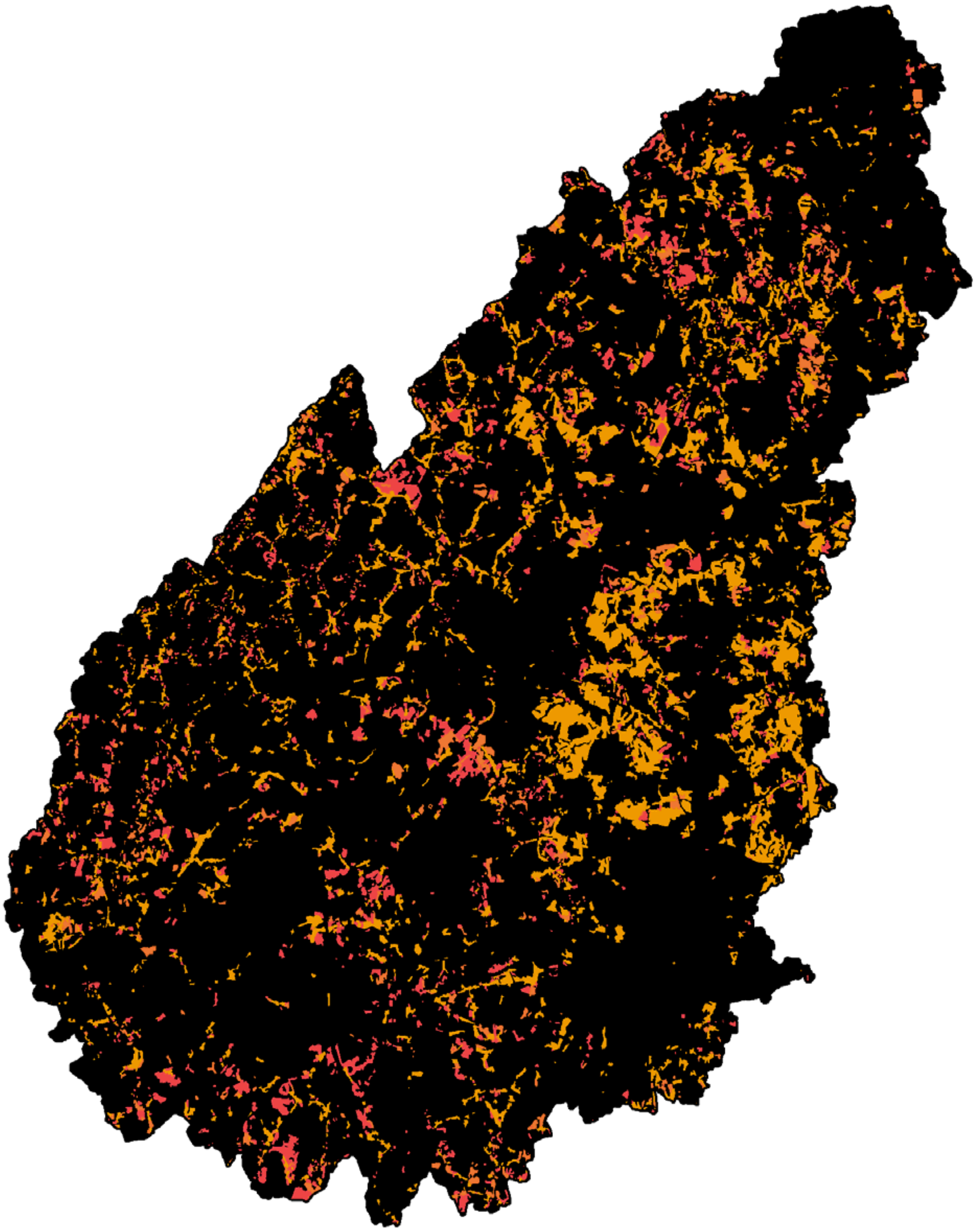

Figure C.8: Growth of low density residential from pink (1971) to dark orange (1985) to light orange (1999)

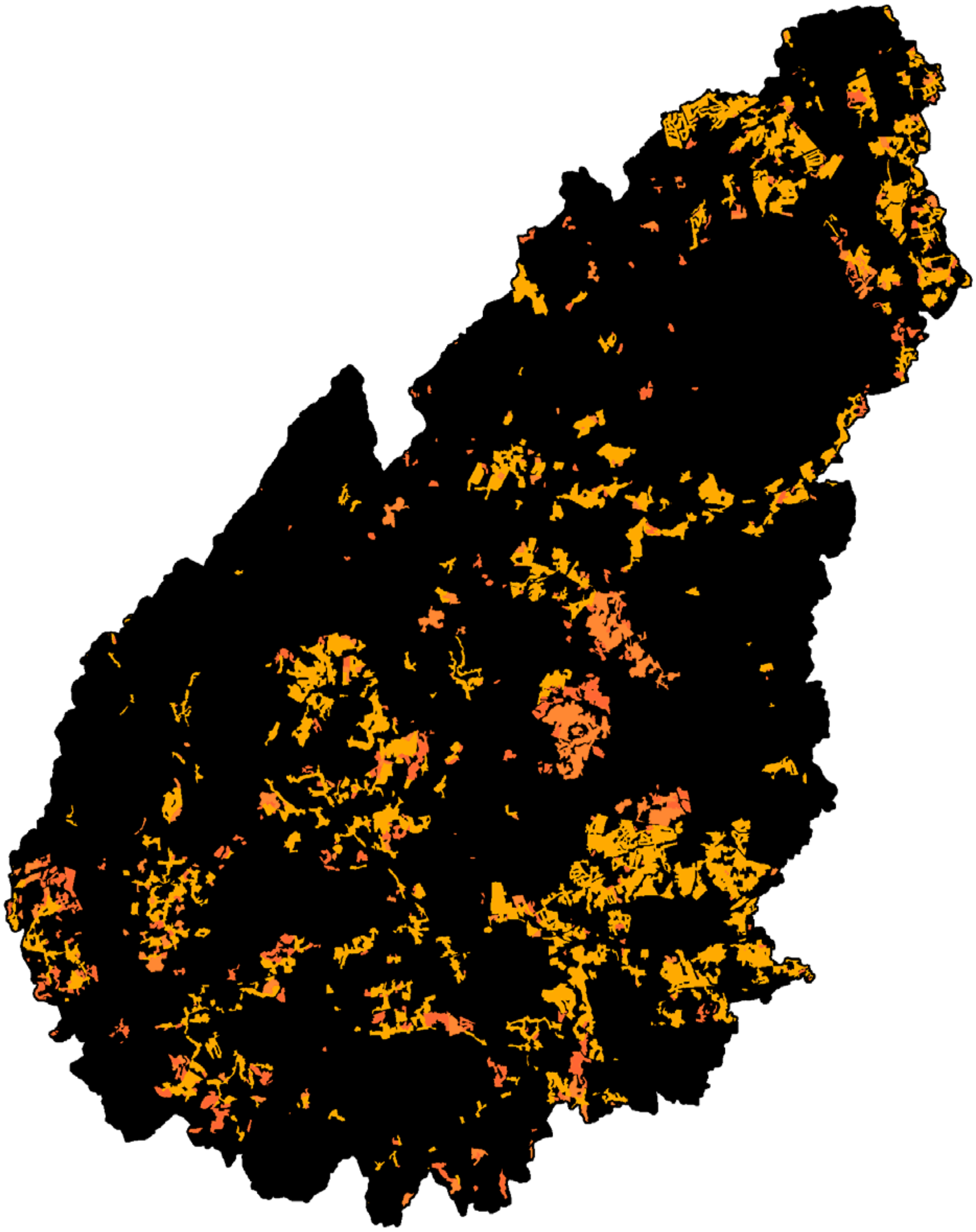

Figure C.8: Growth of medium density residential from orange (1971 and 1985) to dark yellow (1999)

Appendix D: Interview Data Matrix

Interviewee	Subject	Impact on NPSP	Quote
Ron McAdow	Boater's Trail	Positive	"We also initiated a project called the boaters trail on the Sudbury River. It's a self guided trail where you have information available at various point along the river. That project started here and has been carried on by the RSC"
Paul Hogan	General	Positive	"Depending upon the program, about five years ago, when we really started concentrating on addressing storm water, we did a tremendous amount of outreach to the public, to consultants, and to cities and towns. So we have made it a concerted effort, we have worked closely with watershed groups over the many, many years."
Ron McAdow	General	Positive	"I think it's [public participation in the watershed] good. People care about it but, I'd say it's disappointing how much of the public doesn't understand that lawn watering is an egregious waste of natural resources and it's connected to everything else. So, that part is a little frustrating. But, other than that most people in this area would say that they care about natural resources and water resources."
Ron McAdow	General	Negative	"I do find it easier to extract dollars for land protection than for water. In one way that's logical because when we protect a piece of land, if we do it right, it stays protected and if we didn't do it then it might get taped over and out of reach for conservation. Whereas water resources in one way, we can always fix that. "
Ron McAdow	General	Positive	"People used to think of rivers as ways to get rid of stuff. But as for much of my adult life that hasn't been the case. People have regarded the rivers as something to be respected and taken care of. That takes a lot of years for that to become as real as we had hoped."
Ron McAdow	General	Positive	"Well we have events that make it possible for public to get out on the rivers. The rivers are so hidden, they're not visible. So the people who have lived in town for years are quite amazed how beautiful it is to go down the river and how much nature you see from the river … you frequently hear that if you get people on the river that will help."

Nancy Bryant	General	Neutral	"Therefore you have so many stories about the kind of stuff people dump down storm drains and you hope with all environmental education that much of the environmental problems are due to ignorance. If you educate them the ignorance goes away and then people better their practices and NPSP become less."
Paul Hogan	LID	Negative	"I am, to date, somewhat of a skeptic on how effective it has been. The idea is to have less impact on the environment. I live in Holden, the next town over. All I see is big houses built in every part of town. I don't see any attempt of LID in my community. I think it's a nice idea but, a nice idea that isn't widespread."
Ron McAdow	LID	Negative	"People are aware of it [LID]… I don't know how much new construction in the area is using it but there is a lot of push for ecological landscaping by home owners and landscapers. In the little world I live in there's a lot of push for it, but I'm not sure that in world beyond that there is"
Savas Danos	LID	Neutral	The two major ways that we promote storm water management and water quality improvements in the Su-As-Co are through articles in the paper, public presentations, as well as brochures and pamphlets through the Clean Lakes Committee, or directly through the water department.
Savas Danos	LID	Neutral	"We're making a real big push on the use of rain barrels; we have to work a lot harder to keep on educating people to build down, not up. "
Ron McAdow	Riverfest	Positive	"There are many different local organizations that are doing in one way or another some kind of river based event and they are publicized together and coordinated together by the RSC. So, that is to build public awareness of the values of the river and hopefully they'll support the protection"
Nancy Bryant	Storm Water Matters	Neutral	"Back when the towns had to write the notice of intent they've got their control measures to comply with. Control Measure one being outreach and education and control Measure two being public participation and involvement. Those two controls member, we just saw, here's the chance for the SWCC with a despaired membership and pretty collaborative nature and unbiased viewpoint, educational purpose as being a really good entity to help towns comply with control measures one and two."

Nancy Bryant	Storm Water Matters	Positive	"we charge towns an annual subscription fee and we create some tools that they can utilize to educate their people and involve their residence and businesses and all the players who make a difference with the storm water on what storm water is all about and how it can be less polluted. In the very beginning, what we did was, include the notice of intent plans from the first five years for those two control measures and show those to the communities. We have followed through with that plan by subsequently producing the tools for control measure one and two on an annual basis and selling those tools to communities"
Nancy Bryant	Storm Water Matters	Positive	"Actually, one of the posters will actually be about LID. A lot of the towns are trying to pass LID bylaws right now, it's getting talked about more and more. It's trying to get the public to understand that there are these things you can do, rain barrels and stuff that can make a real difference. So, with that storm water matters program, that is a huge avenue by which we advocate, educate, particularly for cleaner watershed controls and NPSP."

Appendix D: GIS Land Use Data

Table E.1: Acres Absolute 1971																									
TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev	%Dev
2	ACTON	658.14	87.41	6839.27	377.56	309.72	306.20	65.35	4.60	0.00	84.79	0.00	1368.16	1833.89	0.00	225.05	185.19	225.04	91.70	17.98	201.34	84.70	8864.34	4101.76	31.63
14	ASHLAND	189.88	49.00	5265.93	75.62	157.85	125.58	40.71	0.00	7.43	36.99	88.90	734.37	541.40	0.00	150.64	104.37	165.75	8.73	0.00	320.40	100.17	6284.43	1879.27	23.02
23	BEDFORD	183.97	37.79	1803.79	291.03	0.00	24.35	2.39	0.00	0.00	0.00	0.00	880.29	221.21	0.00	0.00	0.00	37.91	0.00	13.80	67.93	16.92	2425.78	1155.60	32.27
28	BERLIN	529.94	843.38	5384.03	148.42	149.43	251.77	36.31	0.00	0.00	0.00	0.37	162.35	504.97	0.00	14.46	5.31	27.47	107.91	18.64	115.95	120.59	7543.51	877.80	10.42
31	BILLERICA	285.47	188.69	4655.29	253.22	6.94	362.88	38.64	4.78	2.36	15.91	120.44	2682.81	321.74	0.00	136.91	234.78	209.60	211.66	51.62	318.33	78.87	6149.68	4031.27	39.60
34	BOLTON	783.87	302.86	7704.70	245.42	0.00	237.28	181.06	0.00	0.00	0.00	0.00	10.15	628.51	0.00	20.03	22.94	23.35	210.37	21.28	51.35	526.88	9852.36	1117.69	10.19
37	BOXBOROUGH	249.52	198.40	4009.68	160.90	10.82	68.23	9.40	6.28	0.00	28.72	21.81	0.00	525.18	0.00	5.85	9.57	49.29	194.19	0.00	18.34	9.23	4725.12	850.29	15.25
39	BOYLSTON	24.59	35.87	6889.44	32.96	0.00	58.28	0.00	0.00	0.00	0.00	0.00	30.25	110.38	0.00	1.66	0.00	8.15	28.17	7.57	66.02	40.78	7147.94	186.18	2.54
51	CARLISLE	530.96	348.68	6582.48	399.89	17.93	120.34	3.23	0.00	0.00	0.00	0.00	0.00	1588.90	0.00	20.48	8.11	94.03	0.00	0.00	149.11	49.26	8198.65	1714.75	17.30
56	CHELMSFORD	370.84	286.18	3490.85	357.89	0.00	399.79	64.80	14.92	3.06	13.86	677.73	3364.11	945.77	0.00	132.72	156.97	135.38	567.43	0.00	190.31	26.85	5122.71	6076.74	54.26
64	CLINTON	38.83	28.27	480.24	1.80	0.00	79.66	0.00	1.34	0.00	0.00	118.33	148.63	13.92	0.00	0.00	0.00	16.87	0.00	0.00	27.21	0.00	656.01	299.09	31.31
67	CONCORD	1797.6	328.11	6968.03	996.22	29.22	219.36	274.58	0.00	8.91	8.51	378.04	1338.16	2120.69	0.00	120.83	156.35	414.89	73.57	73.53	708.51	52.16	11099.2	4968.05	30.92
100	FRAMINGHAM	746.99	92.34	5045.56	209.53	72.65	310.69	422.16	8.59	1.57	218.02	1125.5	4083.09	994.77	0.00	1035.3	557.14	735.75	396.04	10.49	882.78	23.63	7384.18	9588.59	56.49
110	GRAFTON	187.23	104.81	1457.07	4.14	0.00	20.61	7.34	0.00	0.00	0.00	0.00	0.00	62.39	0.00	0.00	0.00	78.08	130.79	1.75	0.00	0.00	1773.86	280.36	13.65
125	HARVARD	229.83	97.52	5343.96	87.23	5.85	110.65	0.00	0.00	0.00	0.00	0.00	67.80	493.07	0.00	0.00	0.00	7.57	58.32	0.00	83.62	307.69	6266.35	626.76	9.09
136	HOLLISTON	16.18	1.70	3177.09	0.00	3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.87	0.00	0.00	0.00	0.45	0.00	0.00	0.00	28.22	3226.34	11.32	0.35
139	HOPKINTON	535.55	98.21	11373.7	170.47	112.78	217.80	133.58	7.84	0.90	6.99	292.94	182.60	756.45	0.00	42.48	0.00	177.06	486.13	8.30	671.27	559.24	13739.0	2095.26	13.23
141	HUDSON	395.94	107.74	3509.46	327.60	143.52	117.06	62.34	0.00	1.06	0.00	65.05	1584.36	451.47	0.00	166.73	140.18	154.41	20.32	53.44	155.72	138.56	4895.59	2699.36	35.54
157	LINCOLN	309.82	56.11	3712.01	69.34	0.00	16.36	1.07	0.00	3.33	0.00	0.00	0.00	811.49	0.00	5.87	0.00	8.12	0.23	0.00	129.54	49.24	4342.42	830.10	16.05
158	LITTLETON	682.54	62.40	2735.75	159.61	0.00	70.99	2.54	0.00	0.00	0.00	0.00	402.84	407.54	0.00	63.90	0.00	22.16	342.10	0.00	376.40	141.20	4228.89	1241.08	22.69
160	LOWELL	12.49	0.00	417.51	29.05	0.00	195.82	64.88	6.56	0.00	0.00	1747.7	159.81	32.27	0.00	121.95	263.92	340.05	270.15	22.47	45.17	0.00	700.04	3208.62	82.09
170	MARLBOROUGH	682.79	257.57	6726.24	264.67	92.60	371.46	231.29	12.71	14.66	0.00	445.68	1734.53	591.28	0.00	401.46	275.94	414.20	352.73	96.47	707.51	314.59	9417.43	4683.00	33.21
174	MAYNARD	28.13	7.20	1701.86	109.59	12.43	91.47	67.99	0.00	0.00	0.00	215.44	727.48	62.99	0.00	86.68	95.81	110.62	0.00	5.69	119.44	14.66	2084.77	1376.16	39.76
198	NATICK	12.33	17.68	829.19	48.32	0.00	89.23	112.13	0.00	0.00	0.00	579.61	1825.48	107.35	0.00	494.85	64.22	239.10	117.11	55.28	454.94	11.49	1463.18	3679.77	71.55
215	NORTHBOROUGH	563.49	351.86	6949.27	601.49	49.64	404.88	359.99	0.00	0.00	0.00	55.16	1016.15	745.78	0.00	129.22	33.51	107.93	195.67	9.19	159.82	247.29	9327.74	2668.17	22.24
269	SHERBORN	200.72	101.87	5504.36	43.01	0.00	232.96	0.00	0.00	0.00	0.00	0.00	0.00	460.63	0.00	0.00	12.01	15.34	9.45	0.00	2.89	18.84	6104.65	497.42	7.53
271	SHREWSBURY	253.48	302.30	4460.72	75.06	11.51	220.07	59.42	12.36	0.00	0.00	516.34	665.88	404.14	0.00	68.76	23.26	127.63	280.85	0.00	11.01	11.81	5345.95	2164.79	28.82
277	SOUTHBOROUGH	942.75	111.44	5038.74	119.60	0.00	144.01	130.70	14.53	7.96	0.00	6.32	1092.57	659.25	0.00	109.64	112.75	185.11	247.31	13.68	949.87	75.17	7381.58	2579.82	25.90
286	STOW	904.93	118.85	6841.06	688.66	106.03	362.30	349.18	0.00	0.00	0.00	13.58	213.00	1158.97	0.00	28.25	11.57	153.47	15.51	0.00	239.42	339.62	9600.87	1943.54	16.84
288	SUDBURY	1193	115.56	7623.28	1078	79.81	277.81	187.33	33.42	0.00	0.00	0.00	180.71	4194.02	0.00	138.65	130.34	245.96	9.50	0.00	254.19	94.46	10717	5123.54	32.34
295	TEWKSBURY	3.41	149.57	212.90	23.85	0.00	80.10	0.00	0.00	0.00	0.00	7.53	270.61	15.91	0.00	5.53	48.11	2.34	0.00	3.02	0.03	1.41	471.26	353.05	42.83
303	UPTON	0.00	0.00	3603.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.03	0.00	0.00	0.00	0.00	31.61	0.00	0.00	8.78	3612.68	42.64	1.17
315	WAYLAND	559.45	224.16	3166.11	1275.7	36.26	114.50	269.57	0.00	9.12	0.00	0.00	1072.16	2536.95	0.00	95.11	69.67	148.02	36.14	0.00	366.09	38.53	5780.82	4272.96	42.50
328	WESTBOROUGH	1385.3	297.77	7195.29	717.88	73.89	446.69	81.38	28.71	0.00	0.00	243.76	1141.91	369.44	0.00	166.15	137.10	387.97	370.30	28.21	299.36	196.85	10613.0	3027.34	22.19
330	WESTFORD	358.52	242.64	5412.21	135.93	217.94	465.95	29.86	0.00	0.00	0.00	0.00	0.00	932.75	0.00	53.43	3.61	15.61	187.75	4.50	23.30	83.38	6939.87	1227.52	15.03
333	WESTON	12.37	1.26	2327.23	13.71	0.00	20.63	0.00	0.00	0.00	0.00	0.00	0.00	652.44	0.00	0.00	0.00	41.48	0.00	0.00	0.00	0.00	2375.19	693.92	22.61
	Average	440.61	157.09	4567.73	266.50	47.22	184.33	91.37	4.35	1.68	0.00	186.68	753.90	730.00	0.00	112.30	79.52	142.39	140.33	14.36	226.87	105.86	5996.20	2282.60	27.01

Table E.2: Acres Absolute 1985																								
TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	512.72	30.61	6266.38	370.09	237.49	204.89	68.22	0.00	5.37	208.04	0.00	1483.32	2249.48	0.00	263.10	360.13	299.81	96.73	19.97	212.28	77.48	7911.93	5054.17
14	ASHLAND	127.93	43.62	4829.37	68.90	157.85	78.07	56.16	0.00	7.43	124.91	88.90	971.48	721.90	0.00	167.25	109.41	166.89	8.73	0.00	333.96	100.94	5740.65	2423.05
23	BEDFORD	154.77	30.10	1793.00	285.38	0.00	35.23	2.39	0.00	0.00	0.00	0.00	888.27	268.36	0.00	0.00	0.00	37.91	0.00	9.09	67.93	8.94	2375.35	1206.02
28	BERLIN	547.76	748.19	5143.49	146.65	203.55	256.93	36.31	0.00	0.00	0.00	0.37	170.21	674.92	0.00	22.14	5.31	95.31	107.91	28.95	126.60	106.72	7279.89	1141.42
31	BILLERICA	262.24	149.39	3777.03	237.42	3.64	318.74	60.19	2.88	2.36	43.29	120.44	3058.67	408.38	0.00	218.66	599.70	183.23	228.43	118.59	328.08	59.58	5136.12	5044.83
34	BOLTON	732.30	231.79	7580.84	245.42	0.00	289.91	181.06	0.00	0.00	0.00	0.00	10.15	836.49	0.00	24.46	22.94	30.22	210.37	21.28	51.35	501.46	9633.08	1336.98
37	BOXBOROUGH	222.87	197.23	3796.74	157.99	33.79	63.22	10.30	6.28	0.00	50.53	0.00	0.00	682.28	0.00	26.21	47.37	61.40	194.19	1.64	18.34	5.02	4495.22	1080.19
39	BOYLSTON	38.43	35.87	6776.01	32.96	0.00	63.10	0.00	0.00	0.00	0.00	0.00	33.20	216.53	0.00	1.66	0.00	9.33	28.17	7.57	66.02	25.28	7037.67	296.45
51	CARLISLE	499.60	306.81	6034.36	398.36	17.93	100.14	3.23	0.00	0.00	0.00	0.00	0.00	2243.72	0.00	25.26	9.73	73.53	0.00	0.00	149.11	51.63	7557.93	2355.47
56	CHELMSFORD	342.32	225.74	2935.92	357.89	0.00	287.18	67.79	14.92	3.06	48.76	694.70	3503.92	1180.62	0.00	213.11	379.39	172.90	571.58	5.05	190.31	4.27	4343.63	6855.82
64	CLINTON	38.83	28.27	472.38	1.80	0.00	79.66	0.00	1.34	0.00	14.47	118.33	149.42	13.92	0.00	0.00	0.00	9.48	0.00	0.00	27.21	0.00	648.15	306.95
67	CONCORD	1759.96	288.73	6617.58	992.88	14.38	198.48	284.98	0.00	8.91	44.38	378.04	1370.57	2538.82	0.00	128.34	183.37	354.10	73.57	73.53	708.51	48.17	10628.6	5438.61
100	FRAMINGHAM	674.11	92.34	4701.11	192.31	87.02	317.25	422.16	8.59	1.57	232.94	1128.56	4194.06	1261.81	0.00	1061.81	569.00	717.63	396.04	10.49	882.78	21.18	6968.11	10004.6
110	GRAFTON	168.50	87.02	1421.35	4.14	0.00	21.63	7.34	0.00	0.00	0.00	0.00	0.00	133.62	0.00	0.00	0.00	78.08	130.79	1.75	0.00	0.00	1702.63	351.58
125	HARVARD	223.17	96.71	5121.31	87.23	5.85	58.78	0.00	0.00	0.00	0.00	0.00	67.80	776.51	0.00	0.81	0.00	7.57	58.32	0.00	83.62	305.43	5982.10	911.01
136	HOLLISTON	16.18	1.70	3173.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	10.87	0.00	0.00	0.00	0.45	0.00	3.14	0.00	28.22	3219.76	17.90
139	HOPKINTON	429.43	72.17	10808.2	170.47	107.17	154.26	150.90	7.84	0.90	12.62	292.94	408.76	1151.80	0.00	59.00	97.53	151.84	486.13	13.25	672.32	586.81	13000.8	2833.48
141	HUDSON	265.95	61.23	3270.16	320.94	115.46	98.44	62.34	0.00	1.06	23.48	108.78	1674.93	558.15	0.00	209.96	267.92	177.43	32.63	54.39	155.72	135.99	4423.89	3171.05
157	LINCOLN	309.52	56.11	3646.09	69.34	0.00	11.92	1.07	0.00	3.33	45.95	0.00	0.00	833.69	0.00	8.38	0.00	8.12	0.23	0.00	129.54	49.24	4271.75	900.77
158	LITTLETON	621.06	57.55	2690.97	154.88	0.00	52.14	22.15	0.00	2.13	0.00	0.00	414.60	467.47	0.00	75.54	12.15	60.99	342.10	1.98	376.40	117.85	4070.85	1399.11
160	LOWELL	12.49	0.00	388.43	29.05	0.00	123.93	68.66	6.42	0.00	208.04	1749.95	196.57	2.66	0.00	123.47	328.92	340.05	272.62	12.25	45.17	0.00	599.06	3309.60
170	MARLBOROUGH	481.36	173.88	5865.99	256.88	51.88	323.92	241.15	12.71	1.10	177.34	451.30	1934.39	1053.87	0.00	661.86	500.98	499.17	374.18	119.60	707.51	211.38	8072.79	6027.64
174	MAYNARD	21.37	2.26	1596.60	109.59	12.43	82.38	73.10	0.00	0.00	50.73	228.34	773.34	67.71	0.00	86.68	117.16	99.70	0.00	5.69	119.20	14.66	1958.48	1502.45
198	NATICK	8.87	10.04	767.61	48.32	0.00	82.67	60.86	0.00	0.00	154.00	579.61	1857.87	112.68	0.00	541.88	67.17	214.56	117.11	55.28	454.94	9.47	1381.93	3761.02
215	NORTHBOROUGH	457.06	169.84	6440.29	601.49	52.82	314.90	278.62	0.00	0.00	15.57	55.16	1345.63	1139.36	0.00	246.49	179.75	111.35	195.67	13.12	161.77	217.02	8415.19	3580.72
269	SHERBORN	164.53	102.39	5444.61	43.01	0.00	230.31	0.00	0.00	0.00	0.00	0.00	0.00	564.88	0.00	0.00	12.01	1.88	9.45	0.00	2.89	26.12	6013.86	588.22
271	SHREWSBURY	201.37	238.30	4153.81	75.06	0.00	194.64	59.42	12.36	0.00	35.85	545.13	880.93	501.40	0.00	96.10	87.06	107.46	283.39	6.11	11.01	21.33	4895.52	2615.22
277	SOUTHBOROUGH	806.57	104.07	4835.79	119.60	0.00	194.97	133.59	14.53	7.96	3.17	6.32	1119.79	838.21	0.00	160.21	115.59	207.10	251.98	13.68	953.10	75.17	7089.26	2872.14
286	STOW	805.29	118.85	6523.84	683.69	107.02	223.67	349.63	1.47	0.00	3.36	13.58	528.22	1328.93	0.00	52.62	32.64	252.36	51.83	0.00	239.42	227.99	8929.77	2614.64
288	SUDBURY	950.29	93.97	7293.59	1061.60	75.91	311.54	189.98	33.42	0.00	13.76	0.00	2246.79	2551.25	0.00	169.62	138.03	262.85	9.50	0.00	254.19	184.87	10225.9	5615.21
295	TEWKSBURY	0.00	104.32	159.37	23.85	0.00	60.81	0.00	0.00	0.00	0.87	7.53	308.29	81.72	0.00	8.04	48.11	16.95	0.00	3.02	0.03	1.41	349.79	474.52
303	UPTON	0.00	0.00	3590.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.03	0.00	0.00	0.00	0.00	31.61	0.00	0.00	8.78	3599.68	55.65
315	WAYLAND	533.61	213.73	3116.70	1272.21	36.26	114.91	269.57	0.00	9.12	74.77	0.00	1094.36	2548.67	0.00	100.13	69.67	161.11	36.14	0.00	369.68	33.16	5690.25	4363.53
328	WESTBOROUGH	1190.22	301.84	6404.44	681.09	39.19	316.03	93.78	45.69	0.00	109.29	243.76	1269.55	511.60	0.00	355.89	496.47	318.50	408.55	41.98	630.02	182.54	9745.37	3895.06
330	WESTFORD	351.33	139.07	4895.93	132.85	194.05	356.56	80.59	0.00	0.00	28.78	0.00	86.87	1277.03	0.00	105.50	113.11	102.37	187.75	4.50	45.30	65.79	6180.88	1986.52
333	WESTON	12.37	1.26	2324.60	13.71	0.00	20.63	0.00	0.00	0.00	0.00	0.00	0.00	655.08	0.00	0.00	0.00	41.48	0.00	0.00	0.00	0.00	2372.56	696.56
	Average	387.34	128.19	4296.07	262.42	43.16	156.72	92.65	4.68	1.51	47.91	189.21	890.15	846.90	0.00	144.84	138.07	150.92	144.33	17.94	238.18	97.61	5609.68	2669.12

Table E.3: Acres Absolute 1999																									
TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev	%Dev
2	ACTON	506.57	22.06	5530.7	380.46	86.76	208.41	73.68	0.00	5.37	266.27	54.71	1620.0	2860.0	0.00	331.39	457.50	198.26	96.73	3.43	210.06	53.63	6998.6	5967.4	46.02
14	ASHLAND	76.59	38.20	4080.3	61.99	137.27	102.66	69.48	0.00	7.43	201.76	91.72	1365.4	979.96	0.00	199.44	133.46	241.51	8.73	0.00	333.96	33.76	4864.7	3298.9	40.41
23	BEDFORD	89.52	30.03	1751.4	206.54	0.00	15.81	3.71	0.00	0.00	66.89	0.00	1105.0	188.46	0.00	0.00	0.00	41.34	0.00	11.27	67.93	3.36	2164.6	1416.7	39.56
28	BERLIN	437.15	473.65	5119.5	124.61	55.95	388.30	38.12	0.00	0.00	0.00	0.37	172.72	930.89	0.00	65.36	22.04	113.27	111.65	21.77	129.98	215.92	6945.1	1476.1	17.53
31	BILLERICA	143.44	101.11	3515.2	237.55	0.00	260.20	77.11	0.00	3.60	55.84	120.44	3292.2	502.81	0.00	236.89	721.34	171.64	264.52	115.03	322.85	39.08	4619.5	5561.4	54.63
34	BOLTON	524.48	161.16	7639.0	173.97	0.00	204.52	181.06	0.00	0.00	0.00	0.00	23.07	1237.4	0.00	31.49	44.36	42.50	210.37	1.28	53.77	441.54	9198.4	1771.5	16.15
37	BOXBOROUGH	155.44	137.59	3300.3	160.01	7.59	111.13	10.30	0.00	0.00	57.61	0.00	100.70	1173.3	0.00	31.68	92.31	20.24	194.19	1.64	18.27	3.05	3893.4	1682.0	30.17
39	BOYLSTON	30.63	42.35	6552.9	32.96	0.00	14.83	0.00	0.00	0.00	0.00	0.00	33.20	490.29	0.00	1.66	0.00	11.52	28.17	0.00	66.02	29.51	6769.2	564.83	7.70
51	CARLISLE	457.36	232.67	5708.8	325.90	1.15	98.49	12.48	0.00	0.00	5.15	0.00	0.00	2794.7	0.00	28.72	8.08	50.57	0.00	0.00	149.11	40.14	7013.6	2899.7	29.25
56	CHELMSFORD	256.53	97.08	2492.3	357.89	3.04	238.18	77.54	0.00	3.06	77.88	707.75	3728.1	1450.0	0.00	300.02	494.42	142.95	575.44	0.00	190.31	6.79	3642.1	7557.3	67.48
64	CLINTON	34.62	28.27	516.05	3.75	0.00	30.18	0.00	0.00	0.00	14.47	118.33	155.54	19.58	0.00	0.00	0.00	9.05	0.00	0.00	25.27	0.00	638.14	316.96	33.19
67	CONCORD	1630.1	213.66	6332.4	992.36	5.61	248.72	280.62	0.00	8.91	60.15	378.04	1458.4	2920.7	0.00	130.55	217.16	325.75	73.57	51.46	711.78	27.27	10161	5905.3	36.75
100	FRAMINGHAM	477.39	92.74	4310.3	191.94	96.07	389.97	376.92	8.59	1.57	237.44	1140.0	4354.8	1525.9	0.00	1133.2	673.10	661.90	407.09	9.39	884.32	0.00	6442.7	10530	62.04
110	GRAFTON	148.84	74.56	1387.4	4.14	0.00	10.60	7.34	0.00	0.00	0.00	0.00	2.56	198.52	0.00	0.00	0.00	87.70	130.79	1.75	0.00	0.00	1625.5	428.66	20.87
125	HARVARD	211.05	93.04	5001.1	87.23	5.85	62.97	0.00	0.00	0.00	0.00	0.00	67.80	910.67	0.00	0.81	0.00	11.61	58.32	0.00	83.62	298.99	5843.9	1049.2	15.22
136	HOLLISTON	14.77	0.00	3176.4	0.00	0.00	15.61	0.00	0.00	0.00	0.00	0.00	3.43	26.79	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	3206.8	30.83	0.95
139	HOPKINTON	198.92	51.84	9384.4	169.86	99.78	124.97	178.06	0.00	0.90	47.29	292.63	571.96	2537.9	0.00	98.95	104.11	220.20	498.75	11.06	675.84	566.81	11272	4561.8	28.81
141	HUDSON	138.05	34.42	2650.6	318.41	62.05	165.55	67.72	0.00	1.06	48.04	108.78	1804.3	912.83	0.00	219.25	406.74	317.03	32.63	54.39	155.72	97.37	3622.1	3972.7	52.31
157	LINCOLN	306.51	56.11	3600.3	69.34	0.00	2.20	1.07	0.00	3.33	45.95	0.00	0.00	900.46	0.00	8.38	0.00	8.12	0.23	0.00	129.54	40.96	4204.9	967.53	18.71
158	LITTLETON	474.90	77.13	2537.8	154.88	0.00	120.80	25.62	0.00	2.13	0.00	0.00	431.64	683.17	0.00	75.54	27.26	59.13	342.10	0.00	376.40	81.45	3823.3	1646.5	30.10
160	LOWELL	4.36	0.00	323.12	40.89	0.00	92.50	71.82	0.00	0.00	231.76	1748.9	205.74	2.66	0.00	131.46	362.37	357.03	278.63	12.25	45.17	0.00	506.05	3402.6	87.05
170	MARLBOROUGH	245.89	70.40	4937.7	259.03	0.00	372.11	241.15	12.71	1.10	230.06	537.36	2457.7	1585.5	0.00	867.99	713.12	381.41	370.66	63.41	709.14	43.89	6638.2	7462.1	52.92
174	MAYNARD	19.58	0.00	1460.2	105.17	0.00	67.84	86.25	0.00	0.00	70.08	231.12	842.50	95.24	0.00	86.68	148.60	105.55	0.00	5.69	121.71	14.66	1789.2	1671.7	48.30
198	NATICK	7.12	3.10	677.03	48.32	0.00	78.58	42.97	0.00	0.00	154.00	579.61	1938.4	140.74	0.00	558.23	67.17	213.86	119.35	55.28	454.94	4.24	1273.3	3869.6	75.24
215	NORTHBOROUGH	359.32	153.52	5579.9	601.49	15.27	265.27	392.55	0.00	0.00	26.78	94.22	1542.3	1697.6	0.00	263.25	315.41	145.77	199.15	13.12	161.77	169.04	7305.6	4690.2	39.10
269	SHERBORN	137.41	94.49	5456.9	43.01	0.00	225.23	0.00	0.00	0.00	0.00	0.00	0.00	580.77	0.00	3.58	12.01	1.88	9.45	0.00	2.89	34.38	5994.3	607.68	9.20
271	SHREWSBURY	116.38	132.85	3439.4	54.23	4.37	150.11	61.00	0.00	0.00	68.41	554.93	1610.2	548.53	0.00	121.60	151.15	160.67	292.57	24.56	11.01	8.70	3917.0	3593.6	47.85
277	SOUTHBOROUGH	508.05	69.45	4109.4	116.80	0.00	186.22	160.85	14.53	7.96	11.14	6.32	1385.8	1516.0	0.00	192.14	195.28	191.64	251.98	9.55	953.10	75.17	6018.1	3943.2	39.58
286	STOW	522.07	123.56	6066.9	673.12	17.03	383.53	562.85	1.47	0.00	13.71	13.58	605.69	1755.1	0.00	60.74	41.30	173.26	51.83	0.00	246.52	232.11	8264.8	3279.5	28.41
288	SUDBURY	667.13	118.34	6678.3	1136.4	57.24	238.67	188.63	33.42	0.00	13.76	3.50	3123.1	2643.4	0.00	196.34	139.45	213.16	1.58	0.00	256.84	131.75	9284.7	6556.4	41.39
295	TEWKSBURY	0.00	24.96	137.24	32.33	0.00	98.82	0.00	0.00	0.00	0.87	7.53	335.14	116.36	0.00	12.55	54.05	0.00	0.00	3.02	0.03	1.41	294.80	529.51	64.24
303	UPTON	0.00	0.00	3576.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.10	0.00	0.00	0.00	9.91	31.61	0.00	0.00	3.96	3580.7	74.63	2.04
315	WAYLAND	402.38	153.13	3008.5	1272.2	0.00	111.83	271.30	0.00	9.12	109.23	0.00	1103.2	2825.5	0.00	113.78	77.91	156.58	36.14	0.00	369.68	33.16	5350.9	4702.8	46.78
328	WESTBOROUGH	813.68	148.40	5670.7	684.47	31.83	218.58	113.76	18.75	0.00	158.50	267.82	1928.8	896.17	0.00	484.41	710.03	333.56	412.52	44.29	626.64	77.45	8271.8	5368.6	39.36
330	WESTFORD	220.73	74.81	4226.5	133.63	153.12	238.43	121.39	0.00	0.00	73.47	0.00	263.91	1956.1	0.00	130.70	257.26	37.62	187.75	4.50	45.82	41.53	5134.6	3032.7	37.13
333	WESTON	14.15	0.00	2327.3	9.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	676.71	0.00	0.00	0.00	41.48	0.00	0.00	0.00	0.00	2350.9	718.19	23.40
	Average	287.53	89.57	3951.7	257.34	23.33	153.94	105.43	2.49	1.54	65.18	196.05	1045.3	1119.8	0.00	169.91	184.64	146.06	146.57	14.39	238.61	79.20	5081.3	3197.4	36.94

Table E.4: Change in Acres 1971-1985																								
TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-145.42	-56.81	-572.90	-7.47	-72.23	-101.31	2.87	-4.60	5.37	123.2	0.00	115.16	415.59	0.00	38.05	174.94	74.76	5.03	1.99	10.94	-7.23	-952.42	952.42
14	ASHLAND	-61.95	-5.38	-436.56	-6.72	0.00	-47.51	15.45	0.00	0.00	87.93	0.00	237.11	180.50	0.00	16.61	5.04	1.14	0.00	0.00	13.57	0.77	-543.78	543.78
23	BEDFORD	-29.20	-7.68	-10.79	-5.65	0.00	10.88	0.00	0.00	0.00	0.00	0.00	7.98	47.15	0.00	0.00	0.00	0.00	0.00	-4.71	0.00	-7.98	-50.42	50.42
28	BERLIN	17.82	-95.19	-240.53	-1.77	54.11	5.16	0.00	0.00	0.00	0.00	0.00	7.85	169.94	0.00	7.68	0.00	67.84	0.00	10.31	10.66	-13.87	-263.62	263.62
31	BILLERICA	-23.23	-39.30	-878.26	-15.80	-3.30	-44.14	21.55	-1.90	0.00	27.38	0.00	375.85	86.64	0.00	81.75	364.92	-26.36	16.77	66.97	9.75	-19.28	-1013.56	1013.56
34	BOLTON	-51.57	-71.07	-123.86	0.00	0.00	52.62	0.00	0.00	0.00	0.00	0.00	0.00	207.98	0.00	4.43	0.00	6.87	0.00	0.00	0.00	-25.41	-219.28	219.28
37	BOXBOROUGH	-26.65	-1.17	-212.94	-2.91	22.98	-5.01	0.90	0.00	0.00	21.81	-21.81	0.00	157.10	0.00	20.36	37.80	12.11	0.00	1.64	0.00	-4.20	-229.90	229.90
39	BOYLSTON	13.84	0.00	-113.43	0.00	0.00	4.81	0.00	0.00	0.00	0.00	0.00	2.94	106.15	0.00	0.00	0.00	1.18	0.00	0.00	0.00	-15.50	-110.27	110.27
51	CARLISLE	-31.37	-41.87	-548.12	-1.53	0.00	-20.20	0.00	0.00	0.00	0.00	0.00	0.00	654.82	0.00	4.78	1.62	-20.50	0.00	0.00	0.00	2.38	-640.72	640.72
56	CHELMSFORD	-28.52	-60.44	-554.92	0.00	0.00	-112.61	2.99	0.00	0.00	34.90	16.97	139.81	234.86	0.00	80.39	222.43	37.52	4.15	5.05	0.00	-22.58	-779.07	779.07
64	CLINTON	0.00	0.00	-7.86	0.00	0.00	0.00	0.00	0.00	0.00	14.47	0.00	0.79	0.00	0.00	0.00	0.00	-7.39	0.00	0.00	0.00	0.00	-7.86	7.86
67	CONCORD	-37.67	-39.37	-350.45	-3.35	-14.85	-20.88	10.39	0.00	0.00	35.87	0.00	32.41	418.13	0.00	7.51	27.03	-60.79	0.00	0.00	0.00	-4.00	-470.56	470.56
100	FRAMINGHAM	-72.88	0.00	-344.44	-17.22	14.37	6.56	0.00	0.00	0.00	14.91	2.99	110.98	267.03	0.00	26.42	11.85	-18.12	0.00	0.00	0.00	-2.45	-416.07	416.07
110	GRAFTON	-18.73	-17.79	-35.72	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	71.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-71.22	71.22
125	HARVARD	-6.65	-0.81	-222.65	0.00	0.00	-51.87	0.00	0.00	0.00	0.00	0.00	0.00	283.44	0.00	0.81	0.00	0.00	0.00	0.00	0.00	-2.26	-284.25	284.25
136	HOLLISTON	0.00	0.00	-3.43	0.00	-3.14	0.00	0.00	0.00	0.00	0.00	0.00	3.43	0.00	0.00	0.00	0.00	0.00	0.00	3.14	0.00	0.00	-6.58	6.58
139	HOPKINTON	-106.12	-26.04	-565.54	0.00	-5.61	-63.53	17.32	0.00	0.00	5.64	0.00	226.15	395.34	0.00	16.52	97.53	-25.22	0.00	4.95	1.05	27.58	-738.22	738.22
141	HUDSON	-129.99	-46.51	-239.30	-6.66	-28.05	-18.62	0.00	0.00	0.00	23.48	43.73	90.56	106.68	0.00	43.23	127.74	23.02	12.31	0.95	0.00	-2.57	-471.70	471.70
157	LINCOLN	-0.31	0.00	-65.91	0.00	0.00	-4.45	0.00	0.00	0.00	45.95	0.00	0.00	22.20	0.00	2.51	0.00	0.00	0.00	0.00	0.00	0.00	-70.67	70.67
158	LITTLETON	-61.48	-4.85	-44.77	-4.74	0.00	-18.85	19.61	0.00	2.13	0.00	0.00	11.76	59.94	0.00	11.64	12.15	38.83	0.00	1.98	0.00	-23.36	-158.04	158.04
160	LOWELL	0.00	0.00	-29.09	0.00	0.00	-71.89	3.78	-0.14	0.00	29.22	2.20	36.76	-29.61	0.00	1.52	65.00	0.00	2.47	-10.23	0.00	0.00	-100.98	100.98
170	MARLBOROUGH	-201.43	-83.69	-860.25	-7.79	-40.73	-47.54	9.87	0.00	-13.57	65.29	5.63	199.86	462.59	0.00	260.40	225.04	84.98	21.44	23.13	0.00	-103.21	-1344.64	1344.64
174	MAYNARD	-6.76	-4.94	-105.26	0.00	0.00	-9.09	5.11	0.00	0.00	47.26	12.90	45.85	4.72	0.00	0.00	21.36	-10.91	0.00	0.00	-0.24	0.00	-126.29	126.29
198	NATICK	-3.45	-7.64	-61.58	0.00	0.00	-6.56	-51.27	0.00	0.00	69.36	0.00	32.39	5.32	0.00	47.04	2.95	-24.54	0.00	0.00	0.00	-2.02	-81.25	81.25
215	NORTHBOROUGH	-106.43	-182.02	-508.98	0.00	3.19	-89.99	-81.37	0.00	0.00	0.00	0.00	329.48	393.58	0.00	117.27	146.24	3.42	0.00	3.93	1.95	-30.27	-912.55	912.55
269	SHERBORN	-36.19	0.52	-59.75	0.00	0.00	-2.65	0.00	0.00	0.00	0.00	0.00	0.00	104.26	0.00	0.00	0.00	-13.46	0.00	0.00	0.00	7.28	-90.79	90.79
271	SHREWSBURY	-52.11	-64.00	-306.91	0.00	-11.51	-25.43	0.00	0.00	0.00	29.68	28.79	215.06	97.26	0.00	27.35	63.81	-20.17	2.54	6.11	0.00	9.53	-450.43	450.43
277	SOUTHBOROUGH	-136.18	-7.37	-202.95	0.00	0.00	50.96	2.88	0.00	0.00	3.17	0.00	27.22	178.96	0.00	50.57	2.85	21.99	4.67	0.00	3.23	0.00	-292.31	292.31
286	STOW	-99.65	0.00	-317.22	-4.97	0.99	-138.62	0.44	1.47	0.00	3.36	0.00	315.22	169.96	0.00	24.37	21.07	98.89	36.33	0.00	0.00	-111.63	-671.10	671.10
288	SUDBURY	-243.70	-21.59	-329.69	-16.95	-3.89	33.74	2.65	0.00	0.00	10.15	0.00	2066.08	-1642.7	0.00	30.96	7.69	16.90	0.00	0.00	0.00	90.41	-491.67	491.67
295	TEWKSBURY	-3.41	-45.26	-53.53	0.00	0.00	-19.29	0.00	0.00	0.00	0.87	0.00	37.68	65.81	0.00	2.51	0.00	14.61	0.00	0.00	0.00	0.00	-121.48	121.48
303	UPTON	0.00	0.00	-13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-13.00	13.00
315	WAYLAND	-25.84	-10.43	-49.41	-3.51	0.00	0.41	0.00	0.00	0.00	38.54	0.00	22.21	11.72	0.00	5.02	0.00	13.09	0.00	0.00	3.58	-5.37	-90.57	90.57
328	WESTBOROUGH	-195.13	4.07	-790.86	-36.79	-34.70	-130.66	12.39	16.98	0.00	36.88	0.00	127.64	142.16	0.00	189.74	359.37	-69.47	38.25	13.77	330.66	-14.31	-867.72	867.72
330	WESTFORD	-7.19	-103.57	-516.29	-3.08	-23.89	-109.39	50.73	0.00	0.00	28.78	0.00	86.87	344.28	0.00	52.08	109.50	86.76	0.00	0.00	22.00	-17.59	-759.00	759.00
333	WESTON	0.00	0.00	-2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.64	2.64
	Average	-53.26	-28.89	-271.66	-4.08	-4.06	-27.61	1.29	0.33	-0.17	22.17	2.54	136.25	116.91	0.00	32.54	58.55	8.53	4.00	3.58	11.31	-8.25	-386.52	386.52

Table E.5: Change in Acres 1985-1999

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-6.15	-8.55	-735.64	10.36	-150.73	3.52	5.46	0.00	0.00	58.22	54.71	136.75	610.54	0.00	68.29	97.37	-101.5	0.00	-16.54	-2.22	-23.85	-913.25	913.25
14	ASHLAND	-51.34	-5.42	-749.05	-6.91	-20.58	24.59	13.33	0.00	0.00	76.84	2.83	393.99	258.06	0.00	32.18	24.05	74.62	0.00	0.00	0.00	-67.19	-875.91	875.91
23	BEDFORD	-65.25	-0.07	-41.57	-78.84	0.00	-19.42	1.33	0.00	0.00	66.89	0.00	216.81	-79.90	0.00	0.00	0.00	3.43	0.00	2.18	0.00	-5.58	-210.74	210.74
28	BERLIN	-110.61	-274.53	-23.93	-22.04	-147.60	131.37	1.81	0.00	0.00	0.00	0.00	2.51	255.97	0.00	43.22	16.73	17.95	3.74	-7.18	3.38	109.20	-334.76	334.76
31	BILLERICA	-118.80	-48.28	-261.74	0.13	-3.64	-58.54	16.92	-2.88	1.23	12.55	0.00	233.55	94.43	0.00	18.23	121.64	-11.60	36.10	-3.56	-5.24	-20.50	-516.60	516.60
34	BOLTON	-207.82	-70.63	58.20	-71.45	0.00	-85.39	0.00	0.00	0.00	0.00	0.00	12.92	400.95	0.00	7.03	21.42	12.28	0.00	-20.00	2.42	-59.92	-434.60	434.60
37	BOXBOROUGH	-67.43	-59.64	-496.41	2.02	-26.21	47.91	0.00	-6.28	0.00	7.08	0.00	100.70	491.06	0.00	5.47	44.94	-41.16	0.00	0.00	-0.07	-1.98	-601.81	601.81
39	BOYLSTON	-7.80	6.48	-223.02	0.00	0.00	-48.27	0.00	0.00	0.00	0.00	0.00	0.00	273.76	0.00	0.00	0.00	2.19	0.00	-7.57	0.00	4.23	-268.38	268.38
51	CARLISLE	-42.23	-74.14	-325.55	-72.46	-16.78	-1.64	9.25	0.00	0.00	5.15	0.00	0.00	551.04	0.00	3.45	-1.65	-22.96	0.00	0.00	0.00	-11.49	-544.29	544.29
56	CHELMSFORD	-85.79	-128.66	-443.61	0.00	3.04	-49.00	9.76	-14.92	0.00	29.12	13.05	224.24	269.44	0.00	86.91	115.03	-29.95	3.85	-5.05	0.00	2.53	-701.48	701.48
64	CLINTON	-4.21	0.00	43.67	1.94	0.00	-49.48	0.00	-1.34	0.00	0.00	0.00	6.12	5.66	0.00	0.00	0.00	-0.43	0.00	0.00	-1.94	0.00	-10.02	10.02
67	CONCORD	-129.85	-75.07	-285.18	-0.52	-8.77	50.24	-4.36	0.00	0.00	15.77	0.00	87.89	381.91	0.00	2.21	33.79	-28.35	0.00	-22.07	3.27	-20.90	-466.78	466.78
100	FRAMINGHAM	-196.72	0.40	-390.80	-0.37	9.05	72.72	-45.24	0.00	0.00	4.50	11.45	160.82	264.10	0.00	71.42	104.10	-55.73	11.05	-1.10	1.54	-21.18	-525.37	525.37
110	GRAFTON	-19.66	-12.46	-33.93	0.00	0.00	-11.03	0.00	0.00	0.00	0.00	0.00	2.56	64.91	0.00	0.00	0.00	9.61	0.00	0.00	0.00	0.00	-77.08	77.08
125	HARVARD	-12.12	-3.68	-120.14	0.00	0.00	4.19	0.00	0.00	0.00	0.00	0.00	0.00	134.15	0.00	0.00	0.00	4.04	0.00	0.00	0.00	-6.44	-138.19	138.19
136	HOLLISTON	-1.41	-1.70	2.79	0.00	0.00	15.61	0.00	0.00	0.00	0.00	0.00	0.00	15.92	0.00	0.00	0.00	0.15	0.00	-3.14	0.00	-28.22	-12.93	12.93
139	HOPKINTON	-230.51	-20.33	-1423.7	-0.61	-7.39	-29.30	27.16	-7.84	0.00	34.67	-0.30	163.20	1386.15	0.00	39.96	6.58	68.36	12.62	-2.19	3.52	-20.00	-1728.37	1728.37
141	HUDSON	-127.90	-26.81	-619.56	-2.53	-53.42	67.10	5.39	0.00	0.00	24.56	0.00	129.39	354.67	0.00	9.29	138.81	139.60	0.00	0.00	0.00	-38.62	-801.72	801.72
157	LINCOLN	-3.01	0.00	-45.76	0.00	0.00	-9.72	0.00	0.00	0.00	0.00	0.00	0.00	66.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-8.28	-66.77	66.77
158	LITTLETON	-146.16	19.58	-153.14	0.00	0.00	68.66	3.46	0.00	0.00	0.00	0.00	17.03	215.70	0.00	0.00	15.11	-1.86	0.00	-1.98	0.00	-36.39	-247.46	247.46
160	LOWELL	-8.13	0.00	-65.30	11.85	0.00	-31.43	3.16	-6.42	0.00	23.72	-1.05	9.17	0.00	0.00	7.99	33.45	16.98	6.01	0.00	0.00	0.00	-93.01	93.01
170	MARLBOROUGH	-235.47	-103.47	-928.20	2.15	-51.88	48.20	0.00	0.00	0.00	52.72	86.06	523.30	531.63	0.00	206.14	212.15	-117.7	-3.51	-56.19	1.63	-167.49	-1434.54	1434.54
174	MAYNARD	-1.79	-2.26	-136.34	-4.41	-12.43	-14.54	13.14	0.00	0.00	19.35	2.78	69.17	27.53	0.00	0.00	31.44	5.85	0.00	0.00	2.52	0.00	-169.26	169.26
198	NATICK	-1.75	-6.94	-90.58	0.00	0.00	-4.09	-17.89	0.00	0.00	0.00	0.00	80.53	28.06	0.00	16.34	0.00	-0.70	2.24	0.00	0.00	-5.23	-108.59	108.59
215	NORTHBOROUGH	-97.74	-16.32	-860.30	0.00	-37.55	-49.62	113.93	0.00	0.00	11.21	39.06	196.73	558.27	0.00	16.76	135.66	34.42	3.48	0.00	0.00	-47.98	-1109.52	1109.52
269	SHERBORN	-27.13	-7.90	12.38	0.00	0.00	-5.08	0.00	0.00	0.00	0.00	0.00	0.00	15.88	0.00	3.58	0.00	0.00	0.00	0.00	0.00	8.26	-19.46	19.46
271	SHREWSBURY	-84.99	-105.44	-714.41	-20.83	4.37	-44.53	1.58	-12.36	0.00	32.56	9.80	729.33	47.13	0.00	25.49	64.09	53.22	9.18	18.45	0.00	-12.63	-978.47	978.47
277	SOUTHBOROUGH	-298.52	-34.62	-726.39	-2.80	0.00	-8.75	27.26	0.00	0.00	7.97	0.00	266.02	677.81	0.00	31.93	79.69	-15.46	0.00	-4.13	0.00	0.00	-1071.08	1071.08
286	STOW	-283.22	4.72	-456.90	-10.57	-89.99	159.86	213.22	0.00	0.00	10.36	0.00	77.48	426.17	0.00	8.12	8.65	-79.10	0.00	0.00	7.10	4.12	-664.89	664.89
288	SUDBURY	-283.16	24.36	-615.28	74.85	-18.67	-72.88	-1.35	0.00	0.00	0.00	3.50	876.33	92.23	0.00	26.72	1.42	-49.69	-7.92	0.00	2.65	-53.12	-941.24	941.24
295	TEWKSBURY	0.00	-79.35	-22.13	8.49	0.00	38.01	0.00	0.00	0.00	0.00	0.00	26.85	34.64	0.00	4.51	5.93	-16.95	0.00	0.00	0.00	0.00	-54.99	54.99
303	UPTON	0.00	0.00	-14.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.06	0.00	0.00	0.00	9.91	0.00	0.00	0.00	-4.82	-18.98	18.98
315	WAYLAND	-131.23	-60.60	-108.13	0.00	-36.26	-3.07	1.73	0.00	0.00	34.46	0.00	8.90	276.84	0.00	13.65	8.24	-4.53	0.00	0.00	0.00	0.00	-339.30	339.30
328	WESTBOROUGH	-376.55	-153.44	-733.70	3.37	-7.35	-97.44	19.98	-26.95	0.00	49.21	24.06	659.26	384.57	0.00	128.52	213.56	15.06	3.97	2.31	-3.37	-105.09	-1473.57	1473.57
330	WESTFORD	-130.60	-64.26	-669.34	0.78	-40.93	-118.13	40.80	0.00	0.00	44.69	0.00	177.04	679.10	0.00	25.20	144.15	-64.76	0.00	0.00	0.52	-24.27	-1046.23	1046.23
333	WESTON	1.78	-1.26	2.75	-4.28	0.00	-20.63	0.00	0.00	0.00	0.00	0.00	0.00	21.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-21.63	21.63
	Average	-99.81	-38.62	-344.28	-5.07	-19.83	-2.78	12.77	-2.19	0.03	17.27	6.83	155.24	272.94	0.00	25.07	46.57	-4.86	2.24	-3.55	0.44	-18.41	-528.37	528.37

Table E.6: Change in Acres 1971-1999

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-151.57	-65.36	-1308.54	2.90	-222.96	-97.78	8.33	-4.60	5.37	181.48	54.71	251.91	1026.13	0.00	106.34	272.31	-26.78	5.03	-14.55	8.72	-31.08	-1865.67	1865.67
14	ASHLAND	-113.29	-10.80	-1185.61	-13.64	-20.58	-22.92	28.78	0.00	0.00	164.77	2.83	631.10	438.56	0.00	48.80	29.10	75.76	0.00	0.00	13.57	-66.41	-1419.69	1419.69
23	BEDFORD	-94.46	-7.75	-52.36	-84.49	0.00	-8.54	1.33	0.00	0.00	66.89	0.00	224.79	-32.74	0.00	0.00	0.00	3.43	0.00	-2.54	0.00	-13.56	-261.16	261.16
28	BERLIN	-92.79	-369.73	-264.46	-23.81	-93.48	136.53	1.81	0.00	0.00	0.00	0.00	10.36	425.91	0.00	50.90	16.73	85.79	3.74	3.13	14.03	95.33	-598.38	598.38
31	BILLERICA	-142.03	-87.58	-1140.00	-15.67	-6.94	-102.68	38.46	-4.78	1.23	39.93	0.00	609.40	181.07	0.00	99.98	486.56	-37.96	52.86	63.41	4.52	-39.78	-1530.16	1530.16
34	BOLTON	-259.39	-141.70	-65.66	-71.45	0.00	-32.76	0.00	0.00	0.00	0.00	0.00	12.92	608.93	0.00	11.46	21.42	19.15	0.00	-20.00	2.42	-85.34	-653.88	653.88
37	BOXBOROUGH	-94.08	-60.82	-709.35	-0.89	-3.23	42.89	0.90	-6.28	0.00	28.89	-21.81	100.70	648.16	0.00	25.83	82.75	-29.05	0.00	1.64	-0.07	-6.18	-831.72	831.72
39	BOYLSTON	6.04	6.48	-336.44	0.00	0.00	-43.46	0.00	0.00	0.00	0.00	0.00	2.94	379.91	0.00	0.00	0.00	3.37	0.00	-7.57	0.00	-11.27	-378.65	378.65
51	CARLISLE	-73.60	-116.01	-873.67	-73.99	-16.78	-21.85	9.25	0.00	0.00	5.15	0.00	0.00	1205.86	0.00	8.23	-0.03	-43.46	0.00	0.00	0.00	-9.11	-1185.01	1185.01
56	CHELMSFORD	-114.31	-189.09	-998.53	0.00	3.04	-161.62	12.75	-14.9	0.00	64.02	30.02	364.06	504.30	0.00	167.30	337.46	7.57	8.01	0.00	0.00	-20.06	-1480.56	1480.56
64	CLINTON	-4.21	0.00	35.81	1.94	0.00	-49.48	0.00	-1.34	0.00	14.47	0.00	6.91	5.66	0.00	0.00	0.00	-7.82	0.00	0.00	-1.94	0.00	-17.88	17.88
67	CONCORD	-167.52	-114.44	-635.63	-3.86	-23.61	29.36	6.04	0.00	0.00	51.64	0.00	120.31	800.03	0.00	9.72	60.82	-89.14	0.00	-22.07	3.27	-24.90	-937.34	937.34
100	FRAMINGHAM	-269.60	0.40	-735.24	-17.59	23.41	79.27	-45.24	0.00	0.00	19.42	14.44	271.80	531.13	0.00	97.84	115.95	-73.85	11.05	-1.10	1.54	-23.63	-941.44	941.44
110	GRAFTON	-38.39	-30.25	-69.65	0.00	0.00	-10.01	0.00	0.00	0.00	0.00	0.00	2.56	136.13	0.00	0.00	0.00	9.61	0.00	0.00	0.00	0.00	-148.30	148.30
125	HARVARD	-18.78	-4.49	-342.79	0.00	0.00	-47.68	0.00	0.00	0.00	0.00	0.00	0.00	417.59	0.00	0.81	0.00	4.04	0.00	0.00	0.00	-8.70	-422.44	422.44
136	HOLLISTON	-1.41	-1.70	-0.64	0.00	-3.14	15.61	0.00	0.00	0.00	0.00	0.00	3.43	15.92	0.00	0.00	0.00	0.15	0.00	0.00	0.00	-28.22	-19.51	19.51
139	HOPKINTON	-336.63	-46.38	-1989.28	-0.61	-13.01	-92.83	44.48	-7.84	0.00	40.30	-0.30	389.36	1781.49	0.00	56.47	104.11	43.14	12.62	2.76	4.57	7.57	-2466.59	2466.59
141	HUDSON	-257.89	-73.31	-858.86	-9.19	-81.47	48.49	5.39	0.00	0.00	48.04	43.73	219.96	461.36	0.00	52.52	266.55	162.62	12.31	0.95	0.00	-41.19	-1273.42	1273.42
157	LINCOLN	-3.32	0.00	-111.67	0.00	0.00	-14.16	0.00	0.00	0.00	45.95	0.00	0.00	88.97	0.00	2.51	0.00	0.00	0.00	0.00	0.00	-8.28	-137.43	137.43
158	LITTLETON	-207.64	14.73	-197.92	-4.74	0.00	49.81	23.07	0.00	2.13	0.00	0.00	28.80	275.64	0.00	11.64	27.26	36.97	0.00	0.00	0.00	-59.75	-405.50	405.50
160	LOWELL	-8.13	0.00	-94.39	11.85	0.00	-103.32	6.94	-6.56	0.00	52.94	1.16	45.93	-29.61	0.00	9.51	98.45	16.98	8.48	-10.23	0.00	0.00	-193.99	193.99
170	MARLBOROUGH	-436.90	-187.17	-1788.45	-5.64	-92.60	0.65	9.87	0.00	-13.5	118.01	91.68	723.16	994.22	0.00	466.54	437.19	-32.78	17.93	-33.06	1.63	-270.7	-2779.18	2779.18
174	MAYNARD	-8.55	-7.20	-241.60	-4.41	-12.43	-23.63	18.25	0.00	0.00	66.62	15.68	115.02	32.25	0.00	0.00	52.79	-5.07	0.00	0.00	2.27	0.00	-295.55	295.55
198	NATICK	-5.20	-14.58	-152.16	0.00	0.00	-10.65	-69.16	0.00	0.00	69.36	0.00	112.92	33.39	0.00	63.38	2.95	-25.24	2.24	0.00	0.00	-7.25	-189.84	189.84
215	NORTHBOROUGH	-204.17	-198.34	-1369.28	0.00	-34.36	-139.61	32.56	0.00	0.00	11.21	39.06	526.21	951.85	0.00	134.02	281.90	37.84	3.48	3.93	1.95	-78.25	-2022.07	2022.07
269	SHERBORN	-63.31	-7.38	-47.37	0.00	0.00	-7.73	0.00	0.00	0.00	0.00	0.00	0.00	120.14	0.00	3.58	0.00	-13.46	0.00	0.00	0.00	15.53	-110.26	110.26
271	SHREWSBURY	-137.10	-169.45	-1021.32	-20.83	-7.14	-69.96	1.58	-12.3	0.00	62.25	38.59	944.39	144.39	0.00	52.84	127.90	33.05	11.72	24.56	0.00	-3.11	-1428.90	1428.90
277	SOUTHBOROUGH	-434.71	-41.99	-929.34	-2.80	0.00	42.21	30.14	0.00	0.00	11.14	0.00	293.24	856.76	0.00	82.50	82.54	6.54	4.67	-4.13	3.23	0.00	-1363.40	1363.40
286	STOW	-382.87	4.72	-774.12	-15.54	-89.00	21.23	213.66	1.47	0.00	13.71	0.00	392.70	596.12	0.00	32.49	29.73	19.78	36.33	0.00	7.10	-107.5	-1335.99	1335.99
288	SUDBURY	-526.86	2.78	-944.97	57.91	-22.56	-39.14	1.30	0.00	0.00	10.15	3.50	2942.41	-1550.5	0.00	57.69	9.11	-32.80	-7.92	0.00	2.65	37.28	-1432.91	1432.91
295	TEWKSBURY	-3.41	-124.61	-75.66	8.49	0.00	18.72	0.00	0.00	0.00	0.87	0.00	64.53	100.45	0.00	7.02	5.93	-2.34	0.00	0.00	0.00	0.00	-176.47	176.47
303	UPTON	0.00	0.00	-27.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.07	0.00	0.00	0.00	9.91	0.00	0.00	0.00	-4.82	-31.98	31.98
315	WAYLAND	-157.07	-71.04	-157.54	-3.51	-36.26	-2.67	1.73	0.00	0.00	73.00	0.00	31.11	288.56	0.00	18.67	8.24	8.56	0.00	0.00	3.58	-5.37	-429.87	429.87
328	WESTBOROUGH	-571.68	-149.37	-1524.56	-33.41	-42.06	-228.11	32.38	-9.96	0.00	86.09	24.06	786.89	526.73	0.00	318.27	572.93	-54.41	42.23	16.08	327.28	-119.3	-2341.29	2341.29
330	WESTFORD	-137.78	-167.83	-1185.63	-2.30	-64.83	-227.52	91.53	0.00	0.00	73.47	0.00	263.91	1023.38	0.00	77.28	253.65	22.00	0.00	0.00	22.52	-41.85	-1805.22	1805.22
333	WESTON	1.78	-1.26	0.12	-4.28	0.00	-20.63	0.00	0.00	0.00	0.00	0.00	0.00	24.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-24.27	24.27
	Average	-153.08	-67.51	-615.94	-9.15	-23.89	-30.39	14.06	-1.87	-0.13	39.44	9.37	291.49	389.85	0.00	57.61	105.12	3.67	6.24	0.03	11.75	-26.67	-914.89	914.89

Table E.7: Percent Change 1971-1985																								
TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-22.10	-64.99	-8.38	-1.98	-23.32	-33.09	4.39	-100.00	N/A	145.37	N/A	8.42	22.66	N/A	16.91	94.46	33.22	5.48	11.04	5.43	-8.53	-10.74	23.22
14	ASHLAND	-32.62	-10.98	-8.29	-8.89	0.00	-37.83	37.95	N/A	0.00	237.74	0.00	32.29	33.34	N/A	11.03	4.83	0.69	0.00	N/A	4.23	0.77	-8.65	28.94
23	BEDFORD	-15.87	-20.34	-0.60	-1.94	N/A	44.68	0.00	N/A	N/A	N/A	N/A	0.91	21.32	N/A	N/A	N/A	0.00	N/A	-34.13	0.00	-47.17	-2.08	4.36
28	BERLIN	3.36	-11.29	-4.47	-1.19	36.21	2.05	0.00	N/A	N/A	N/A	0.00	4.84	33.65	N/A	53.10	0.00	246.92	0.00	55.31	9.19	-11.50	-3.49	30.03
31	BILLERICA	-8.14	-20.83	-18.87	-6.24	-47.58	-12.16	55.75	-39.73	0.00	172.06	0.00	14.01	26.93	N/A	59.71	155.43	-12.58	7.92	129.75	3.06	-24.45	-16.48	25.14
34	BOLTON	-6.58	-23.47	-1.61	0.00	N/A	22.18	0.00	N/A	N/A	N/A	N/A	0.00	33.09	N/A	22.14	0.00	29.40	0.00	0.00	0.00	-4.82	-2.23	19.62
37	BOXBOROUGH	-10.68	-0.59	-5.31	-1.81	212.44	-7.35	9.53	0.00	N/A	75.95	-100.00	N/A	29.91	N/A	348.34	395.19	24.56	0.00	N/A	0.00	-45.54	-4.87	27.04
39	BOYLSTON	56.29	0.00	-1.65	0.00	N/A	8.26	N/A	N/A	N/A	N/A	N/A	9.73	96.17	N/A	0.00	N/A	14.44	0.00	0.00	0.00	-38.00	-1.54	59.23
51	CARLISLE	-5.91	-12.01	-8.33	-0.38	0.00	-16.79	0.00	N/A	N/A	N/A	N/A	N/A	41.21	N/A	23.33	19.97	-21.80	N/A	N/A	0.00	4.83	-7.81	37.37
56	CHELMSFORD	-7.69	-21.12	-15.90	0.00	N/A	-28.17	4.62	0.00	0.00	251.82	2.50	4.16	24.83	N/A	60.57	141.70	27.72	0.73	N/A	0.00	-84.11	-15.21	12.82
64	CLINTON	0.00	0.00	-1.64	0.00	N/A	0.00	N/A	0.00	N/A	N/A	0.00	0.53	0.00	N/A	N/A	N/A	-43.83	N/A	N/A	0.00	N/A	-1.20	2.63
67	CONCORD	-2.10	-12.00	-5.03	-0.34	-50.80	-9.52	3.78	N/A	0.00	421.67	0.00	2.42	19.72	N/A	6.22	17.29	-14.65	0.00	0.00	0.00	-7.66	-4.24	9.47
100	FRAMINGHAM	-9.76	0.00	-6.83	-8.22	19.77	2.11	0.00	0.00	0.00	6.84	0.27	2.72	26.84	N/A	2.55	2.13	-2.46	0.00	0.00	0.00	-10.37	-5.63	4.34
110	GRAFTON	-10.00	-16.98	-2.45	0.00	N/A	4.95	0.00	N/A	N/A	N/A	N/A	N/A	114.15	N/A	N/A	N/A	0.00	0.00	0.00	N/A	N/A	-4.02	25.40
125	HARVARD	-2.90	-0.83	-4.17	0.00	0.00	-46.88	N/A	N/A	N/A	N/A	N/A	0.00	57.48	N/A	N/A	N/A	0.00	0.00	N/A	0.00	-0.73	-4.54	45.35
136	HOLLISTON	0.00	0.00	-0.11	N/A	-100.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	N/A	N/A	N/A	0.00	N/A	N/A	N/A	0.00	-0.20	58.12
139	HOPKINTON	-19.81	-26.52	-4.97	0.00	-4.98	-29.17	12.96	0.00	0.00	80.65	0.00	123.85	52.26	N/A	38.88	N/A	-14.24	0.00	59.59	0.16	4.93	-5.37	35.23
141	HUDSON	-32.83	-43.17	-6.82	-2.03	-19.55	-15.90	0.00	N/A	0.00	N/A	67.22	5.72	23.63	N/A	25.92	91.12	14.91	60.56	1.78	0.00	-1.86	-9.64	17.47
157	LINCOLN	-0.10	0.00	-1.78	0.00	N/A	-27.16	0.00	N/A	0.00	N/A	N/A	N/A	2.74	N/A	42.81	N/A	0.00	0.00	N/A	0.00	0.00	-1.63	8.51
158	LITTLETON	-9.01	-7.77	-1.64	-2.97	N/A	-26.55	771.35	N/A	N/A	N/A	N/A	2.92	14.71	N/A	18.21	N/A	175.22	0.00	N/A	0.00	-16.54	-3.74	12.73
160	LOWELL	0.00	N/A	-6.97	0.00	N/A	-36.71	5.83	-2.08	N/A	16.34	0.13	23.01	-91.76	N/A	1.24	24.63	0.00	0.91	-45.50	0.00	N/A	-14.42	3.15
170	MARLBOROUGH	-29.50	-32.49	-12.79	-2.94	-43.98	-12.80	4.27	0.00	-92.53	58.27	1.26	11.52	78.23	N/A	64.86	81.55	20.52	6.08	23.97	0.00	-32.81	-14.28	28.71
174	MAYNARD	-24.04	-68.58	-6.18	0.00	0.00	-9.94	7.52	N/A	N/A	1363.6	5.99	6.30	7.49	N/A	0.00	22.29	-9.87	N/A	0.00	-0.20	0.00	-6.06	9.18
198	NATICK	-28.02	-43.19	-7.43	0.00	N/A	-7.35	-45.73	N/A	N/A	81.94	0.00	1.77	4.96	N/A	9.51	4.60	-10.26	0.00	0.00	0.00	-17.59	-5.55	2.21
215	NORTHBOROUGH	-18.89	-51.73	-7.32	0.00	6.42	-22.23	-22.60	N/A	N/A	0.00	0.00	32.42	52.77	N/A	90.75	436.42	3.17	0.00	42.81	1.22	-12.24	-9.78	34.20
269	SHERBORN	-18.03	0.51	-1.09	0.00	N/A	-1.14	N/A	N/A	N/A	N/A	N/A	N/A	22.63	N/A	N/A	0.00	-87.75	0.00	N/A	0.00	38.61	-1.49	18.25
271	SHREWSBURY	-20.56	-21.17	-6.88	0.00	-100.00	-11.55	0.00	0.00	N/A	481.42	5.58	32.30	24.07	N/A	39.77	274.37	-15.80	0.90	N/A	0.00	80.70	-8.43	20.81
277	SOUTHBOROUGH	-14.45	-6.61	-4.03	0.00	N/A	35.39	2.21	0.00	0.00	N/A	0.00	2.49	27.15	N/A	46.13	2.52	11.88	1.89	0.00	0.34	0.00	-3.96	11.33
286	STOW	-11.01	0.00	-4.64	-0.72	0.93	-38.26	0.13	N/A	N/A	N/A	0.00	147.99	14.66	N/A	86.26	182.15	64.43	234.27	N/A	0.00	-32.87	-6.99	34.53
288	SUDBURY	-20.41	-18.68	-4.32	-1.57	-4.88	12.14	1.42	0.00	N/A	280.75	N/A	1143.3	-39.17	N/A	22.33	5.90	6.87	0.00	N/A	0.00	95.71	-4.59	9.60
295	TEWKSBURY	-100.00	-30.26	-25.14	0.00	N/A	-24.08	N/A	N/A	N/A	N/A	0.00	13.93	413.64	N/A	45.31	0.00	625.52	N/A	0.00	0.00	0.00	-25.78	34.41
303	UPTON	N/A	N/A	-0.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	117.88	N/A	N/A	N/A	N/A	0.00	N/A	N/A	0.00	-0.36	30.49
315	WAYLAND	-4.62	-4.65	-1.56	-0.27	0.00	0.36	0.00	N/A	0.00	106.37	N/A	2.07	0.46	N/A	5.28	0.00	8.84	0.00	N/A	0.98	-13.95	-1.57	2.12
328	WESTBOROUGH	-14.09	1.37	-10.99	-5.12	-46.97	-29.25	15.23	59.16	N/A	50.93	0.00	11.18	38.48	N/A	114.20	262.13	-17.91	10.33	48.82	110.46	-7.27	-8.18	28.66
330	WESTFORD	-2.00	-42.69	-9.54	-2.26	-10.96	-23.48	169.86	N/A	N/A	N/A	N/A	N/A	36.91	N/A	97.47	3030.0	555.65	0.00	0.00	94.41	-21.10	-10.94	61.83
333	WESTON	0.00	0.00	-0.11	0.00	N/A	0.00	N/A	N/A	N/A	N/A	N/A	N/A	0.40	N/A	N/A	N/A	0.00	N/A	N/A	N/A	-13.80	-0.11	0.38
	Average	-12.63	-17.97	-6.06	-1.44	-8.44	-11.04	37.09	-6.36	-8.41	225.40	-0.85	60.77	38.43	N/A	48.32	209.95	46.08	11.35	14.67	7.17	-6.89	-6.55	22.69

Table E.8: Percent Change 1985-1999

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-1.20	-27.94	-11.74	2.80	-63.47	1.72	8.00	N/A	0.00	27.99	N/A	9.22	27.14	N/A	25.96	27.04	-33.87	0.00	-82.83	-1.04	-30.78	-11.54	18.07
14	ASHLAND	-40.13	-12.43	-15.51	-10.03	-13.04	31.49	23.73	N/A	0.00	61.52	3.18	40.56	35.75	N/A	19.24	21.99	44.72	0.00	N/A	0.00	-66.56	-15.26	36.15
23	BEDFORD	-42.16	-0.22	-2.32	-27.63	N/A	-55.12	55.74	N/A	N/A	N/A	N/A	24.41	-29.77	N/A	N/A	N/A	9.05	N/A	23.92	0.00	-62.46	-8.87	17.47
28	BERLIN	-20.19	-36.69	-0.47	-15.03	-72.51	51.13	4.99	N/A	N/A	N/A	0.00	1.48	37.93	N/A	195.19	315.26	18.84	3.47	-24.80	2.67	102.33	-4.60	29.33
31	BILLERICA	-45.30	-32.32	-6.93	0.06	-100.00	-18.36	28.11	-100.00	52.21	28.98	0.00	7.64	23.12	N/A	8.34	20.28	-6.33	15.80	-3.01	-1.60	-34.40	-10.06	10.24
34	BOLTON	-28.38	-30.47	0.77	-29.11	N/A	-29.45	0.00	N/A	N/A	N/A	N/A	127.28	47.93	N/A	28.73	93.38	40.65	0.00	-93.99	4.71	-11.95	-4.51	32.51
37	BOXBOROUGH	-30.26	-30.24	-13.07	1.28	-77.55	75.78	0.00	-100.00	N/A	14.02	N/A	N/A	71.97	N/A	20.87	94.88	-67.04	0.00	0.00	-0.40	-39.34	-13.39	55.71
39	BOYLSTON	-20.30	18.07	-3.29	0.00	N/A	-76.50	N/A	N/A	N/A	N/A	N/A	0.00	126.43	N/A	0.00	N/A	23.48	0.00	-100.00	0.00	16.73	-3.81	90.53
51	CARLISLE	-8.45	-24.16	-5.39	-18.19	-93.60	-1.64	286.60	N/A	N/A	N/A	N/A	N/A	24.56	N/A	13.67	-16.93	-31.22	N/A	N/A	0.00	-22.25	-7.20	23.11
56	CHELMSFORD	-25.06	-56.99	-15.11	0.00	N/A	-17.06	14.39	-100.00	0.00	59.73	1.88	6.40	22.82	N/A	40.78	30.32	-17.32	0.67	-100.00	0.00	59.22	-16.15	10.23
64	CLINTON	-10.83	0.00	9.25	107.89	N/A	-62.12	N/A	-100.00	N/A	0.00	0.00	4.10	40.66	N/A	N/A	N/A	-4.52	N/A	N/A	-7.15	N/A	-1.55	3.26
67	CONCORD	-7.38	-26.00	-4.31	-0.05	-60.98	25.31	-1.53	N/A	0.00	35.52	0.00	6.41	15.04	N/A	1.72	18.43	-8.01	0.00	-30.02	0.46	-43.40	-4.39	8.58
100	FRAMINGHAM	-29.18	0.44	-8.31	-0.19	10.40	22.92	-10.72	0.00	0.00	1.93	1.01	3.83	20.93	N/A	6.73	18.30	-7.77	2.79	-10.52	0.17	-100.00	-7.54	5.25
110	GRAFTON	-11.67	-14.32	-2.39	0.00	N/A	-50.99	0.00	N/A	N/A	N/A	N/A	N/A	48.58	N/A	N/A	N/A	12.31	0.00	0.00	N/A	N/A	-4.53	21.92
125	HARVARD	-5.43	-3.80	-2.35	0.00	0.00	7.13	N/A	N/A	N/A	N/A	N/A	0.00	17.28	N/A	0.00	N/A	53.30	0.00	N/A	0.00	-2.11	-2.31	15.17
136	HOLLISTON	-8.71	-100.00	0.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	146.50	N/A	N/A	N/A	33.49	N/A	-100.00	N/A	-100.00	-0.40	72.25
139	HOPKINTON	-53.68	-28.17	-13.17	-0.36	-6.90	-18.99	18.00	-100.00	0.00	274.66	-0.10	39.93	120.35	N/A	67.73	6.75	45.02	2.60	-16.52	0.52	-3.41	-13.29	61.00
141	HUDSON	-48.09	-43.78	-18.95	-0.79	-46.26	68.16	8.64	N/A	0.00	104.57	0.00	7.73	63.54	N/A	4.43	51.81	78.68	0.00	0.00	0.00	-28.40	-18.12	25.28
157	LINCOLN	-0.97	0.00	-1.25	0.00	N/A	-81.54	0.00	N/A	0.00	0.00	N/A	N/A	8.01	N/A	0.00	N/A	0.00	0.00	N/A	0.00	-16.81	-1.56	7.41
158	LITTLETON	-23.53	34.02	-5.69	0.00	N/A	131.68	15.62	N/A	0.00	N/A	N/A	4.11	46.14	N/A	0.00	124.40	-3.06	0.00	-100.00	0.00	-30.88	-6.08	17.69
160	LOWELL	-65.07	N/A	-16.81	40.78	N/A	-25.36	4.60	-100.00	N/A	11.40	-0.06	4.66	0.00	N/A	6.47	10.17	4.99	2.20	0.00	0.00	N/A	-15.53	2.81
170	MARLBOROUGH	-48.92	-59.51	-15.82	0.84	-100.00	14.88	0.00	0.00	0.00	29.73	19.07	27.05	50.45	N/A	31.15	42.35	-23.59	-0.94	-46.98	0.23	-79.24	-17.77	23.80
174	MAYNARD	-8.37	-100.00	-8.54	-4.03	-100.00	-17.65	17.98	N/A	N/A	38.15	1.22	8.94	40.66	N/A	0.00	26.83	5.86	N/A	0.00	2.11	0.00	-8.64	11.27
198	NATICK	-19.73	-69.15	-11.80	0.00	N/A	-4.94	-29.39	N/A	N/A	0.00	0.00	4.33	24.91	N/A	3.02	0.00	-0.33	1.91	0.00	0.00	-55.20	-7.86	2.89
215	NORTHBOROUG H	-21.38	-9.61	-13.36	0.00	-71.09	-15.76	40.89	N/A	N/A	72.02	70.82	14.62	49.00	N/A	6.80	75.47	30.91	1.78	0.00	0.00	-22.11	-13.18	30.99
269	SHERBORN	-16.49	-7.71	0.23	0.00	N/A	-2.21	N/A	N/A	N/A	N/A	N/A	N/A	2.81	N/A	N/A	0.00	0.00	0.00	N/A	0.00	31.62	-0.32	3.31
271	SHREWSBURY	-42.21	-44.25	-17.20	-27.75	N/A	-22.88	2.66	-100.00	N/A	90.83	1.80	82.79	9.40	N/A	26.53	73.61	49.52	3.24	302.17	0.00	-59.21	-19.99	37.41
277	SOUTHBOROUGH	-37.01	-33.26	-15.02	-2.34	N/A	-4.49	20.41	0.00	0.00	251.30	0.00	23.76	80.86	N/A	19.93	68.94	-7.46	0.00	-30.19	0.00	0.00	-15.11	37.29
286	STOW	-35.17	3.97	-7.00	-1.55	-84.09	71.47	60.98	0.00	N/A	308.47	0.00	14.67	32.07	N/A	15.43	26.51	-31.34	0.00	N/A	2.97	1.81	-7.45	25.43
288	SUDBURY	-29.80	25.93	-8.44	7.05	-24.59	-23.39	-0.71	0.00	N/A	0.00	N/A	39.00	3.62	N/A	15.75	1.03	-18.90	-83.37	N/A	1.04	-28.74	-9.20	16.76
295	TEWKSBURY	N/A	-76.07	-13.89	35.60	N/A	62.50	N/A	N/A	N/A	0.00	0.00	8.71	42.39	N/A	56.12	12.33	-100.00	N/A	0.00	0.00	0.00	-15.72	11.59
303	UPTON	N/A	N/A	-0.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37.71	N/A	N/A	N/A	N/A	0.00	N/A	N/A	-54.91	-0.53	34.10
315	WAYLAND	-24.59	-28.36	-3.47	0.00	-100.00	-2.67	0.64	N/A	0.00	46.09	N/A	0.81	10.86	N/A	13.63	11.83	-2.81	0.00	N/A	0.00	0.00	-5.96	7.78
328	WESTBOROUGH	-31.64	-50.83	-11.46	0.50	-18.76	-30.83	21.31	-58.97	N/A	45.03	9.87	51.93	75.17	N/A	36.11	43.02	4.73	0.97	5.50	-0.54	-57.57	-15.12	37.83
330	WESTFORD	-37.17	-46.21	-13.67	0.59	-21.09	-33.13	50.63	N/A	N/A	155.27	N/A	203.79	53.18	N/A	23.89	127.44	-63.26	0.00	0.00	1.15	-36.88	-16.93	52.67
333	WESTON	14.42	-100.00	0.12	-31.21	N/A	-100.00	N/A	N/A	N/A	N/A	N/A	N/A	3.30	N/A	N/A	N/A	0.00	N/A	N/A	N/A	N/A	-0.91	3.11
	Average	-25.41	-29.71	-7.69	0.86	-54.92	-3.85	22.91	-58.38	4.02	69.05	5.72	26.49	39.76	N/A	23.73	49.09	0.82	-1.69	-16.29	0.17	-24.22	-9.04	25.01

Table E.9: Percent Change 1971-1999

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-23.03	-74.77	-19.13	0.77	-71.99	-31.93	12.74	-100.00	N/A	214.03	N/A	18.41	55.95	N/A	47.25	147.04	-11.90	5.48	-80.94	4.33	-36.69	-21.05	45.48
14	ASHLAND	-59.66	-22.04	-22.51	-18.03	-13.04	-18.25	70.69	N/A	0.00	445.51	3.18	85.94	81.00	N/A	32.39	27.88	45.71	0.00	N/A	4.23	-66.30	-22.59	75.54
23	BEDFORD	-51.34	-20.51	-2.90	-29.03	N/A	-35.07	55.74	N/A	N/A	N/A	N/A	25.54	-14.80	N/A	N/A	N/A	9.05	N/A	-18.37	0.00	-80.17	-10.77	22.60
28	BERLIN	-17.51	-43.84	-4.91	-16.04	-62.56	54.23	4.99	N/A	N/A	N/A	0.00	6.38	84.34	N/A	351.93	315.26	312.26	3.47	16.79	12.10	79.05	-7.93	68.17
31	BILLERICA	-49.75	-46.42	-24.49	-6.19	-100.00	-28.30	99.53	-100.00	52.21	250.90	0.00	22.71	56.28	N/A	73.03	207.24	-18.11	24.97	122.85	1.42	-50.44	-24.88	37.96
34	BOLTON	-33.09	-46.79	-0.85	-29.11	N/A	-13.81	0.00	N/A	N/A	N/A	N/A	127.28	96.89	N/A	57.24	93.38	82.00	0.00	-93.99	4.71	-16.20	-6.64	58.50
37	BOXBOROUGH	-37.70	-30.65	-17.69	-0.55	-29.85	62.86	9.53	-100.00	N/A	100.61	-100.00	N/A	123.42	N/A	441.93	865.03	-58.94	0.00	N/A	-0.40	-66.97	-17.60	97.82
39	BOYLSTON	24.56	18.07	-4.88	0.00	N/A	-74.56	N/A	N/A	N/A	N/A	N/A	9.73	344.19	N/A	0.00	N/A	41.32	0.00	-100.00	0.00	-27.63	-5.30	203.38
51	CARLISLE	-13.86	-33.27	-13.27	-18.50	-93.60	-18.16	286.60	N/A	N/A	N/A	N/A	N/A	75.89	N/A	40.19	-0.34	-46.22	N/A	N/A	0.00	-18.50	-14.45	69.11
56	CHELMSFORD	-30.82	-66.08	-28.60	0.00	N/A	-40.42	19.68	-100.00	0.00	461.96	4.43	10.82	53.32	N/A	126.06	214.99	5.59	1.41	N/A	0.00	-74.70	-28.90	24.36
64	CLINTON	-10.83	0.00	7.46	107.89	N/A	-62.12	N/A	-100.00	N/A	N/A	0.00	4.65	40.66	N/A	N/A	N/A	-46.37	N/A	N/A	-7.15	N/A	-2.72	5.98
67	CONCORD	-9.32	-34.88	-9.12	-0.39	-80.81	13.38	2.20	N/A	0.00	606.97	0.00	8.99	37.73	N/A	8.04	38.90	-21.49	0.00	-30.02	0.46	-47.73	-8.45	18.87
100	FRAMINGHAM	-36.09	0.44	-14.57	-8.39	32.23	25.52	-10.72	0.00	0.00	8.91	1.28	6.66	53.39	N/A	9.45	20.81	-10.04	2.79	-10.52	0.17	-100.00	-12.75	9.82
110	GRAFTON	-20.51	-28.86	-4.78	0.00	N/A	-48.56	0.00	N/A	N/A	N/A	N/A	N/A	218.18	N/A	N/A	N/A	12.31	0.00	0.00	N/A	N/A	-8.36	52.90
125	HARVARD	-8.17	-4.60	-6.41	0.00	0.00	-43.09	N/A	N/A	N/A	N/A	N/A	0.00	84.69	N/A	N/A	N/A	53.30	0.00	N/A	0.00	-2.83	-6.74	67.40
136	HOLLISTON	-8.71	-100.00	-0.02	N/A	-100.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	146.50	N/A	N/A	N/A	33.49	N/A	N/A	N/A	-100.00	-0.60	172.36
139	HOPKINTON	-62.86	-47.22	-17.49	-0.36	-11.53	-42.62	33.30	-100.00	0.00	576.83	-0.10	213.23	235.51	N/A	132.94	N/A	24.36	2.60	33.22	0.68	1.35	-17.95	117.72
141	HUDSON	-65.13	-68.05	-24.47	-2.80	-56.76	41.42	8.64	N/A	0.00	N/A	67.22	13.88	102.19	N/A	31.50	190.14	105.32	60.56	1.78	0.00	-29.73	-26.01	47.17
157	LINCOLN	-1.07	0.00	-3.01	0.00	N/A	-86.55	0.00	N/A	0.00	N/A	N/A	N/A	10.96	N/A	42.81	N/A	0.00	0.00	N/A	0.00	-16.81	-3.16	16.56
158	LITTLETON	-30.42	23.61	-7.23	-2.97	N/A	70.17	907.47	N/A	N/A	N/A	N/A	7.15	67.63	N/A	18.21	N/A	166.81	0.00	N/A	0.00	-42.31	-9.59	32.67
160	LOWELL	-65.07	N/A	-22.61	40.78	N/A	-52.76	10.70	-100.00	N/A	29.60	0.07	28.74	-91.76	N/A	7.80	37.30	4.99	3.14	-45.50	0.00	N/A	-27.71	6.05
170	MARLBOROUGH	-63.99	-72.67	-26.59	-2.13	-100.00	0.18	4.27	0.00	-92.53	105.32	20.57	41.69	168.15	N/A	116.21	158.44	-7.92	5.08	-34.27	0.23	-86.05	-29.51	59.35
174	MAYNARD	-30.40	-100.00	-14.20	-4.03	-100.00	-25.84	26.85	N/A	N/A	1922	7.28	15.81	51.19	N/A	0.00	55.11	-4.58	N/A	0.00	1.90	0.00	-14.18	21.48
198	NATICK	-42.22	-82.47	-18.35	0.00	N/A	-11.93	-61.68	N/A	N/A	81.94	0.00	6.19	31.10	N/A	12.81	4.60	-10.56	1.91	0.00	0.00	-63.08	-12.97	5.16
215	NORTHBOROUGH	-36.23	-56.37	-19.70	0.00	-69.23	-34.48	9.05	N/A	N/A	72.02	70.82	51.79	127.63	N/A	103.71	841.26	35.06	1.78	42.81	1.22	-31.64	-21.68	75.78
269	SHERBORN	-31.54	-7.24	-0.86	0.00	N/A	-3.32	N/A	N/A	N/A	N/A	N/A	N/A	26.08	N/A	N/A	0.00	-87.75	0.00	N/A	0.00	82.44	-1.81	22.17
271	SHREWSBURY	-54.09	-56.05	-22.90	-27.75	-62.01	-31.79	2.66	-100.00	N/A	1009	7.47	141.83	35.73	N/A	76.85	549.95	25.89	4.17	N/A	0.00	-26.30	-26.73	66.01
277	SOUTHBOROUGH	-46.11	-37.68	-18.44	-2.34	N/A	29.31	23.06	0.00	0.00	N/A	0.00	26.84	129.96	N/A	75.25	73.20	3.53	1.89	-30.19	0.34	0.00	-18.47	52.85
286	STOW	-42.31	3.97	-11.32	-2.26	-83.94	5.86	61.19	N/A	N/A	N/A	0.00	184.37	51.44	N/A	114.99	256.95	12.89	234.27	N/A	2.97	-31.66	-13.92	68.74
288	SUDBURY	-44.13	2.40	-12.40	5.37	-28.27	-14.09	0.70	0.00	N/A	280.75	N/A	1628	-36.97	N/A	41.60	6.99	-13.33	-83.37	N/A	1.04	39.47	-13.37	27.97
295	TEWKSBURY	-100.0	-83.31	-35.54	35.60	N/A	23.37	N/A	N/A	N/A	N/A	0.00	23.85	631.39	N/A	126.87	12.33	-100.00	N/A	0.00	0.00	0.00	-37.45	49.98
303	UPTON	N/A	N/A	-0.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	200.04	N/A	N/A	N/A	N/A	0.00	N/A	N/A	-54.91	-0.89	74.99
315	WAYLAND	-28.08	-31.69	-4.98	-0.27	-100.00	-2.33	0.64	N/A	0.00	201.50	N/A	2.90	11.37	N/A	19.63	11.83	5.78	0.00	N/A	0.98	-13.95	-7.44	10.06
328	WESTBOROUGH	-41.27	-50.16	-21.19	-4.65	-56.92	-51.07	39.78	-34.69	N/A	118.89	9.87	68.91	142.57	N/A	191.56	417.90	-14.03	11.40	57.01	109.33	-60.65	-22.06	77.34
330	WESTFORD	-38.43	-69.17	-21.91	-1.69	-29.75	-48.83	306.48	N/A	N/A	N/A	N/A	N/A	109.72	N/A	144.64	7018	140.91	0.00	0.00	96.64	-50.20	-26.01	147.06
333	WESTON	14.42	-100.00	0.01	-31.21	N/A	-100.00	N/A	N/A	N/A	N/A	N/A	N/A	3.72	N/A	N/A	N/A	0.00	N/A	N/A	N/A	N/A	-1.02	3.50
	Average	-34.14	-40.19	-13.07	-0.54	-58.00	-17.46	68.72	-64.21	-3.67	381.60	4.60	103.06	98.48	N/A	87.32	462.61	19.12	9.71	-8.47	7.35	-31.04	-14.77	55.91

Table E.10: Percent land use change divided by percent population change 1971-1985

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-13.80	-40.60	-5.23	-1.24	-14.57	-20.67	2.74	-62.47	N/A	90.81	N/A	5.26	14.16	N/A	10.56	59.01	20.75	3.42	6.90	3.39	-5.33	-6.71	14.51
14	ASHLAND	-1.18	-0.40	-0.30	-0.32	0.00	-1.36	1.37	N/A	0.00	8.56	0.00	1.16	1.20	N/A	0.40	0.17	0.02	0.00	N/A	0.15	0.03	-0.31	1.04
23	BEDFORD	-7.30	-9.36	-0.28	-0.89	N/A	20.55	0.00	N/A	N/A	N/A	N/A	0.42	9.81	N/A	N/A	N/A	0.00	N/A	-15.70	0.00	-21.70	-0.96	2.01
28	BERLIN	0.75	-2.53	-1.00	-0.27	8.10	0.46	0.00	N/A	N/A	N/A	0.00	1.08	7.53	N/A	11.88	0.00	55.26	0.00	12.38	2.06	-2.57	-0.78	6.72
31	BILLERICA	-2185.	-5594	-5067	-1675	-12782	-3267	14977	-10673	0.00	46220	0.00	3763	7233	N/A	16039	41751	-3378	2127.69	34854	823.12	-6568	-4427	6753.83
34	BOLTON	-0.38	-1.35	-0.09	0.00	N/A	1.28	0.00	N/A	N/A	N/A	N/A	0.00	1.91	N/A	1.28	0.00	1.70	0.00	0.00	0.00	-0.28	-0.13	1.13
37	BOXBOROUGH	-1.51	-0.08	-0.75	-0.26	30.06	-1.04	1.35	0.00	N/A	10.75	-14.15	N/A	4.23	N/A	49.29	55.91	3.48	0.00	N/A	0.00	-6.44	-0.69	3.83
39	BOYLSTON	12.70	0.00	-0.37	0.00	N/A	1.86	N/A	N/A	N/A	N/A	N/A	2.20	21.70	N/A	0.00	N/A	3.26	0.00	0.00	0.00	-8.58	-0.35	13.37
51	CARLISLE	-0.22	-0.44	-0.31	-0.01	0.00	-0.62	0.00	N/A	N/A	N/A	N/A	N/A	1.52	N/A	0.86	0.74	-0.81	N/A	N/A	0.00	0.18	-0.29	1.38
56	CHELMSFORD	-1.34	-3.68	-2.77	0.00	N/A	-4.90	0.80	0.00	0.00	43.82	0.44	0.72	4.32	N/A	10.54	24.66	4.82	0.13	N/A	0.00	-14.64	-2.65	2.23
64	CLINTON	0.00	0.00	-0.18	0.00	N/A	0.00	N/A	0.00	N/A	N/A	0.00	0.06	0.00	N/A	N/A	N/A	-4.71	N/A	N/A	0.00	N/A	-0.13	0.28
67	CONCORD	-0.38	-2.19	-0.92	-0.06	-9.29	-1.74	0.69	N/A	0.00	77.10	0.00	0.44	3.60	N/A	1.14	3.16	-2.68	0.00	0.00	0.00	-1.40	-0.78	1.73
100	FRAMINGHAM	-31.10	0.00	-21.76	-26.19	63.04	6.73	0.00	0.00	0.00	21.81	0.85	8.66	85.57	N/A	8.13	6.78	-7.85	0.00	0.00	0.00	-33.07	-17.96	13.83
110	GRAFTON	-0.65	-1.10	-0.16	0.00	N/A	0.32	0.00	N/A	N/A	N/A	N/A	N/A	7.42	N/A	N/A	N/A	0.00	0.00	0.00	N/A	N/A	-0.26	1.65
125	HARVARD	0.34	0.10	0.49	0.00	0.00	5.52	N/A	N/A	N/A	N/A	N/A	0.00	-6.77	N/A	N/A	N/A	0.00	0.00	N/A	0.00	0.09	0.53	-5.34
136	HOLLISTON	0.00	0.00	-0.38	N/A	-353.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	N/A	N/A	N/A	0.00	N/A	N/A	N/A	0.00	-0.72	205.61
139	HOPKINTON	-0.72	-0.96	-0.18	0.00	-0.18	-1.06	0.47	0.00	0.00	2.93	0.00	4.49	1.90	N/A	1.41	N/A	-0.52	0.00	2.16	0.01	0.18	-0.19	1.28
141	HUDSON	30.16	39.66	6.26	1.87	17.96	14.61	0.00	N/A	0.00	N/A	-61.76	-5.25	-21.71	N/A	-23.82	-83.71	-13.69	-55.63	-1.63	0.00	1.71	8.85	-16.05
157	LINCOLN	-0.03	0.00	-0.46	0.00	N/A	-6.99	0.00	N/A	0.00	N/A	N/A	N/A	0.70	N/A	11.02	N/A	0.00	0.00	N/A	0.00	0.00	-0.42	2.19
158	LITTLETON	5.00	4.31	0.91	1.65	N/A	14.74	-428.20	N/A	N/A	N/A	N/A	-1.62	-8.16	N/A	-10.11	N/A	-97.27	0.00	N/A	0.00	9.18	2.07	-7.07
160	LOWELL	0.00	N/A	-0.42	0.00	N/A	-2.22	0.35	-0.13	N/A	0.99	0.01	1.39	-5.56	N/A	0.08	1.49	0.00	0.06	-2.76	0.00	N/A	-0.87	0.19
170	MARLBOROUGH	-25.09	-27.63	-10.88	-2.50	-37.40	-10.88	3.63	0.00	-78.69	49.55	1.07	9.80	66.53	N/A	55.16	69.36	17.45	5.17	20.39	0.00	-27.90	-12.14	24.42
174	MAYNARD	-3.20	-9.12	-0.82	0.00	0.00	-1.32	1.00	N/A	N/A	181.44	0.80	0.84	1.00	N/A	0.00	2.97	-1.31	N/A	0.00	-0.03	0.00	-0.81	1.22
198	NATICK	-19.19	-29.58	-5.09	0.00	N/A	-5.04	-31.32	N/A	N/A	56.12	0.00	1.22	3.40	N/A	6.51	3.15	-7.03	0.00	0.00	0.00	-12.05	-3.80	1.51
215	NORTHBOROUGH	-1.10	-3.01	-0.43	0.00	0.37	-1.29	-1.31	N/A	N/A	0.00	0.00	1.89	3.07	N/A	5.28	25.38	0.18	0.00	2.49	0.07	-0.71	-0.57	1.99
269	SHERBORN	2.42	-0.07	0.15	0.00	N/A	0.15	N/A	N/A	N/A	N/A	N/A	N/A	-3.04	N/A	N/A	0.00	11.79	0.00	N/A	0.00	-5.19	0.20	-2.45
271	SHREWSBURY	-1.94	-2.00	-0.65	0.00	-9.44	-1.09	0.00	0.00	N/A	45.43	0.53	3.05	2.27	N/A	3.75	25.89	-1.49	0.09	N/A	0.00	7.61	-0.80	1.96
277	SOUTHBOROUGH	-2.87	-1.31	-0.80	0.00	N/A	7.03	0.44	0.00	0.00	N/A	0.00	0.50	5.39	N/A	9.17	0.50	2.36	0.38	0.00	0.07	0.00	-0.79	2.25
286	STOW	-2.13	0.00	-0.90	-0.14	0.18	-7.39	0.02	N/A	N/A	N/A	0.00	28.60	2.83	N/A	16.67	35.20	12.45	45.28	N/A	0.00	-6.35	-1.35	6.67
288	SUDBURY	-5.46	-5.00	-1.16	-0.42	-1.30	3.25	0.38	0.00	N/A	75.07	N/A	305.73	-10.47	N/A	5.97	1.58	1.84	0.00	N/A	0.00	25.59	-1.23	2.57
295	TEWKSBURY	-5.83	-1.76	-1.47	0.00	N/A	-1.40	N/A	N/A	N/A	N/A	0.00	0.81	24.11	N/A	2.64	0.00	36.46	N/A	0.00	0.00	0.00	-1.50	2.01
303	UPTON	N/A	N/A	-0.02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.99	N/A	N/A	N/A	N/A	0.00	N/A	N/A	0.00	-0.02	1.55
315	WAYLAND	1.22	1.23	0.41	0.07	0.00	-0.09	0.00	N/A	0.00	-28.22	N/A	-0.55	-0.12	N/A	-1.40	0.00	-2.35	0.00	N/A	-0.26	3.70	0.42	-0.56
328	WESTBOROUGH	-1.44	0.14	-1.12	-0.52	-4.80	-2.99	1.56	6.05	N/A	5.20	0.00	1.14	3.93	N/A	11.67	26.79	-1.83	1.06	4.99	11.29	-0.74	-0.84	2.93
330	WESTFORD	-0.10	-2.11	-0.47	-0.11	-0.54	-1.16	8.42	N/A	N/A	N/A	N/A	N/A	1.83	N/A	4.83	150.13	27.53	0.00	0.00	4.68	-1.05	-0.54	3.06
333	WESTON	0.00	0.00	0.01	0.00	N/A	0.00	N/A	N/A	N/A	N/A	N/A	N/A	-0.05	N/A	N/A	N/A	0.00	N/A	N/A	N/A	1.61	0.01	-0.04
	Average	-64.58	-167.46	-142.19	-50.16	-623.51	-96.01	519.26	-825.37	-7.15	2756.57	-3.61	153.16	207.31	N/A	579.73	1686.44	-94.88	73.37	1744.18	26.39	-202.01	-124.27	195.76

Table E.11: Percent land use change divided by percent population change 1985-1999

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-0.09	-2.15	-0.90	0.22	-4.88	0.13	0.61	N/A	0.00	2.15	N/A	0.71	2.09	N/A	1.99	2.08	-2.60	0.00	-6.36	-0.08	-2.37	-0.89	1.39
14	ASHLAND	-1.40	-0.43	-0.54	-0.35	-0.45	1.10	0.83	N/A	0.00	2.14	0.11	1.41	1.24	N/A	0.67	0.77	1.56	0.00	N/A	0.00	-2.32	-0.53	1.26
23	BEDFORD	20.68	0.11	1.14	13.55	N/A	27.04	-27.35	N/A	N/A	N/A	N/A	-11.97	14.61	N/A	N/A	N/A	-4.44	N/A	-11.74	0.00	30.64	4.35	-8.57
28	BERLIN	-4.04	-7.35	-0.09	-3.01	-14.52	10.24	1.00	N/A	N/A	N/A	0.00	0.30	7.59	N/A	39.08	63.12	3.77	0.69	-4.97	0.53	20.49	-0.92	5.87
31	BILLERICA	-13.79	-9.84	-2.11	0.02	-30.44	-5.59	8.56	-30.44	15.89	8.82	0.00	2.32	7.04	N/A	2.54	6.18	-1.93	4.81	-0.91	-0.49	-10.47	-3.06	3.12
34	BOLTON	-0.78	-0.84	0.02	-0.80	N/A	-0.81	0.00	N/A	N/A	N/A	N/A	3.51	1.32	N/A	0.79	2.58	1.12	0.00	-2.59	0.13	-0.33	-0.12	0.90
37	BOXBOROUGH	-0.68	-0.68	-0.29	0.03	-1.75	1.71	0.00	-2.25	N/A	0.32	N/A	N/A	1.62	N/A	0.47	2.14	-1.51	0.00	0.00	-0.01	-0.89	-0.30	1.26
39	BOYLSTON	-1.25	1.11	-0.20	0.00	N/A	-4.72	N/A	N/A	N/A	N/A	N/A	0.00	7.80	N/A	0.00	N/A	1.45	0.00	-6.17	0.00	1.03	-0.24	5.58
51	CARLISLE	-0.52	-1.49	-0.33	-1.12	-5.78	-0.10	17.71	N/A	N/A	N/A	N/A	N/A	1.52	N/A	0.84	-1.05	-1.93	N/A	N/A	0.00	-1.38	-0.45	1.43
56	CHELMSFORD	-4.10	-9.31	-2.47	0.00	N/A	-2.79	2.35	-16.34	0.00	9.76	0.31	1.05	3.73	N/A	6.66	4.95	-2.83	0.11	-16.34	0.00	9.68	-2.64	1.67
64	CLINTON	-2.43	0.00	2.07	24.19	N/A	-13.93	N/A	-22.42	N/A	0.00	0.00	0.92	9.12	N/A	N/A	N/A	-1.01	N/A	N/A	-1.60	N/A	-0.35	0.73
67	CONCORD	-5.25	-18.49	-3.06	-0.04	-43.36	18.00	-1.09	N/A	0.00	25.26	0.00	4.56	10.70	N/A	1.22	13.10	-5.69	0.00	-21.34	0.33	-30.86	-3.12	6.10
100	FRAMINGHAM	-10.52	0.16	-3.00	-0.07	3.75	8.26	-3.86	0.00	0.00	0.70	0.37	1.38	7.54	N/A	2.42	6.59	-2.80	1.01	-3.79	0.06	-36.04	-2.72	1.89
110	GRAFTON	-0.64	-0.79	-0.13	0.00	N/A	-2.80	0.00	N/A	N/A	N/A	N/A	N/A	2.67	N/A	N/A	N/A	0.68	0.00	0.00	N/A	N/A	-0.25	1.20
125	HARVARD	0.11	0.08	0.05	0.00	0.00	-0.15	N/A	N/A	N/A	N/A	N/A	0.00	-0.36	N/A	0.00	N/A	-1.11	0.00	N/A	0.00	0.04	0.05	-0.32
136	HOLLISTON	-1.40	-16.13	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.00	23.63	N/A	N/A	N/A	5.40	N/A	-16.13	N/A	-16.13	-0.06	11.65
139	HOPKINTON	-1.04	-0.55	-0.26	-0.01	-0.13	-0.37	0.35	-1.94	0.00	5.33	0.00	0.77	2.33	N/A	1.31	0.13	0.87	0.05	-0.32	0.01	-0.07	-0.26	1.18
141	HUDSON	-11.49	-10.46	-4.53	-0.19	-11.05	16.29	2.07	N/A	0.00	24.99	0.00	1.85	15.18	N/A	1.06	12.38	18.80	0.00	0.00	0.00	-6.79	-4.33	6.04
157	LINCOLN	-0.16	0.00	-0.21	0.00	N/A	-13.65	0.00	N/A	0.00	0.00	N/A	N/A	1.34	N/A	0.00	N/A	0.00	0.00	N/A	0.00	-2.81	-0.26	1.24
158	LITTLETON	-1.72	2.48	-0.42	0.00	N/A	9.60	1.14	N/A	0.00	N/A	N/A	0.30	3.37	N/A	0.00	9.07	-0.22	0.00	-7.29	0.00	-2.25	-0.44	1.29
160	LOWELL	-9.80	N/A	-2.53	6.14	N/A	-3.82	0.69	-15.06	N/A	1.72	-0.01	0.70	0.00	N/A	0.97	1.53	0.75	0.33	0.00	0.00	N/A	-2.34	0.42
170	MARLBOROUGH	-3.75	-4.57	-1.21	0.06	-7.67	1.14	0.00	0.00	0.00	2.28	1.46	2.08	3.87	N/A	2.39	3.25	-1.81	-0.07	-3.60	0.02	-6.08	-1.36	1.83
174	MAYNARD	-2.42	-28.89	-2.47	-1.16	-28.89	-5.10	5.19	N/A	N/A	11.02	0.35	2.58	11.75	N/A	0.00	7.75	1.69	N/A	0.00	0.61	0.00	-2.50	3.25
198	NATICK	-3.63	-12.72	-2.17	0.00	N/A	-0.91	-5.41	N/A	N/A	0.00	0.00	0.80	4.58	N/A	0.55	0.00	-0.06	0.35	0.00	0.00	-10.16	-1.45	0.53
215	NORTHBOROUGH	-0.98	-0.44	-0.61	0.00	-3.26	-0.72	1.88	N/A	N/A	3.31	3.25	0.67	2.25	N/A	0.31	3.46	1.42	0.08	0.00	0.00	-1.01	-0.61	1.42
269	SHERBORN	-9.42	-4.41	0.13	0.00	N/A	-1.26	N/A	N/A	N/A	N/A	N/A	N/A	1.61	N/A	N/A	0.00	0.00	0.00	N/A	0.00	18.06	-0.18	1.89
271	SHREWSBURY	-1.32	-1.38	-0.54	-0.87	N/A	-0.71	0.08	-3.12	N/A	2.84	0.06	2.59	0.29	N/A	0.83	2.30	1.55	0.10	9.44	0.00	-1.85	-0.62	1.17
277	SOUTHBOROUGH	-1.18	-1.06	-0.48	-0.07	N/A	-0.14	0.65	0.00	0.00	7.99	0.00	0.76	2.57	N/A	0.63	2.19	-0.24	0.00	-0.96	0.00	0.00	-0.48	1.19
286	STOW	-3.03	0.34	-0.60	-0.13	-7.23	6.15	5.25	0.00	N/A	26.54	0.00	1.26	2.76	N/A	1.33	2.28	-2.70	0.00	N/A	0.26	0.16	-0.64	2.19
288	SUDBURY	-1.75	1.52	-0.49	0.41	-1.44	-1.37	-0.04	0.00	N/A	0.00	N/A	2.29	0.21	N/A	0.92	0.06	-1.11	-4.89	N/A	0.06	-1.69	-0.54	0.98
295	TEWKSBURY	N/A	-7.10	-1.30	3.32	N/A	5.83	N/A	N/A	N/A	0.00	0.00	0.81	3.95	N/A	5.24	1.15	-9.33	N/A	0.00	0.00	0.00	-1.47	1.08
303	UPTON	N/A	N/A	-0.02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.48	N/A	N/A	N/A	N/A	0.00	N/A	N/A	-2.15	-0.02	1.34
315	WAYLAND	-3.17	-3.65	-0.45	0.00	-12.88	-0.34	0.08	N/A	0.00	5.94	N/A	0.10	1.40	N/A	1.76	1.52	-0.36	0.00	N/A	0.00	0.00	-0.77	1.00
328	WESTBOROUGH	-1.11	-1.78	-0.40	0.02	-0.66	-1.08	0.75	-2.06	N/A	1.58	0.35	1.82	2.63	N/A	1.26	1.51	0.17	0.03	0.19	-0.02	-2.01	-0.53	1.32
330	WESTFORD	-1.18	-1.47	-0.44	0.02	-0.67	-1.06	1.61	N/A	N/A	4.95	N/A	6.49	1.69	N/A	0.76	4.06	-2.02	0.00	0.00	0.04	-1.18	-0.54	1.68
333	WESTON	1.94	-13.45	0.02	-4.20	N/A	-13.45	N/A	N/A	N/A	N/A	N/A	N/A	0.44	N/A	N/A	N/A	0.00	N/A	N/A	N/A	N/A	-0.12	0.42
	Average	-2.39	-4.52	-0.80	1.06	-9.02	0.90	0.47	-7.20	1.22	6.15	0.33	1.04	4.60	N/A	2.62	5.67	-0.13	0.09	-3.72	0.00	-1.83	-0.85	1.85

Table E.12: Percent land use change divided by percent population change 1985-1999

TOWNID	TOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Undev	Dev
2	ACTON	-1.55	-5.04	-1.29	0.05	-4.86	-2.15	0.86	-6.75	N/A	14.44	N/A	1.24	3.77	N/A	3.19	9.92	-0.80	0.37	-5.46	0.29	-2.47	-1.42	3.07
14	ASHLAND	-0.93	-0.34	-0.35	-0.28	-0.20	-0.28	1.10	N/A	0.00	6.91	0.05	1.33	1.26	N/A	0.50	0.43	0.71	0.00	N/A	0.07	-1.03	-0.35	1.17
23	BEDFORD	-563.59	-225.17	-31.87	-318.67	N/A	-384.97	611.90	N/A	N/A	N/A	N/A	280.30	-162.49	N/A	N/A	N/A	99.37	N/A	-201.69	0.00	-879.99	-118.18	248.08
28	BERLIN	-1.81	-4.53	-0.51	-1.66	-6.46	5.60	0.51	N/A	N/A	N/A	0.00	0.66	8.71	N/A	36.33	32.55	32.24	0.36	1.73	1.25	8.16	-0.82	7.04
31	BILLERICA	-15.13	-14.11	-7.45	-1.88	-30.41	-8.60	30.27	-30.41	15.88	76.30	0.00	6.91	17.11	N/A	22.21	63.02	-5.51	7.59	37.36	0.43	-15.34	-7.57	11.54
34	BOLTON	-0.55	-0.78	-0.01	-0.49	N/A	-0.23	0.00	N/A	N/A	N/A	N/A	2.13	1.62	N/A	0.96	1.56	1.37	0.00	-1.57	0.08	-0.27	-0.11	0.98
37	BOXBOROUGH	-0.69	-0.56	-0.32	-0.01	-0.55	1.15	0.17	-1.83	N/A	1.84	-1.83	N/A	2.26	N/A	8.10	15.85	-1.08	0.00	N/A	-0.01	-1.23	-0.32	1.79
39	BOYLSTON	1.15	0.85	-0.23	0.00	N/A	-3.49	N/A	N/A	N/A	N/A	N/A	0.46	16.11	N/A	0.00	N/A	1.93	0.00	-4.68	0.00	-1.29	-0.25	9.52
51	CARLISLE	-0.29	-0.70	-0.28	-0.39	-1.97	-0.38	6.02	N/A	N/A	N/A	N/A	N/A	1.60	N/A	0.84	-0.01	-0.97	N/A	N/A	0.00	-0.39	-0.30	1.45
56	CHELMSFORD	-2.52	-5.41	-2.34	0.00	N/A	-3.31	1.61	-8.18	0.00	37.81	0.36	0.89	4.36	N/A	10.32	17.60	0.46	0.12	N/A	0.00	-6.11	-2.37	1.99
64	CLINTON	-0.76	0.00	0.53	7.60	N/A	-4.38	N/A	-7.05	N/A	N/A	0.00	0.33	2.87	N/A	N/A	N/A	-3.27	N/A	N/A	-0.50	N/A	-0.19	0.42
67	CONCORD	-1.34	-5.02	-1.31	-0.06	-11.62	1.93	0.32	N/A	0.00	87.30	0.00	1.29	5.43	N/A	1.16	5.59	-3.09	0.00	-4.32	0.07	-6.87	-1.21	2.71
100	FRAMINGHAM	-11.65	0.14	-4.70	-2.71	10.40	8.24	-3.46	0.00	0.00	2.88	0.41	2.15	17.24	N/A	3.05	6.72	-3.24	0.90	-3.40	0.06	-32.29	-4.12	3.17
110	GRAFTON	-0.56	-0.79	-0.13	0.00	N/A	-1.33	0.00	N/A	N/A	N/A	N/A	N/A	5.99	N/A	N/A	N/A	0.34	0.00	0.00	N/A	N/A	-0.23	1.45
125	HARVARD	0.16	0.09	0.12	0.00	0.00	0.82	N/A	N/A	N/A	N/A	N/A	0.00	-1.61	N/A	N/A	N/A	-1.01	0.00	N/A	0.00	0.05	0.13	-1.28
136	HOLLISTON	-1.34	-15.39	0.00	N/A	-15.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.54	N/A	N/A	N/A	5.15	N/A	N/A	N/A	-15.39	-0.09	26.52
139	HOPKINTON	-0.67	-0.51	-0.19	0.00	-0.12	-0.46	0.36	-1.07	0.00	6.18	0.00	2.28	2.52	N/A	1.42	N/A	0.26	0.03	0.36	0.01	0.01	-0.19	1.26
141	HUDSON	-21.35	-22.31	-8.02	-0.92	-18.61	13.58	2.83	N/A	0.00	N/A	22.04	4.55	33.50	N/A	10.33	62.33	34.52	19.85	0.58	0.00	-9.74	-8.53	15.46
157	LINCOLN	-0.11	0.00	-0.30	0.00	N/A	-8.58	0.00	N/A	0.00	N/A	N/A	N/A	1.09	N/A	4.24	N/A	0.00	0.00	N/A	0.00	-1.67	-0.31	1.64
158	LITTLETON	-2.61	2.02	-0.62	-0.25	N/A	6.02	77.80	N/A	N/A	N/A	N/A	0.61	5.80	N/A	1.56	N/A	14.30	0.00	N/A	0.00	-3.63	-0.82	2.80
160	LOWELL	-2.68	N/A	-0.93	1.68	N/A	-2.18	0.44	-4.12	N/A	1.22	0.00	1.19	-3.78	N/A	0.32	1.54	0.21	0.13	-1.88	0.00	N/A	-1.14	0.25
170	MARLBOROUGH	-4.46	-5.06	-1.85	-0.15	-6.96	0.01	0.30	0.00	-6.44	7.33	1.43	2.90	11.71	N/A	8.09	11.03	-0.55	0.35	-2.39	0.02	-5.99	-2.05	4.13
174	MAYNARD	-2.70	-8.90	-1.26	-0.36	-8.90	-2.30	2.39	N/A	N/A	171.04	0.65	1.41	4.56	N/A	0.00	4.90	-0.41	N/A	0.00	0.17	0.00	-1.26	1.91
198	NATICK	-6.05	-11.82	-2.63	0.00	N/A	-1.71	-8.84	N/A	N/A	11.75	0.00	0.89	4.46	N/A	1.84	0.66	-1.51	0.27	0.00	0.00	-9.04	-1.86	0.74
215	NORTHBOROUGH	-0.85	-1.32	-0.46	0.00	-1.62	-0.81	0.21	N/A	N/A	1.69	1.66	1.21	2.99	N/A	2.43	19.69	0.82	0.04	1.00	0.03	-0.74	-0.51	1.77
269	SHERBORN	5.41	1.24	0.15	0.00	N/A	0.57	N/A	N/A	N/A	N/A	N/A	N/A	-4.48	N/A	N/A	0.00	15.06	0.00	N/A	0.00	-14.15	0.31	-3.80
271	SHREWSBURY	-1.18	-1.22	-0.50	-0.60	-1.35	-0.69	0.06	-2.17	N/A	21.94	0.16	3.08	0.78	N/A	1.67	11.95	0.56	0.09	N/A	0.00	-0.57	-0.58	1.43
277	SOUTHBOROUGH	-1.21	-0.99	-0.48	-0.06	N/A	0.77	0.61	0.00	0.00	N/A	0.00	0.71	3.41	N/A	1.98	1.92	0.09	0.05	-0.79	0.01	0.00	-0.49	1.39
286	STOW	-2.43	0.23	-0.65	-0.13	-4.82	0.34	3.52	N/A	N/A	N/A	0.00	10.60	2.96	N/A	6.61	14.77	0.74	13.46	N/A	0.17	-1.82	-0.80	3.95
288	SUDBURY	-2.06	0.11	-0.58	0.25	-1.32	-0.66	0.03	0.00	N/A	13.10	N/A	75.98	-1.73	N/A	1.94	0.33	-0.62	-3.89	N/A	0.05	1.84	-0.62	1.31
295	TEWKSBURY	-3.37	-2.80	-1.20	1.20	N/A	0.79	N/A	N/A	N/A	N/A	0.00	0.80	21.25	N/A	4.27	0.42	-3.37	N/A	0.00	0.00	0.00	-1.26	1.68
303	UPTON	N/A	N/A	-0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.98	N/A	N/A	N/A	N/A	0.00	N/A	N/A	-1.09	-0.02	1.49
315	WAYLAND	-7.59	-8.56	-1.34	-0.07	-27.02	-0.63	0.17	N/A	0.00	54.45	N/A	0.78	3.07	N/A	5.31	3.20	1.56	0.00	N/A	0.26	-3.77	-2.01	2.72
328	WESTBOROUGH	-1.00	-1.22	-0.51	-0.11	-1.38	-1.24	0.97	-0.84	N/A	2.89	0.24	1.67	3.46	N/A	4.65	10.15	-0.34	0.28	1.39	2.66	-1.47	-0.54	1.88
330	WESTFORD	-0.66	-1.19	-0.38	-0.03	-0.51	-0.84	5.29	N/A	N/A	N/A	N/A	N/A	1.89	N/A	2.50	121.23	2.43	0.00	0.00	1.67	-0.87	-0.45	2.54
333	WESTON	-8.05	55.85	0.00	17.43	N/A	55.85	N/A	N/A	N/A	N/A	N/A	N/A	-2.08	N/A	N/A	N/A	0.00	N/A	N/A	N/A	N/A	0.57	-1.95
	Average	-19.00	-8.33	-2.00	-8.84	-6.37	-9.81	26.27	-4.80	0.86	30.53	1.26	15.05	1.17	N/A	5.21	16.69	5.32	1.38	-9.19	0.21	-31.47	-4.44	10.06

Table E.13: Total land use type changes and land use key										
Land use type	Land Use #	Total Land use in Acres			Land Use Change in Acres Total			Percent Land Use Change Total		
		1971	1985	1999	1971-1985	1985-1999	1971-1999	1971-1985	1985-1999	1971-1999
Crop Land	1	15861.93	13944.39	10351.11	-1917.54	-3593.28	-5510.82	-12.09	-25.77	-34.74
Pasture	2	5655.20	4615.00	3224.70	-1040.20	-1390.30	-2430.50	-18.39	-30.13	-42.98
Forest	3	164438.23	154658.44	142264.31	-9779.78	-12394.14	-22173.92	-5.95	-8.01	-13.48
Wetland	4	9593.92	9447.04	9264.37	-146.88	-182.67	-329.55	-1.53	-1.93	-3.43
Mining	5	1699.97	1553.68	839.98	-146.29	-713.71	-859.99	-8.61	-45.94	-50.59
Open Land	6	6635.76	5641.82	5541.80	-993.94	-100.02	-1093.96	-14.98	-1.77	-16.49
Part Rec	7	3289.22	3335.51	3795.36	46.29	459.85	506.14	1.41	13.79	15.39
Spec Rec	8	156.63	168.46	89.47	11.82	-78.99	-67.16	7.55	-46.89	-42.88
Water Rec	9	60.36	54.29	55.52	-6.07	1.23	-4.84	-10.06	2.27	-8.01
MF Residential	10	926.76	1724.90	2346.52	798.15	621.61	1419.76	86.12	36.04	153.20
HD Residential	11	6720.32	6811.73	7057.68	91.41	245.95	337.36	1.36	3.61	5.02
MD Residential	12	27140.25	32045.39	37633.97	4905.14	5588.57	10493.71	18.07	17.44	38.66
LD Residential	13	26279.83	30488.42	40314.26	4208.59	9825.84	14034.43	16.01	32.23	53.40
Cranberry Bog	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Commerical	15	4042.65	5214.17	6116.79	1171.51	902.62	2074.13	28.98	17.31	51.31
Industrial	16	2862.71	4970.64	6647.01	2107.93	1676.38	3784.30	73.63	33.73	132.19
Urban Open	17	5126.16	5433.10	5258.24	306.95	-174.86	132.09	5.99	-3.22	2.58
Transportation	18	5051.75	5195.70	5276.52	143.95	80.81	224.76	2.85	1.56	4.45
Waste Disposal	19	516.92	645.90	518.12	128.97	-127.77	1.20	24.95	-19.78	0.23
Water	20	8167.17	8574.32	8590.02	407.15	15.70	422.85	4.99	0.18	5.18
Woody Perennial	21	3811.07	3513.91	2851.07	-297.16	-662.84	-960.00	-7.80	-18.86	-25.19

Table E.14: Census data and interpolation calculations													
		Population from Census Data			Interpolated populations			Change in Acres of Interpolated Population			Percent Change Interpolated Population		
TOWNID	TOWN	1980	1990	2000	1971.00	1985.00	1999.00	1971-1985	1985-1999	1971-1999	1971-1985	1985-1999	1971-1999
2	ACTON	17672.00	17872.00	20331.00	17492.00	17772.00	20085.10	280.00	2313.10	2593.10	1.60	13.02	14.82
14	ASHLAND	10328.00	12066.00	14674.00	8763.80	11197.00	14413.20	2433.20	3216.20	5649.40	27.76	28.72	64.46
23	BEDFORD	12800.00	12996.00	12595.00	12623.60	12898.00	12635.10	274.40	-262.90	11.50	2.17	-2.04	0.09
28	BERLIN	2224.00	2293.00	2380.00	2161.90	2258.50	2371.30	96.60	112.80	209.40	4.47	4.99	9.69
31	BILLERICA	37608.00	37609.00	38981.00	37607.10	37608.50	38843.80	1.40	1235.30	1236.70	0.00	3.28	3.29
34	BOLTON	2820.00	3134.00	4159.00	2537.40	2977.00	4056.50	439.60	1079.50	1519.10	17.32	36.26	59.87
37	BOXBOROUGH	3189.00	3343.00	4868.00	3050.40	3266.00	4715.50	215.60	1449.50	1665.10	7.07	44.38	54.59
39	BOYLSTON	3412.00	3517.00	4083.00	3317.50	3464.50	4026.40	147.00	561.90	708.90	4.43	16.22	21.37
51	CARLISLE	3721.00	4333.00	4717.00	3170.20	4027.00	4678.60	856.80	651.60	1508.40	27.03	16.18	47.58
56	CHELMSFORD	31150.00	32383.00	33858.00	30040.30	31766.50	33710.50	1726.20	1944.00	3670.20	5.75	6.12	12.22
64	CLINTON	12441.00	13222.00	13424.00	11738.10	12831.50	13403.80	1093.40	572.30	1665.70	9.31	4.46	14.19
67	CONCORD	16455.00	17076.00	16993.00	15896.10	16765.50	17001.30	869.40	235.80	1105.20	5.47	1.41	6.95
100	FRAMINGHAM	64844.00	64989.00	66910.00	64713.50	64916.50	66717.90	203.00	1801.40	2004.40	0.31	2.77	3.10
110	GRAFTON	11850.00	13035.00	14894.00	10783.50	12442.50	14708.10	1659.00	2265.60	3924.60	15.38	18.21	36.39
125	HARVARD	13174.00	12329.00	5981.00	13934.50	12751.50	6615.80	-1183.00	-6135.70	-7318.70	-8.49	-48.12	-52.52
136	HOLLISTON	12900.00	12926.00	13801.00	12876.60	12913.00	13713.50	36.40	800.50	836.90	0.28	6.20	6.50
139	HOPKINTON	7874.00	9191.00	13346.00	6688.70	8532.50	12930.50	1843.80	4398.00	6241.80	27.57	51.54	93.32
141	HUDSON	17369.00	17233.00	18113.00	17491.40	17301.00	18025.00	-190.40	724.00	533.60	-1.09	4.18	3.05
157	LINCOLN	7464.00	7666.00	8056.00	7282.20	7565.00	8017.00	282.80	452.00	734.80	3.88	5.97	10.09
158	LITTLETON	7144.00	7051.00	8184.00	7227.70	7097.50	8070.70	-130.20	973.20	843.00	-1.80	13.71	11.66
160	LOWELL	93473.00	103439.00	105167.00	84503.60	98456.00	104994.20	13952.40	6538.20	20490.60	16.51	6.64	24.25
170	MARLBOROUGH	31550.00	31813.00	36255.00	31313.30	31681.50	35810.80	368.20	4129.30	4497.50	1.18	13.03	14.36
174	MAYNARD	9822.00	10325.00	10433.00	9369.30	10073.50	10422.20	704.20	348.70	1052.90	7.52	3.46	11.24
198	NATICK	30198.00	30510.00	32170.00	29917.20	30354.00	32004.00	436.80	1650.00	2086.80	1.46	5.44	6.98
215	NORTHBOROUGH	10741.00	11929.00	14013.00	9671.80	11335.00	13804.60	1663.20	2469.60	4132.80	17.20	21.79	42.73
269	SHERBORN	4225.00	3989.00	4200.00	4437.40	4107.00	4178.90	-330.40	71.90	-258.50	-7.45	1.75	-5.83
271	SHREWSBURY	22548.00	24146.00	31565.00	21109.80	23347.00	30823.10	2237.20	7476.10	9713.30	10.60	32.02	46.01
277	SOUTHBOROUGH	6405.00	6628.00	8781.00	6204.30	6516.50	8565.70	312.20	2049.20	2361.40	5.03	31.45	38.06
286	STOW	5144.00	5328.00	5902.00	4978.40	5236.00	5844.60	257.60	608.60	866.20	5.17	11.62	17.40
288	SUDBURY	13993.00	14358.00	16841.00	13664.50	14175.50	16592.70	511.00	2417.20	2928.20	3.74	17.05	21.43
295	TEWKSBURY	24556.00	27266.00	28847.00	22117.00	25911.00	28688.90	3794.00	2777.90	6571.90	17.15	10.72	29.71
303	UPTON	4158.00	4677.00	5642.00	3690.90	4417.50	5545.50	726.60	1128.00	1854.60	19.69	25.53	50.25
315	WAYLAND	12211.00	11874.00	13100.00	12514.30	12042.50	12977.40	-471.80	934.90	463.10	-3.77	7.76	3.70
328	WESTBOROUGH	13261.00	14133.00	17997.00	12476.20	13697.00	17610.60	1220.80	3913.60	5134.40	9.79	28.57	41.15
330	WESTFORD	14537.00	16392.00	20754.00	12867.50	15464.50	20317.80	2597.00	4853.30	7450.30	20.18	31.38	57.90
333	WESTON	10908.00	10200.00	11465.00	11545.20	10554.00	11338.50	-991.20	784.50	-206.70	-8.59	7.43	-1.79
	Average	16782.47	17535.31	18985.56	16104.92	17158.89	18840.53	1053.97	1681.64	2735.61	7.33	13.42	22.73

Table E.15: Core Community Land Use in Acres																					
Town Name	1071							1985							1999						
	UND	HDR	LDR	COM	IND	TOT	POP	UND	HDR	LDR	COM	IND	TOT	POP	UND	HDR	LDR	COM	IND	TOT	POP
Acton	8929.697	1452.946	1833.891	450.0904	185.1933	12966	17492	7985.515	1691.365	2249.481	562.9094	360.1318	12966	17772	7077.722	1941.047	2860.019	529.6533	457.5003	12966	20085.1
Carlisle	8201.877	0	1588.901	114.5103	8.10739	9913.4	3170.2	7561.16	0	2243.72	98.78971	9.72669	9913.4	4027	7026.121	5.15292	2794.757	79.28564	8.08011	9913.4	4678.6
Framingham	7807.914	5426.681	994.7746	1771.14	557.1444	16973	64713.5	7391.844	5555.564	1261.805	1779.441	568.9993	16973	64916.5	6821.242	5732.331	1525.906	1795.124	673.0993	16973	66717.9
Hudson	4958.981	1649.412	451.4681	321.141	140.1838	7594.9	17491.4	4487.284	1807.188	558.1527	387.3842	267.9215	7594.9	17301	3690.95	1961.139	912.8276	536.2795	406.7353	7594.9	18025
Marlborough	9663.383	2292.262	591.2814	815.6534	275.9385	14100	31313.3	8315.042	2563.034	1053.868	1161.028	500.9756	14100	31681.5	6880.505	3225.116	1585.497	1249.407	713.1246	14100	35810.8
Maynard	2152.765	946.3888	62.99123	197.2913	95.80586	3460.9	9369.3	2031.583	1052.409	67.70953	186.3786	117.1625	3460.9	10073.5	1875.471	1143.706	95.23952	192.2251	148.6008	3460.9	10422.2
Southborough	7520.241	1098.886	659.2522	294.7482	112.7466	9961.4	6204.3	7230.81	1129.278	838.2072	367.3163	115.5931	9961.4	6516.5	6186.989	1403.264	1516.017	383.7845	195.2825	9961.4	8565.7
Stow	9950.054	226.5808	1158.974	181.7219	11.5695	11544	4978.4	9279.395	545.1577	1328.931	304.9759	32.64317	11544	5236	8827.724	632.9905	1755.098	233.993	41.29676	11544	5844.6
Sudbury	10904.97	184.3248	4194.017	384.6112	130.3395	15841	13664.5	10415.96	2260.558	2551.252	432.4713	138.0276	15841	14175.5	9473.363	3140.388	2643.48	409.5017	139.4524	15841	16592.7
SUM	70089.89	13277.48	11535.55	4530.908	1517.029	102354.6	168396.9	64698.59	16604.55	12153.13	5280.695	2111.181	102354.6	171699.5	57860.09	19185.13	15688.84	5409.254	2783.172	102354.6	186742.6

Table E.16: Core Community Land Use Change in Acres																					
Town Name	1971-1985							1985-1999							1971-1999						
	UND	HDR	LDR	COM	IND	POP		UND	HDR	LDR	COM	IND	POP		UND	HDR	LDR	COM	IND	POP	
Acton	-944.182	238.4186	415.5902	112.819	174.9385	280		-907.793	249.6822	610.5381	-33.2561	97.3685	2313.1		-1851.98	488.1008	1026.128	79.56287	272.307	2593.1	
Carlisle	-640.717	0	654.8188	-15.7206	1.6193	856.8		-535.039	5.15292	551.0368	-19.5041	-1.64658	651.6		-1175.76	5.15292	1205.856	-35.2247	-0.02728	1508.4	
Framingham	-416.07	128.8834	267.0307	8.301	11.85488	203		-570.602	176.767	264.1012	15.68286	104.1	1801.4		-986.672	305.6504	531.1319	23.98386	115.9549	2004.4	
Hudson	-471.698	157.7766	106.6846	66.24321	127.7378	-190.4		-796.334	153.9501	354.6749	148.8953	138.8137	724		-1268.03	311.7267	461.3595	215.1385	266.5515	533.6	
Marlborough	-1348.34	270.7725	462.5866	345.3748	225.0372	368.2		-1434.54	662.0816	531.6289	88.37878	212.149	4129.3		-2782.88	932.854	994.2154	433.7536	437.1862	4497.5	
Maynard	-121.182	106.02	4.7183	-10.9127	21.35662	704.2		-156.112	91.29731	27.52999	5.84646	31.43827	348.7		-277.294	197.3173	32.24829	-5.06624	52.79489	1052.9	
Southborough	-289.43	30.39243	178.955	72.56805	2.84644	312.2		-1043.82	273.9861	677.8095	16.46817	79.68946	2049.2		-1333.25	304.3785	856.7645	89.03622	82.5359	2361.4	
Stow	-670.659	318.5769	169.9565	123.254	21.07367	257.6		-451.671	87.83286	426.1674	-70.9829	8.65359	608.6		-1122.33	406.4097	596.1239	52.27116	29.72726	866.2	
Sudbury	-489.016	2076.233	-1642.77	47.86007	7.68813	511		-942.595	879.8299	92.22782	-22.9696	1.42475	2417.2		-1431.61	2956.063	-1550.54	24.89051	9.11288	2928.2	

Table E.17: Core Community Land Use Percent Change																					
Town Name	1971-1985							1985-1999							1971-1999						
	UND	HDR	LDR	COM	IND	POP		UND	HDR	LDR	COM	IND	POP		UND	HDR	LDR	COM	IND	POP	
Acton	-11.8237	14.09623	18.47494	20.04212	48.57623	1.575512		-12.8260	12.86327	21.34735	-6.27885	21.28272	11.5165		-26.1663	25.14626	35.87837	15.02169	59.52061	12.91057	
Carlisle	-8.4738	N/A	29.18451	-15.9132	16.64800	21.27638		-7.615	100	19.71681	-24.5998	-20.3782	13.92724		-16.7341	100	43.14706	-44.4276	-0.33762	32.24041	
Framingham	-5.62877	2.319898	21.16259	0.466495	2.083461	0.312709		-8.36508	3.083684	17.30782	0.873637	15.46577	2.700025		-14.4647	5.332044	34.80763	1.336056	17.22701	3.004291	
Hudson	-10.5119	8.730498	19.11388	17.10013	47.67729	-1.10051		-21.575	7.850036	38.85453	27.76449	34.12877	4.016644		-34.3552	15.89519	50.5418	40.11686	65.53439	2.960333	
Marlborough	-16.2157	10.56453	43.89417	29.74732	44.91978	1.162192		-20.8493	20.52893	33.53074	7.073658	29.74922	11.53088		-40.4458	28.92467	62.70687	34.71676	61.30572	12.55906	
Maynard	-5.96492	10.07403	6.968443	-5.85512	18.22820	6.990618		-8.32388	7.982585	28.90606	3.041466	21.1562	3.345743		-14.7853	17.25245	33.8602	-2.63558	35.52801	10.10247	
Southborough	-4.00273	2.691315	21.34974	19.75628	2.462466	4.790915		-16.8712	19.52491	44.7099	4.290994	40.80727	23.92332		-21.5493	21.69075	56.51419	23.19954	42.26487	27.56809	
Stow	-7.2274	58.43757	12.78897	40.41435	64.55767	4.919786		-5.11651	13.87586	24.28169	-30.3355	20.95465	10.41303		-12.7137	64.20471	33.96528	22.33877	71.98448	14.82052	
Sudbury	-4.69487	91.84605	-64.3906	11.06665	5.569994	3.604811		-9.94995	28.0166	3.488879	-5.60915	1.021675	14.56785		-15.112	94.13051	-58.6552	6.078243	6.534763	17.64752	

Table E.18: Core Community Percent land use change divided by percent population change																	
1971-1985	1971-1985						1985-1999						1971-1999				
	UND	HDR	LDR	COM	IND		UND	HDR	LDR	COM	IND		UND	HDR	LDR	COM	IND
Acton	-7.50466	8.947075	11.72631	12.72102	30.832030		-1.113712	1.116943	1.853632	-0.5452	1.84802		-2.02673	1.947727	2.778993	1.163519	4.610225
Carlisle	-0.39827	INF	1.371686	-0.74793	0.7824640		-0.54677	7.180172	1.415701	-1.7663	-1.46319		-0.51904	3.101697	1.338291	-1.37801	-0.01047
Framingham	-18	7.418703	67.67494	1.491784	6.6626116		-3.09815	1.142095	6.410245	0.323566	5.728011		-4.81468	1.774809	11.58597	0.444716	5.734135
Hudson	9.551784	-7.93311	-17.3681	-15.5383	-43.32273		-5.371479	1.954377	9.673383	6.912362	8.496837		-11.6052	5.369392	17.07301	13.55147	22.13751
Marlborough	-13.9527	9.090171	37.76841	25.59587	38.650898		-1.80813	1.780344	2.907909	0.613454	2.579961		-3.22045	2.303092	4.992959	2.76428	4.881394
Maynard	-0.85327	1.441079	0.996828	-0.83757	2.6075241		-2.487904	2.385893	8.639653	0.909055	6.323319		-1.46353	1.707745	3.351674	-0.26088	3.516764
Southborough	-0.83548	0.561754	4.456296	4.123697	0.5139865		-0.70522	0.816145	1.868883	0.179364	1.705753		-0.78167	0.786806	2.049986	0.841536	1.533108
Stow	-1.46905	11.87807	2.599497	8.214656	13.122048		-0.49136	1.332547	2.331856	-2.91322	2.012348		-0.85784	4.33215	2.291774	1.507287	4.857083
Sudbury	-1.30239	25.47874	-17.8624	3.069966	1.5451557		-0.68301	1.92318	0.239492	-0.38504	0.070132		-0.85632	5.333923	-3.32371	0.344425	0.370294