Massachusetts Water Resource Outreach Project: Water Management in Leicester

An Interactive Qualifying Project

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Abstract

All towns and municipalities face the task of ensuring that public water systems have safe and adequate supplies of drinking water to protect the health and well-being of its consumers. Working with the Massachusetts Department of Environmental Protection and the Town of Leicester, our project goal was to identify the challenges Leicester's three water districts face and provide an analysis for available improvements in order to meet the water quality standards and water demand in Leicester. Our recommendations provide short and long term goals working towards improving communication and efficiency of the districts' operations.

Acknowledgements

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Executive Summary

Turning on the faucet every morning, clear water flows out in a steady stream. Now, imagine if the water that flowed out of the faucet began to make you sick. Between 1989 and 1990 in the town of Cabool, Missouri, there were 240 cases of diarrhea and six deaths due to *E. coli* found in the drinking water (Lund, 2002). An investigation by the Center for Disease Control and the United States Environmental Protection Agency (USEPA) found the cause of the illness was due to line breaks in their water distribution system, allowing contaminants to get into the water supply after treatment (Lund, 2002). Although these events were unfortunate, they showcase the importance of protecting the purity and quantity of drinking water for the public well-being.

All Massachusetts public drinking water management systems must comply with the federal Safe Drinking Water Act (SDWA) as well as the Massachusetts Water Management Act (MWMA). The SDWA sets standards for over 80 contaminants that may be found in drinking water. Additionally, the SDWA requires all public water systems to distribute annual reports to its consumers that includes information on the system's water sources, water contaminants and associated health risks, and any improvements that were made to the water system. (United, 2004). The MWMA gives authority to the Commonwealth of Massachusetts to regulate the quantity of water withdrawn from both surface and groundwater sources (Massachusetts, 2015a). This act ensures that there are sufficient water supplies for current and future generations. In order to achieve that goal, the MWMA makes public water suppliers accountable for any water losses throughout their system (Massachusetts, 1996). Water systems that do not comply with the SDWA or MWMA are issued Notices of Non-Compliance.

One town that is trying to comply with the SDWA and MWMA is the Town of Leicester, MA. Leicester is located within Worcester County and is situated on three watersheds: the

Chicopee, French, and Blackstone. As of 2015, 72% of Leicester's 23.36 square miles were open land, providing the town with the opportunity to expand through smart-growth projects (CMRPC, n.d.). However, the limited supply of water in Leicester hindered most of the smart growth projects and other economic development projects. The development projects would not have been provided with sufficient water for necessary fire suppression systems or basic water uses. Leicester is unique in that their public water system is made up of three water districts: Leicester Water Supply District, Hillcrest Water Supply District, and Cherry Valley & Rochdale Water District shown in Figure 1 below. Each of the water districts were facing challenges in meeting state regulations and providing an adequate supply of water to their customers.

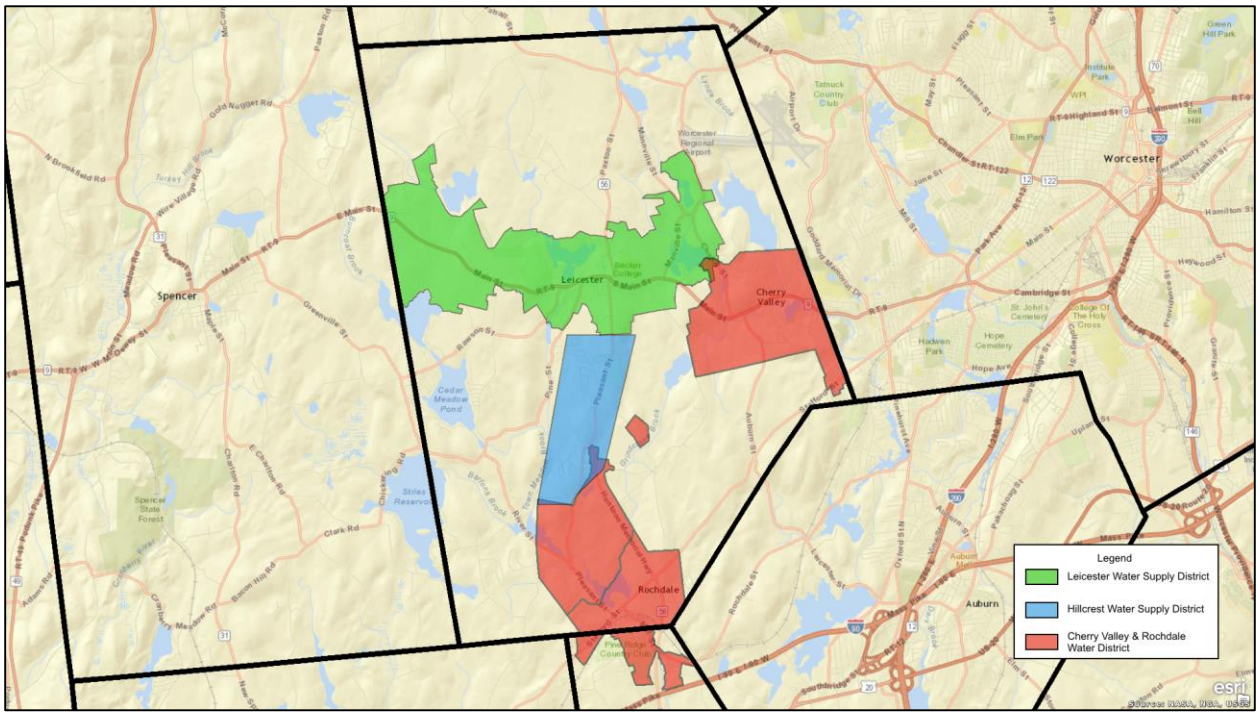

Figure 1: Map of Leicester's three water districts

In 2015, the Town of Leicester reached out to the Worcester Polytechnic Institute (WPI) Massachusetts Water Resource Outreach Center (WROC) for assistance with identifying the most feasible approach to comply with water quality requirements and increase its capacity to meet current and projected water needs. Our project goal was to identify the challenges

Leicester's three water districts were facing and provide a cost-benefit analysis for available improvements in order to meet the water quality standards and water demand in Leicester, Massachusetts. In order to accomplish this goal we developed the following five objectives:

1. Gather information on the current and projected water demands of residents in Leicester.
2. Identify the water districts' challenges in meeting regulation requirements.
3. Using GIS, generate a map of the Town of Leicester with geographic water management system attributes.
4. Identify potential changes to improve Leicester's water management system.
5. Develop comparative analysis of proposed improvements based on gathered data.

Methodology

In order to accomplish these objectives we conducted semi-structured interviews, reviewed water reports, and researched case studies. We spoke with representatives from Leicester's three water districts, water consultants, MassDEP drinking water officials, and local water departments. We gathered data from Leicester's water districts' 2014 Annual Water Quality Reports and 2014 Annual Statistical Reports.

Findings

The Town of Leicester is primarily a residential town of owner-occupied, single family homes. Specifically, there are more than 3,000 owner-occupied housing, about 900 renter-occupied housing, and approximately 300 vacant buildings (CMRPC, n.d.). As of 2010, Leicester had a population of 10,970 people living within these housing units. Population projections done by the Central Massachusetts Regional Planning Commission (CMRPC, 2010) indicated that the population would reach almost 11,500 by 2020 and almost 12,500 people by the year 2040. Cherry Valley & Rochdale Water District and Leicester Water Supply District would continue to contribute most of its finished water to this population.

We projected the water demand within the Cherry Valley & Rochdale Water District would increase from approximately 95.73 MGY to 102.47 MGY from 2014 to 2024. The

Leicester Water Supply District water demand would also increase from 73.41 MGY reported in 2014 rises to 74.88 MGY in 2024. These calculations were based on Leicester's projected growth rates and the water districts reported usage in their 2014 Annual Statistical Reports. There are no projections for Hillcrest Water Supply District's water demand because the information concerning their water usage in different sectors was not available at the time.

We identified four major issues that one or more of the districts have dealt with in the past. These issues consist of the limited oversight and staffing, water quantity and supply issues, water quality issues, and the inability to take advantage of economies of scale. Knowing these issues within Leicester and its water districts, we analyzed several approaches the water districts could use to improve their water systems. We concluded that privatization would not work for Leicester's water districts. Privatization involves the complete sale of a water utility's assets to a private company for operation and maintenance. After speaking with Mike Knox from the Cherry Valley & Rochdale Water District, Don Lennerton from the Leicester Water Supply District, and Kevin Mizikar, the town administrator, we learned all parties agreed complete privatization of the water systems was not in the best interest of the town (personal communication, November 2, 2015). Because Leicester's residents are used to voting for water commissioners to represent them, they may not want a private entity controlling their system (K. Mizikar, personal communication, November 16, 2015).

Forming an interconnection with the City of Worcester would allow water districts to purchase water from the Worcester Water Department by connecting their water systems. This would likely not provide a steady and reliable supply for the three water districts for the foreseeable future, due to the fact that Worcester is reaching its permitted level of water it can pump. Phil Guerin, Director of the Worcester Water Department, stated that his first priority is to

the department's current customers and honoring its contracts with Holden and Paxton who already have interconnections in place (personal communication, November 15, 2015). To supply the entire Town of Leicester, Worcester would need to sell additional water which would put them even closer to their permit level.

There are many different ways that the water districts could consolidate to improve their water quality and quantity issues. Consolidation is a restructuring option involving two or more water systems to help resolve their issues. The water districts could consolidate through physical connections of their distribution systems. Another approach to consolidation would be to unify the districts under either a coordinator/representative or one managerial body (C. Dehner and K. Mizikar, personal communication, December 3, 2015). Both approaches have the same benefit of reducing costs by eliminating duplicate costs. Duplicate costs include maintaining more treatment facilities than necessary or having more than one billing department for one town. Consolidating also results in combining capital and resources that may lead to improvements within the water system and a sufficient supply of water. If Leicester's three water districts consolidated into one district, further studies must ensure the system would have sound infrastructure between districts. Another factor to consider would be how to manage the new district. To take one step further on the spectrum of restructuring options, we also consider Moose Hill Reservoir as a possible water source for Leicester.

Moose Hill Reservoir, located in the northwestern section of town, has an adequate water volume to be the primary source of water for the town. An initial study conducted in 1966 by SEA consultants concluded that Moose Hill Reservoir has enough water to supply the entire Town of Leicester (Sanitary, 1966). However in order for Moose Hill Reservoir to become a drinking water source, a treatment plant needs to be built. This plan would be a costly endeavor,

and the Moose Hill Water Commission estimated that the total cost of building a water treatment facility and distribution system improvements at $5,843,437 (SEA, 1986). One method to bring this plan to fruition was to have the town fund the project and become a water wholesaler for the districts.

Recommendations

We provided several recommendations for the Town of Leicester and its water districts. For a short term solution to meet Cherry Valley & Rochdale Water District's water demand, we recommend that **the district forms an interconnection with the City of Worcester** and begin the process of purchasing water from their system. Also, **Hillcrest Water Supply should continue buying water from Leicester Water Supply District** as a short term solution to meet their customer's water demand. Meanwhile, **all three water districts should work towards consolidating their water districts in the long term**. The Town of Leicester should work with Moose Hill Water Commission to fund the initial studies needed to classify Moose Hill Reservoir as a drinking water source. Then, the newly consolidated water district s**hould commit to using Moose Hill Reservoir as their main water source.**

The water districts in Leicester have been working to improve their water systems to meet the quality standards and the demand of their residents. The approaches we have identified outline long term and short term investments, ranging from consolidation to interconnecting with Worcester for additional water, that serve as a means for the districts to work together in various capacities. In addition to these approaches, we have provided a GIS map of the Town of Leicester’s three districts that highlights the details for implementing any one of our plans. This map, and the project as a whole, encourages the water districts to pool resources and work together to strive for the well-being and prosperity of the Town of Leicester.

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3. Water Management Systems	Yao Yuan Chow	Edited by All
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4. Objective 3: Generate GIS map of the Town of Leicester with water district boundaries and distribution systems	Yao Yuan Chow	Edited by All
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potential changes to improve Leicester's water management system		
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Valley & Rochdale should consider forming an interconnection with the City of Worcester		
Recommendation 2: Hillcrest Water Supply District should consider continuing to buy water from the Leicester Water Supply District	Anna Franciosa	Edited by All
Recommendation 3: The Leicester Water Supply and Hillcrest Water Supply Districts evaluate the option of hiring a superintendent to manage both of the water districts	Yao Yuan Chow	Edited by All
Recommendation 4: All of Leicester's water districts should consider having quarterly meetings between their Board of Commissioners and Superintendents	Aditya Nivarthi	Edited by All
Recommendation 5: All of Leicester's water districts should evaluate the possibility of consolidating into one new water district	Yao Yuan Chow	Edited by All
Recommendation 6: The newly consolidated water district should consider contracting an on-call employee from a water consulting company	Anna Franciosa	Edited by All
Recommendation 7: The Town of Leicester should consider working with the	Timothy Berube	Edited by All

Moose Hill Water Commission to certify Moose Hill as a drinking water source		
Recommendation 8: If all of Leicester's water districts consolidate, the new water district should evaluate the possibility of using Moose Hill Reservoir as a drinking water source	Timothy Berube	Edited by All
Recommendation 9: The town should consider financing free lab tests for the residents on private wells	Yao Yuan Chow	Edited by All
10. Further Study	Anna Franciosa	Edited by All
11. Conclusion	Aditya Nivarthi	Edited by All

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

CMRPC: Central Massachusetts Regional Planning Commission

EIR: Environmental Impact Report

GIS: Geographic Information System

MassDEP: Massachusetts Department of Environmental Protection

MCL: Maximum Contaminant Levels

MG: Million Gallons

MGD: Million Gallons per Day

MGY: Million Gallons per Year

MWMA: Massachusetts Water Management Act

MWRC: Massachusetts Water Resources Commission

NEWWA: New England Water Works Association

SDWA: Safe Drinking Water Act

USEPA: United States Environmental Protection Agency

WPI: Worcester Polytechnic Institute

WROC: Massachusetts Water Resource Outreach Center

CHAPTER 1: INTRODUCTION

Turning on the faucet every morning, clear water flows out in a steady stream. Not many people in the United States think twice about drinking water from the tap. Imagine if the water that flowed out of the faucet began to make you sick. Between 1989 and 1990 in the town of Cabool, Missouri, there were 240 cases of diarrhea and six deaths due to *E. coli* found in the drinking water (Lund, 2002). An investigation by the Center for Disease Control and the United States Environmental Protection Agency (USEPA) found the cause of the illness was due to an unusually cold winter. The low temperatures caused line breaks in their water distribution system and allowed contaminants to get into the water supply after the water was already treated (Lund, 2002). Although these events were unfortunate, they showcase the importance of protecting the purity and quantity of drinking water for the public well-being.

The need for water is summarized into four different uses: drinking water, personal hygiene, sanitation, and household food preparation. The average person uses 50 liters a day to maintain these four needs (Gleick, 2002). Additionally, the amount of water used for human consumption only accounts for 20% of the total amount of water supplied to residences (Drinking, 2006). Now, think about 7 billion individuals using this amount of water every day from the finite supply of freshwater. Due to the sheer volume of water required, there is a need to manage water resources effectively to provide for current and future generations.

Clean drinking water is vital to society. In fact, in 2010, the United Nations general assembly declared safe, clean drinking water a human right (United, 2015). In the United States, federal laws, such as the Safe Drinking Water Act (SDWA), protect the nation’s drinking water quality. The SDWA regulates water source protection, treatment, distribution, system integrity, and circulation of information to consumers. This federal law also enables states to create their

own regulations that may be stricter than the federal requirements. In addition to the SDWA, the state of Massachusetts regulates water withdrawal and water loss pursuant to the Massachusetts Water Management Act (MWMA). The MWMA holds public water systems responsible for notifying consumers and local public officials of the water distribution program including actions for eliminating hazardous conditions (Massachusetts, 2015a). Water systems that do not comply with the SDWA or MWMA are issued Notices of Non-Compliance. Three systems that have dealt with compliance issues are in the town of Leicester, Massachusetts.

A growing concern within Leicester lies in its ability to provide safe drinking water to its residents. The town consists of three separate water districts: these districts are the Leicester Water Supply District, Hillcrest Water Supply District, and Cherry Valley & Rochdale Water District. Each district faces different challenges and obstacles in meeting the water-related needs of the community. Specifically, Leicester is working to improve the town's water quality and water supply.

Leicester's three water districts already attempted a number of improvements to their water management systems. The districts tried flushing their water distribution systems and tapping into Worcester's water supply for more water. Due to the water districts' small customer bases, any improvements had to be affordable. Our project expanded upon these ideas and gave rise to new options for Leicester.

The focus of our project was to find a cost effective solution to meet drinking water regulations and help the water districts meet their community's water needs. We identified five objectives that helped us reach our project goal that included: (1) gathering information on the current and projected water demands in Leicester, (2) identifying challenges water districts face in meeting regulation requirements, (3) generating a map of the town showing each of the water

district's boundaries, (4) identifying potential changes to improve the water management systems, and (5) developing a cost benefit analysis to recommend the most feasible changes. In order to achieve our project goal and objectives, we collaborated with the Leicester Town Administrator, Kevin Mizikar, and the Central Massachusetts Department of Environmental Protection (MassDEP) Deputy Director, Andrea Briggs.

To gain a better understanding of the project, this report is divided into five chapters: Introduction, Background, Methodology, Leicester Case Study, Restructuring Leicester's Water Management Systems and Recommendations. We discuss pertinent information about regulations, water management systems, and the Town of Leicester in the Background Chapter. In Chapter 3, we explain our methodologies for achieving our project goal and objectives. Chapter 4 focuses on the current situation in each of the water districts and the challenges each system faces. Chapter 5 discusses our findings on the various approaches Leicester can use to improve their water management systems, while chapter 6 explores our recommendations on utilizing these potential approaches for the water districts in Leicester.

CHAPTER 2: BACKGROUND

Water sustains all aspects of human life, but many individuals are unaware of the amount of work required to provide potable water to consumers. Additionally, not many people realize that their drinking water supply is limited. In fact, the supply of freshwater available in 2014 accounted for less than 1% of the freshwater present in the world. In order to efficiently manage this finite supply of clean drinking water, a need exists for water management systems to handle the treatment, monitoring, and distribution of water to consumers. Defined in the United States Safe Drinking Water Act (SDWA), a public water management system supplies piped water for human consumption to 15 or more separate buildings or to an average of 25 people each day for at least 60 days in a year (Massachusetts, 2014b). These systems constantly monitor and reassess their current methods to utilize the most efficient, environmentally sound processes for extracting, maintaining and delivering clean drinking water.

In this chapter, we discuss the laws governing public water systems and a water system's responsibility to its customers. In section 4, we explore the different types of water management systems along with examples of each type. Within section 5, we describe several challenges within municipal water management and introduce the specific challenges in the town of Leicester, Massachusetts.

2.1 Regulations: Supervising the Water Domain

All public drinking water management systems in Massachusetts must comply with the federal Safe Drinking Water Act (SDWA) as well as the Massachusetts Water Management Act (MWMA). The SDWA not only ensures that drinking water satisfies the human criteria for water such as purity, taste, appearance, and smell, but also sets the standards for the total amount of contaminants allowed in drinking water. Additionally, the Massachusetts Water Management

Act is the result of state legislature that pertains to the amount of water that can be safely extracted from a water source and the amount of water lost through distribution leaks. To meet these requirements, government agencies like the United States Environmental Protection Agency (USEPA) and the Massachusetts Department of Environmental Protection (MassDEP) pass regulations of compliance. Before considering these requirements, the first step is to understand the standards outlined by the water statutes.

2.1.1 Safe Drinking Water Act

The federal Safe Drinking Water Act (SDWA), enacted in 1974, sets standards for the quality of public drinking water treated within water management systems. As part of the SDWA, each management system must complete an annual water quality report that is publicly available to its consumers. These annual reports include information about the water distributed such as contaminant concentrations in the water, the water source(s), possible health effects, and any improvements made to the water system (United, 2004). Consumers have an opportunity to learn about the water they drink by having access to the annual water quality report. For the USEPA, the SWDA grants the agency authority to set water quality standards, as well as oversee the water suppliers that implement those standards in their management systems (Drinking, 2006). There are specific standards for over 80 different contaminants that public drinking water must meet. If a water management system exceeds any of these maximum contaminant levels (MCL), there are ramifications; this rule ensures the public health of the consumers. See Appendix A for the specific rules outlining these water quality standards. The goal behind these standards is to monitor water management systems and determine if the water provided from such systems is safe and clean for the community. For example, the Lead and Copper Rule forces systems to monitor the lead and copper levels in water. The Surface Water Treatment Rule makes sure that the disinfectants used to clean water in water management systems are not

contaminating the water (Drinking, 2006). The Total Coliform Rule sets a legal limit (MCL) for the presence of total coliform in drinking water to protect public health (Drinking, 2006). All three of these rules address different aspects of the water management and treatment process, and set standards for the quality of the resultant drinking water.

2.1.2 Massachusetts Water Management Act

The Massachusetts Water Management Act (MWMA), enacted in 1986, establishes procedures and standards that will allow the Commonwealth of Massachusetts to regulate the quantity of water withdrawn from both surface and groundwater sources (Massachusetts, 2015a). This law ensures that there are sufficient water supplies for current and future generations. Specifically, the MWMA sets standards for volume of water that can be withdrawn from a source at 100,000 gallons of water per day, but this standard may increase or decrease in order to protect the public health, safety, and welfare (Massachusetts, 2015c).

The MWMA program issues permits to individuals who draw more than 100,000 gallons of water per day or nine million gallons in a three-month period (Massachusetts, 2015c). Permit holders must submit annual reports with their average monthly withdrawal information. If an entity violates these permits or fails to comply with an order, then they are subject to civil fines. The extent of the fines depends on the MassDEP's determinations of "the willfulness of the violation, damage or injury to the water resources and other water users, [and] the cost of restoration of the water resources" (Massachusetts, 2015b).

Another important aspect put in place through the MWMA is making public water suppliers accountable for any water losses throughout the distribution system. To do so, water suppliers develop a water conservation program when applying for their permit (Massachusetts, 1996). Several areas that water management systems focus on include meter installation and

maintenance, leak detection, and reducing peak water usage (Massachusetts, 1996). The MWMA is not the only state statute whose purpose is to protect and conserve water resources.

2.1.3 Interbasin Transfer Act

Enacted in 1984, the Massachusetts Interbasin Transfer Act's goal is to ensure that transfer of water between river basins is done in a way that conserves water resources within the different river basins (Massachusetts, 2003a). This state legislation minimizes the quantity of water transferred between watersheds. An interbasin transfer is, "any transfer of surface, groundwater, or wastewater of the Commonwealth outside of its river basin of origin" (Massachusetts, 2003a, 2). The Massachusetts Water Resources Commission (MWRC) is the authority that approves or denies these interbasin transfer application. During the application review process, the MWRC checks to make sure there are plans to conserve water and minimize impacts to the watershed's wildlife habitat (Massachusetts, 2003a). The transfer of water between river basins in the same municipality is exempt from the requirements of the Interbasin Transfer Act. Therefore, the distribution of water between river basins within a single town by one water system would not be subject to the requirements of this act (Massachusetts, 2003a).

One policy related to the Interbasin Transfer Act is the MWRC's Offsets Policy Regarding Proposed Interbasin Transfers. The goal for this policy is to minimize the amount of interbasin transfers (Commonwealth, 2007). It is important to try and minimize the number of interbasin transfers because transfers can lead to soil erosion, reduced stream flows, and in some cases decreased water quality (Cosens, 2010). These offsets can include reducing the demand for water through water conservation efforts and preventing water contamination and water loss by repairing water pipes to prevent leaks in the water distribution system (Commonwealth, 2007). Identifying environmental offsets may be done through conducting Environmental Impact

Reports (EIR). Environmental Impact Reports are required by the Interbasin Transfer Act for any interbasin transfers that are greater than one million gallons per day (Massachusetts, 2003a).

The Interbasin Transfer Act and the Offsets Policy Regarding Proposed Interbasin Transfers are important for any water management system that distributes water across river basin barriers. In order to provide potable drinking water to a community, the main concern of water management systems is to provide a sufficient amount of high quality water. In the next section, we discuss the evolution of water management system and processes of water treatment and distribution.

2.2. Water Management Systems

Water management systems have undergone many changes since the first drinking water system. Formed in 1652, the Massachusetts Water Works' Company was the first municipal water utility in the United States. The utility used a reservoir to provide domestic water and fire protection (Drinking, 2006). The use of a reservoir evolved into the first piped public water system in the 1900s with the utilization of gravity to transport water from higher elevations to lower elevations (Dehner, 2009). By the late 1800s to early 1900s, towns implemented new methods of water treatment resulting in a decrease in waterborne disease (Drinking, 2006). As new methodology was implemented to protect and treat water sources, there were a variety of water management systems, each tailored to meeting the needs of different towns or communities.

2.2.1 Water Treatment and Distribution

All public drinking water systems follow a standard process for water treatment to produce water that complies with the SDWA standards, even though individual systems execute treatment in various ways. As for distribution, a water distribution system is the method of

transporting the water through pipes from a treatment plant to consumers' homes. A distribution system must monitor, protect, and maintain the quality of the water after leaving the treatment facility.

The main stages of water treatment are pretreatment, prefiltration, filtration and disinfection (Agardy, 2005). Please see Appendix B for an illustration of the different stages of water treatment. Pretreatment is the initial stage where the water goes through sedimentation, filtration, preliminary chlorination, and removal of solids as well as harmful chemicals (Agardy, 2005). In other words, this stage removes any larger solid matter from the water through filters and initially sanitizes the water. Once the water completes this part of its journey, the prefiltration process begins.

During prefiltration, the water treatment system adds chemicals that cause the unwanted particles to clump together, allowing for easy removal of the remaining debris (Agardy, 2005). With the debris clumped together, extracting all suspended solids in the water is easier for the next stage, filtration. The treated water, in the process of filtration, passes through filters and leaves behind suspended and colloidal materials found in the water (Massachusetts, 2014a). Finally, the last stage of the treatment process is disinfection, the process of removing remnant chemicals from previous stages and sanitizing the water (Agardy, 2005). Chlorination and ultraviolet radiation (UV radiation) are major components of the disinfection stage. UV disinfection involves shining a UV lamp onto the flowing water, rendering the cells of most organisms unable to reproduce (Massachusetts, 2014a). When qualified water experts deem the water as clean and safe to drink, the system distributes the water through a collection of water mains and pipes to its consumers.

Once the water completes the treatment process, the water travels through the distribution network. An important aspect of water distribution is the disinfection of the delivery system. Disinfecting the delivery system maintains the quality of water as it travels through the water mains and pipelines (Massachusetts, 2004). The process of disinfecting the distribution system has three stages: 1) flushing; 2) disinfecting; and 3) water quality testing. First, flushing of the distribution medium, usually pipes, removes any lingering sediment. Then, a disinfecting solution such as calcium hypochlorite fills the distribution system (Massachusetts, 2004). Finally, employees of the water system check quality by testing total coliform counts.

Monitoring, protecting, and disinfecting water distribution systems can be expensive, so managing a water system requires an understanding of the available funding methods.

2.2.2 Methods for Funding Water Systems

Water utilities should implement financial management practices that can provide adequate funding to support the needs of the water system. Their financial strategies should include a strategic vision, establishing effective financial policies and procedures, setting reserve levels, and balancing rate affordability with pricing that encourages judicious use of water (Water, 2014). The funding for water management systems can come from a variety of sources.

2.2.2.1 Types of Funding

Funding for water systems can come from two categories of funds: revenue generation and loan accumulation. Revenue generation includes setting aside a portion of taxes to funding the water management system, implementing user fees, or being awarded national or state grants (Regional, 2002). For expensive long term projects, water management systems may develop a water usage fee (Water, 2014). A water usage fee would divide up the total cost of the improvements over a longer period of time, keeping rates constant. This fee ensures that the current population is not paying more than future consumers. An alternative to revenue

generation is loan accumulation. Loan accumulation involves water management systems issuing bonds or securing loans (Regional, 2002). Additionally, all states have programs to help communities meet drinking-water treatment requirements by providing subsidized loans (Water, 2014). One of these programs is the state revolving fund.

2.2.2.2 State Revolving Fund

The state revolving fund is a source of funding that public water systems may be able to take advantage of if loan acquisition and revenue generation are not viable options in their situation. The state revolving fund, established as a part of the 1996 Safe Drinking Water Act Amendments, allows states to use grant money to form a funding account for infrastructure such as public water systems (Massachusetts, 2004). The terms for the loan allow water systems to easily obtain money in a time of need, especially small and disadvantaged communities. The nearby water facilities would be able to either improve water quality through new treatment facilities or fix any problems in their distribution or storage systems to comply with state water regulations. Of course, the water facility would have to repay the money, but as of 2000 some of the loans were offered at 0% interest and have a repayment time period of up to 20 years (United, 2000). Public, private and nonprofit community water sources are all eligible for funding from the revolving fund (United, 2000).

2.3 Methodologies for Improving Water Management

As long as water management systems have been in existence people have been exploring ways in which to improve them. In particular, struggling water systems typically search for restructuring options to assist them. Such systems are likely to face various challenges that may include ensuring a reliable supply of potable water, replacing old technology, meeting regulatory standards, or even security (Raucher, 2006). The three different methods we explored as potential strategies for improving water management are regionalization, consolidation, and

privatization. We will present detailed definitions of each method and the possible advantages and disadvantages to each.

2.3.1 Regionalization

Regionalization is a type of restructuring option for struggling water systems to consider. Regionalization is, "the administrative or physical combination of two or more community water systems for improved planning, operation, and/or management" (Beecher, 1996, 1). There are a variety of methods to implement regionalization of water management systems. An administrative combination of water systems can include sharing resources or services between the regionalized entities, whereas the physical combination of water systems includes interconnecting water systems, or a merger of all the water systems under one new entity (Beecher, 1996). Specifically, the entity that is assisting the struggling water system is known as the restructuring agent. The restructuring agent(s) typically resides in the same geographic area or region as the struggling system, and is physically close enough to share resources or connect with the other water system. A restructuring agent could be the neighboring community's water system, an investor-owned water services company, or some county or regional authority (Raucher, 2006).

A case study done in Sanford, North Carolina exhibited the benefits of regionalization. In this case study, a small community water system known as the Lee County Water Plant started facing issues due to lack of water management expertise. The system was unable to acquire sufficient technical help because they lacked the financial resources to hire a qualified operator to run the system. A contract between the Lee County Water Plant and a larger water system arranged for the larger system to handle financial management and billing, while both operated their water management systems concurrently. By sharing these monetary responsibilities, the smaller water system was able to hire a part-time operator to work on their system (Hansen,

2013). In this case, the larger water system was the restructuring agent that assumed control of billing. This study illustrated how cooperation between two water systems can be mutually beneficial, since the Lee County Water Plant was able to afford technical experts to manage the facility.

Similarly, smaller systems in general experience a multitude of benefits from sharing their resources, specifically from decreasing the cost of the output (i.e. water) by increasing the amount of the output. With more drinking water available for distribution, the cost of distributing each gallon decreases. The financial burden on each system, consequently, is not as daunting. However, regionalization also has its drawbacks. Depending on the components of the systems that are shared, the costs of regionalization can be higher due to implementation costs. For instance, physical connections between any two water systems may be costly because of distance or even terrain (hills, mountains, etc.). Additionally, the systems involved, may not share implementation costs even though they share the resources, leading to disproportionate water rates for the residents within the region (Raucher, 2006). For some communities, consolidation is a better method for reducing cost and improving quality. Similar to regionalization, consolidation is also a relationship between two water entities.

2.3.2 Consolidation

Consolidation is an encompassing term that refers to restructuring through an agreement involving two or more smaller water systems, similar to regionalization. According to Dr. Robert Raucher who is a noted expert on matters ranging from water resources management to water-related valuation issues and regulatory policy, consolidation spans a spectrum of changes to water management systems such as joint cooperation for resolving water quality or quantity issues and the transfer of ownership from a collection of small water systems to a larger organization (Raucher, 2004). Both regionalization and consolidation share similar benefits and

drawbacks. Unlike regionalization, however, consolidating water systems do not need to be geographically near each other to make agreements on merging systems or transferring ownership. Problems that lead smaller systems to consider consolidation include customer demand for more water, lack of water quality compliance, environmental restrictions on potential sources, technical complexity of operation, and economic constraints (Raucher, 2004). Since small rural/community water systems do not have a large customer base, these systems are more likely to have fewer resources. Sometimes, fewer resources may lead to lower resultant water quality for customers. One example of consolidation is the merging of the water management systems in the town of Boylston, Massachusetts.

Prior to 2002, there were two water districts in Boylston, Massachusetts. These districts were the Morningdale and Boylston water districts (Boylston, 2015). Originally, both districts provided water to the town of Boylston, but the systems in Morningdale were failing and the district did not have the funding to repair its infrastructure (Boylston, 2015). The Morningdale system was unable to get proper funds from the state or federal government since improving their system would not impact a large customer base. Even though they were separate districts, they shared certain water facilities and operator personnel (Boylston, 2010). The Morningdale and Boylston districts consolidated after conducting a study on the practical impacts of the new management structure. They formed one water department for the town, which eliminated duplicate expenses such as administration and insurance costs between both districts because they now shared resources and funds (Boylston, 2015). By consolidating the new water district was able to expand its distribution boundaries to cover the entire town (Boylston, 2010). This consolidation also gave the new department the ability to borrow up to one million dollars from state and federal funds, since the consolidated entities customer base was much larger (Boylston,

2010), and any funding would result in improvements to a larger population. With changes to their water management system, the town of Boylston was in a better position to meet regulatory requirements and water demand.

2.3.3 Privatization

There are many different forms of privatization of water management systems. These forms can be partial, leading to public/private partnerships or complete, leading to total elimination of the government responsibility and ownership of the water system (Gleick, 2002). The public/private partnership entails private contracting for a water plant's operation and maintenance or the use of a private company to design, construct, and operate new facilities. The complete sale of a water utility's assets to a private company is an example of complete privatization (Committee, 2002). Knowing that privatization exists on a continuum, we describe in the next paragraphs some examples of each form.

One case study that illustrates a public-private partnership was the Town of Norfolk, Massachusetts. In the early 2000's, the water system in Norfolk transitioned from operating as a Water Board to a division within a Department of Public Works. As a fledgling system, there were quality issues, monitoring issues, and leakage problems (Dehner, 2009). The Norfolk water system needed assistance in order to provide clean drinking water for the residents of the town. Norfolk first contracted WhiteWater, Inc. in 2003 to resolve maintenance and water quality issues. After 2005, the town contracted WhiteWater, Inc. to preserve the water quality and teach Norfolk water department staff best practices for maintaining water quality (Dehner, 2009). To summarize, Norfolk's goal was to learn from WhiteWater, Inc.'s water management expertise and, at some point in the near future, to independently operate the facility without WhiteWater, Inc.'s cooperation.

A case study of the Aquarion water system illustrated how private ownership may lead to higher water rates. Before 1879, a private company provided water services to the town of Hingham and part of Hull, Massachusetts. Then, after a legislative action in 1879, the Hingham Water Company under the American Water Works Company serviced the water demand of both towns. Eventually after 1980, the Hingham Water Company became Aquarion of Massachusetts (Aquarion), a subsidiary of Macquarie Bank Limited (Dehner, 2009). These events showcased that one water company assumed control of the town's water management and operation. According to Dr. Dehner, the author of the case study, the Hingham/Hull public water rates were approximately $300 more than the average water rates of all the towns in her study (Dehner, 2009). This case study showed that increased water rates could be a drawback of privatization.

As with many models, there are drawbacks and benefits to privatization. Aside from the rise in water rates evident in the Aquarion case study, other drawbacks include motivation by profit, complicated and costly regulation, and the exclusion of communities from decisions about their own resources (Bakker, 2003). Most opposition to privatization essentially lies in this exclusion of government and communities. Since privatization can lead to total control over local water system ownership, an additional drawback is the neglect of public interest (Gleick, 2002). According to Peter Gleick, a leading expert and communicator of water-related and environmental issues, total privatization allows the private company to exclude the community from the decision making process and to ignore the community's right to have a say in how the water system operates. Other drawbacks include possible neglect of nearby environments and ecosystems as well as possible neglect of water-use conservation. One notable drawback is that, with certain contracts, privatization is irreversible (Gleick, 2002). In other words, a town that

relinquishes ownership of their water system to a private company may not be able to buy back the rights to the town's water system in the future.

On another note, there are also benefits to privatization of water systems. Private companies can provide financing and resources that the water system did not originally possess. If regulations are effective, innovation and competition create new efficient methodologies for water management. In other words, private water companies strive to implement improvements to the water that save money and produce more output since its main motivation is profit (Bakker, 2003). This motivation may ultimately lead to efficient management practices. Additionally, the use of privatization brings professional management and technological expertise to small and medium-sized water systems (Committee, 2002). With its drawbacks and benefits, privatization of water systems is only one of the models for addressing challenges to municipal water systems.

Given these examples of the different improvement models of municipal water systems, one can observe that some management models suit certain municipal water systems, whereas other municipal water systems were unable to gain any improvements. Therefore, one must understand the story of Leicester's issues before considering the different options for improving their water systems.

2.4. The Town of Leicester

The Town of Leicester is located in central Massachusetts, 46 miles from Boston. A majority of residents commuted to other towns for work, but there were over 300 businesses, including farms, recreation, and professional service businesses, located in Leicester (Town, n.d.a). Leicester is situated on three watersheds: the Chicopee, French, and Blackstone (Massachusetts, n.d.a). As of 2015, most of Leicester's 23.36 square miles were open land,

providing the town with the opportunity to expand through smart-growth projects. However, the limited supply of water in Leicester hindered most of the smart growth projects and other economic development projects. For instance, lack of a fire suppression system was a main obstacle in developing commercial businesses in the area. Therefore, the projects were put on hold until their public water systems could be improved (Central, n.d.).

2.4.1 Overview of Leicester's Water Districts

In order to make sure that the town could meet its current and future water needs, Leicester needed to make sure that its water management systems could support the communities' water demand. As of 2015, Leicester did not have a town water department. Instead, the town's water systems operated under three separate districts: Cherry Valley & Rochdale Water District, Hillcrest Water Supply District, and Leicester Water Supply District. A comparison of the three districts is shown below in Table 1 based on the water districts 2014 annual water quality reports.

District	Cherry Valley & Rochdale	Hillcrest Water Supply	Leicester Water Supply
Population Served	~4,400 Residents	~350 Residents and Memorial School	~3,300 Residents
Water Sources	-Henshaw Pond -Grindstone Well	-Lehigh Road Well	-Whitemore Street Well -Rawson Street Well -1 Well Field in Paxton
Contaminants Treated at Water Treatment Facilities	Microbial, sediment, algae, bacteria, lead and copper, radon, uranium and naturally occurring radionuclides, arsenic	Microbial, uranium and naturally occurring radionuclides, arsenic	Microbial, lead and copper, radon, iron and manganese, uranium and naturally occurring radionuclides, arsenic
System Susceptibility Rating	High	Moderate	Moderate

Table 1: Comparison of Leicester's three water districts (Source: Cherry, Hillcrest, Leicester)

As shown, each district was responsible for populations of different sizes. Each district was also treating different contaminants in different locations throughout the town. However, all of the districts had moderate to high system susceptibility ratings; these ratings measured the water source's potential to become contaminated due to nearby activities and land uses (Massachusetts, 2003b).

2.4.2 Overview of Leicester's Water Districts' Challenges

Each of Leicester's three water districts faced various challenges in managing their water systems in 2015. Under an Administrative Consent Order in April 2012, the MassDEP required the Cherry Valley & Rochdale Water District to bring their water management system into compliance with several regulations. Since then, the Cherry Valley & Rochdale Water District started the interconnection process to purchase water from the City of Worcester (Cherry, 2014b).

A challenge for Hillcrest Water Supply District was that their only water supply source was one well. Although many towns received their water from groundwater sources, this well did not supply enough safe drinking water for all nearby residents. Therefore, the Hillcrest Water Supply District augmented their water supplies by buying water from Leicester Water Supply District in the summer months (Central, 2010). Hillcrest Water Supply District performed maintenance on their water system by disinfecting and flushing their water distribution system after the district violated the total coliform regulation multiple times in 2014 (Hillcrest, 2014).

The water supply of the Leicester Water District consisted of wells in the Town of Paxton and two groundwater sources within the Town of Leicester. The district faced supply challenges from having to temporarily close one of its Leicester wells and remain closed until treatment processes can be put in place for the removal of arsenic and uranium (Leicester, 2014).

According to Leicester Water Supply District's 2014 Annual Water Quality Report, these additional treatment processes would be operational by November 2016 (Leicester, 2014).

In 2015, the three water districts had separate administrations, maintenance, and operations for their facilities (Central, 2010). As separate entities, each district was struggling to support the costs associated with bringing their system into compliance with their small customer base and available financing. In 2015, the Town of Leicester reached out to the Worcester Polytechnic Institute (WPI) Massachusetts Water Resource Outreach Center (WROC) for assistance with identifying the most feasible approach to comply with water quality requirements and increase its capacity to meet current and projected water needs. As part of the WROC, our project was to analyze different water management systems and other methodologies that could improve Leicester's systems.

2.5. An End to a Chapter

The goal of our project was to provide a cost benefit analysis on solutions for the issues faced by each of Leicester's water systems. We provided recommendations on the most feasible approach to tackling Leicester's drinking water challenges. In the next chapter, we discuss our methodological approach to tackling this project goal.

CHAPTER 3: METHODOLOGY

Our project goal was to identify the challenges Leicester's three water districts were facing and provide a cost-benefit analysis for available solutions in order to meet the water quality standards and water demand in Leicester, Massachusetts as of 2015. In order to accomplish this goal we developed the following five objectives:

1. Gather information on the current and projected water demands of residents in Leicester.
2. Identify the water districts' challenges in meeting regulation requirements.
3. Using GIS, generate a map of the Town of Leicester with geographic water management system attributes.
4. Identify potential changes to improve Leicester's water management system.
5. Develop comparative analysis of proposed improvements based on gathered data.

In order to achieve all five objectives, we conducted in-person and phone interviews and analyzed the content of water quality reports and other documents, incorporating our findings into the proposed changes to Leicester's water management systems. In the following sections of the methods chapter, we discuss each objective and the corresponding tasks to accomplish each objective.

Objective 1. Gather information on current and projected water demands of residents in Leicester

For this project, the information referred to data of the quantitative water amounts withdrawn from each source, the amount of treated water produced, and the demand from the water districts' customers. Current water demand was taken from how much water Leicester used in 2014. Extrapolated from the current water demand, projected demand consisted of the amount of water required for anticipated town growth within the next ten to fifteen years. Utilizing this information and data, we gained an understanding of the town's water needs now and in the future, as well as the gap between what the water districts were providing and continuing to provide. To find this information, we conducted interviews with Massachusetts Department of

Environmental Protection (MassDEP) employees in the Drinking Water Program and with Leicester Water District Managers.

We collected the water demand information through semi-structured interviews with the three water district managers. Our semi-structured interviews were essentially conversations in which we had a set of questions to ask but the conversations and discussions were free to vary and change substantially between us and the participants. As a result, our interview questions were open-ended, allowing the interviewee to expand upon their experiences (Fylan, 2005). With semi-structured interviews, we wanted to get the perspective of the district managers on what they believe the water demands were and how the town's growth affected water demand in the future (See Appendix D for Sample Questions). Given the district managers' first-hand experience in the field, they were able to assess this water demand, or necessary water capacity to support the town of Leicester. With semi-structured interviews, its framework for friendly, two-way conversation gave us an opportunity to develop a business-related relationship with the interviewees (Berg, 2012). These interviews were also the most efficient way to access the data that was not available online, such as the number of service connections and the number of residents on private well-water. In addition to the Leicester water district managers, we held weekly meetings with MassDEP employees.

These weekly meetings served as an information sharing and data collection mechanism. In terms of information sharing, we distributed meeting agendas that summarized our weekly progress and outlined our tasks for the upcoming week. While we facilitated the meetings, MassDEP employees in the Drinking Water Program continually intervened with their insights and suggestions for our project, occasionally correcting the direction of our project. These employees knew where to find the data we were looking for and gave us context to what the data

meant in relation to Leicester's situation. This information from the MassDEP included reports, from which we carried out a content analysis that allowed us to develop a basis for the projected supply needed in future years. Once we obtained an accurate estimate of the difference between the current water supply and projected water demand, we had a general idea of the Town of Leicester's water supply needs.

Objective 2. Identify water districts' challenges in meeting regulation requirements

After we acquired an understanding of Leicester's current and projected water needs, we began to identify the water districts' regulatory challenges. To identify these challenges, we read and analyzed each district's water system reviews and annual quality reports, as well as conducted semi-structured interviews with the water district managers. The 2012-2014 annual statisical reports and annual water quality reports assisted us in understanding the specifics of the compliance issues in each water district, and the district manager interviews gave us additional insight on the issues and challenges the districts face.

Sanitary surveys, or water system reviews, and annual water quality reports shed light on different aspects of compliance issues in the three water districts. A sanitary survey is an, "on-site review of a public water system's water source, facilities, equipment, operation, and maintenance" (United, 2012). These surveys, in other words, reflected the state of the water management systems in each district. Additionally, the annual water quality reports we analyzed provided information on the state of the treated water in each district, mainly the composition and purity of the drinking water post-treatment. With this information, we assessed whether the compliance issues resided in the water distribution systems, or in the treatment systems. To assist in this endeavor, we created an overview of the districts and the region to illustrate the situation graphically.

Objective 3. Using GIS, generate a map of the Town of Leicester with geographic water management system attributes

The Leicester Water Supply District, Hillcrest Water Supply District, Cherry Valley & Rochdale water districts act as separate water districts, meaning that each district does not interact or share their resources when providing water to nearby residents. As a result, district boundaries exist that dictate which district contributes to a particular sector of the town. However, the MassDEP officials did not possess a consolidated map of all these existing boundaries.

Per suggestion by Andrea Briggs, the Deputy Regional Director at the MassDEP, we created a map using the Geographic Information System (GIS), marking the locations of the distribution systems and district boundaries within the region. GIS is a "computer-based system for the capture, storage, retrieval, analysis, and display of diverse types of spatial data" (Hammock, 2-3, 1989). The spatial data generated from GIS consisted of locations of water sources, locations of pipes (distribution system from facility to residents), and district boundaries for one district, culminating into a different layers of the map. Since each of the districts acted as separate entities of each other, this map would provide the MassDEP and Leicester with a visual of the geographic relationships between the three districts' water distribution networks as well as each district's contribution to Leicester's water demand.

In order to create this map, we conducted semi-structured interviews with each of the district managers and combined any relevant maps of the region. As overseers of the water management facilities, the district managers were able to provide detailed maps and general approximations of their district's distribution lines. Using the semi-structured approach allowed us to collect as much information and resources from the district managers as possible and, simultaneously, coordinate a conversational interview. As noted by MassDEP officials, obtaining

this information proved to be challenging because much of the information was not current and the operators in charge had demanding schedules throughout the 7-week project term. After acquiring distribution information, we began to create the map using GIS software.

In order to create a GIS map for the Leicester water district region, we consolidated all the smaller geographical maps acquired throughout our interviews. To begin, we analyzed the content of the maps and overlaid the maps to see the location of resources for each district in relation to the other districts. These resources included treatment plants, underground pipes and distribution centers. Finally, we inputted the data from the maps onto the computer; here, the GIS software generated a layered overview of the region. Juliet Swigor, the Central Regional Coordinator for the MassDEP GIS Program, assisted us in processing the data and generating the final deliverable. A preview of the map with the water district boundaries can be seen in the figure below. With the guidance of the GIS map, we were able to assess possibilities to improve Leicester's water management system.

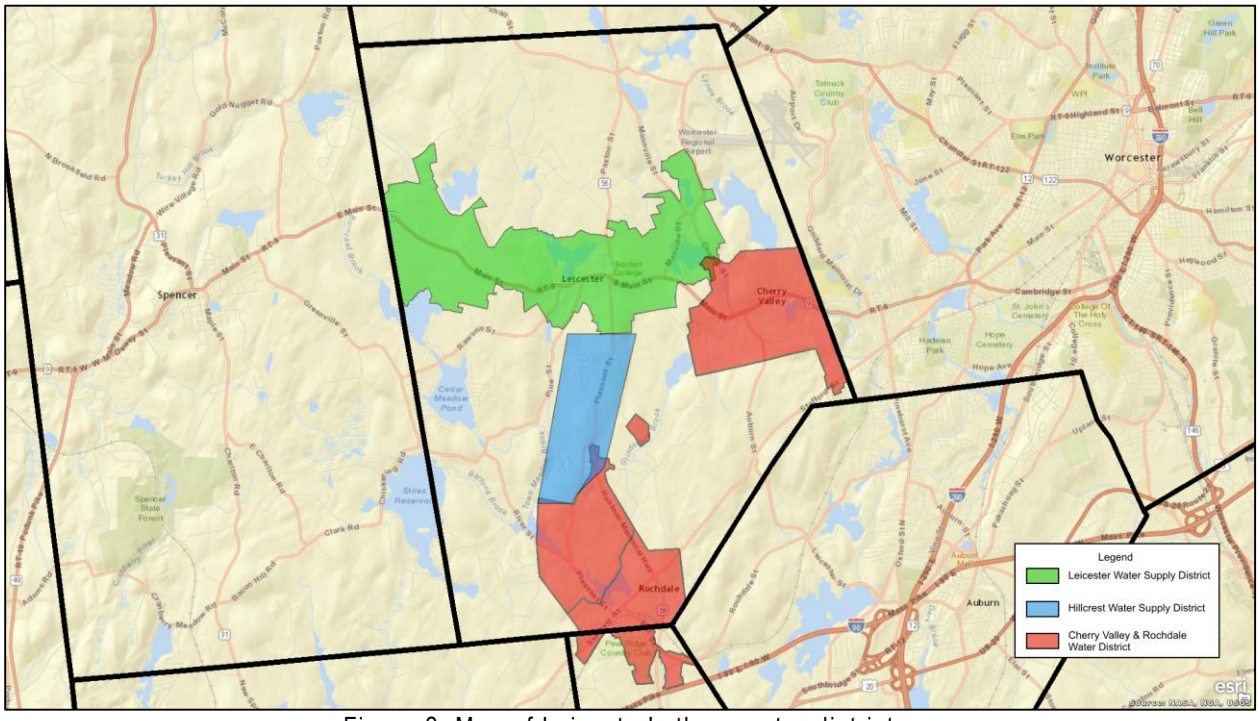

Figure 2: Map of Leicester's three water districts

Objective 4. Identify potential changes to improve Leicester's water management system

Identifying potential changes to Leicester's water management system would help the Town of Leicester meet their water demand and water supply requirements. In order to accomplish this objective, our focus was on finding potential changes and the feasibility of any potential changes. Of course, the reason for evaluating feasibility was to narrow down the list of options to cost-effective plans that the districts would further research. To assess feasibility, we reviewed the implementation requirements of the changes that included necessary funds, labor, and expertise. We acquired estimates from consulting/engineering firms such as WhiteWater, Inc. If any of the potential improvements required a substantial resource the water districts did not have, such as capital investments, we considered them as drawbacks to the potential change.

One of the plans, proposed by MassDEP, was to introduce Moose Hill Reservoir as a new water source. A feasibility study of the Moose Hill Reservoir was conducted in 1986, but not much progress occurred since then due to the high costs involved in building a treatment facility and laying distribution lines to the water districts. We interviewed an elected board member of the Moose Hill Commission in order to deepen our general understanding of any progress between 1986 and 2015 and to acquire any resources that the Commission possessed.

Another proposed plan was to utilize an interconnection with Worcester's water utilities. The water supplied from Worcester would possibly satisfy the water demand of the Town of Leicester. To obtain more information of the future obstacles, we interviewed the superintendent of the Worcester Water Department, Phillip Guerin. To evaluate the costs for any potential change, we found information in a number of ways, such as conducting case study analysis and interviewing nearby towns that had solved similar issues.

To identify the potential changes of Leicester's water management system, we conducted multiple interviews with water consultants and officials from the MassDEP. Participants included water consultants from Whitewater, Inc. and the New England Water Works Association (NEWWA). We also discussed a continuum of changes ranging from full consolidation to individual water district fixes with officials from the MassDEP, obtaining their feedback/critiques. MassDEP experts included Robert Bostwick, section chief of the Drinking Water Program, and Paula Carron, a Water Quality Program Coordinator. The reason for conducting these interviews was to collect qualitative data from a homogenous group of individuals pertaining to a focused topic (Krueger, 2015). Our plan was to compare the discussions between the MassDEP and water consultants about our ideas for potential changes and any other ideas that officials from each organization possessed on the subject.

In addition to comparing discussions between the MassDEP and water consultants, we also triangulated our research by analyzing case studies from water districts with similar issues and water districts that have gone through restructuring. Our rationale for selecting case studies as an additional data source was that case studies provided a strong, empirical grounding from which we drew generalizations about similar issues in other water districts and how these issues were resolved (Berg, 2012). Based on our search criteria, we extracted patterns or lists of actions that led to a resolution. By interviewing water consultants and representatives from water associations, we were able to identify water districts from around the New England region that have faced similar regulatory compliance and water supply issues. Additionally, we only evaluated water districts that were in similar situations as the Town of Leicester such as having a small water district and a small customer base. We researched consolidation studies that have occurred from 2000 to present-day. Throughout our research, we found examples of

consolidation within New York, specifically the Burnt Hills and Ballston Lake consolidation and Town of Eden consolidation. We utilized Robert Yin's *Case Study Research* for a model of identifying exemplary case studies to compare their situations with Leicester's situation as well as to model our own Leicester case study (2003). After identifying some of the potential changes to the three water districts, we assessed the costs and benefits of each improvement.

Objective 5. Develop comparative analysis of proposed changes and recommend the most feasible option

Finally, using the data obtained in Objectives 1-4, we developed a cost-benefit analysis for the current functionality of the three water districts as well as any of the proposed changes to the water districts' management structures that we identified in Objective 4. The cost-benefit analysis could help the town assess whether the benefits of the proposed changes outweighed the implementation costs. In addition, we investigated the benefits/costs of daily operation and maintenance to include in the comparative analysis. We created a list of steps that were necessary to complete for each of these scenarios.

After outlining potential plans for improving the water systems, we met with representatives from WhiteWater, Inc. and the New England Waterworks Association to get a better idea of the cost associated with each potential step. We analyzed costs such as materials, resources, time needed, and labor requirements. We then created a list of potential qualitative benefits gained over time; such as improved quality of water, larger quantity of water, opportunities for development, and new sources of water. In conclusion, we compared the costs, benefits, and drawbacks for each proposed scenario to determine their feasibility and provided our findings to our sponsors. At the conclusion of our project, we presented our findings to the MassDEP and the Town of Leicester, hoping to initiate a positive change within this community.

3.6 Ethical Considerations and the Institutional Review Board

Our goal was to minimize any potential risks associated with this project. Before speaking with any of our interviewees, we had them read and sign an Informed Consent Form prior to beginning any interviews. We spent as much time as necessary to respond to any questions interviewees had and offered to provide them with a copy of our final project report. For a copy of our Informed Consent Form see Appendix F.

We, as a group of students, acted as a neutral party whose main goal was to conduct research. This final report highlights information concerning the possible solutions to Leicester's water management challenges as of 2015 and provides them with a strategy to move forward. For the purposes of this project, the MassDEP served as an educational liaison rather than an enforcement body.

From the data collected for Objectives 1-3, we give a brief case study of the situation in Leicester, Massachusetts in the next chapter, detailing the regulatory issues and water capacity issues. The subsequent chapter outlines our findings based upon interviewee responses and interpretations of all the data gathered for Objectives 4 & 5. We categorized this data into a case study on Leicester and several approaches the water systems could use to make improvements.

CHAPTER 4: LEICESTER CASE STUDY

In this case study, we provide context for our recommendations. The information summarizes the numerous interviews with district representatives, water consultants such as WhiteWater, Inc. and the New England Water Works Association, sponsor meetings with our advisors, the MassDEP, and the town officials of Leicester. Specifically, this information details the population growth over the last few years, projected population growth, data pertaining to the water sources, district capabilities, and necessary areas of improvement.

4.1 The Town of Leicester

The Town of Leicester, primarily a residential town of owner-occupied, single family homes, resides in central Massachusetts. There are more than 3,000 owner-occupied housing, about 900 renter-occupied housing, and approximately 300 vacant buildings (Central, n.d.). Through exploration of the town, one would discover patches of these suburban homes scattered along either side of the road. In one part of the town, there are small buildings for schools, restaurants, retail stores, and homes; most of the buildings are rarely larger than 2 stories. Of course, there are a few gas stations and even a Wal-Mart within the town. Wide-open grasslands and surrounding forests compose the remaining area of the town. There is even one area in Leicester where the grass has grown so tall from the lack of inhabitants, and the landscape stretches far into the horizon. Before discussing the undeveloped land, this case study begins with a description of Leicester's population.

The population of Leicester had steadily increased since 2000 from 10,471 people. As of 2010, the population reached 10,970 people, of which 1,900 were school age (pre-K to grade 12) and 2,200 were senior citizens (Town, n.d.b). These 1,900 children, as the future of Leiceser, would take on the triumphs and challenges within the town. The rest of the local population have

worked to ensure that these children have a suitable community in the future; they include the doctors, the teachers, the police officers, the historians, as well as the hard-working parents of Leicester. In terms of gender distributions, there are about 3,300 men between the ages 20 to 79, whereas there are about 4,000 women between the ages 20 to 79; in both cases, the most prevalent age groups range from 40 to 49 and 50 to 59. Out of the families that made up the population, at least 3.2% were families below the poverty level. Population projections done by the Central Massachusetts Regional Planning Commission (CMRPC) indicated that the population would reach almost 11,500 by 2020 and almost 12,500 people by the year 2040. These projections, shown in ten year increments within Figure 3, exhibited an average yearly increase of 39.42 people or an increase of 0.36% each year.

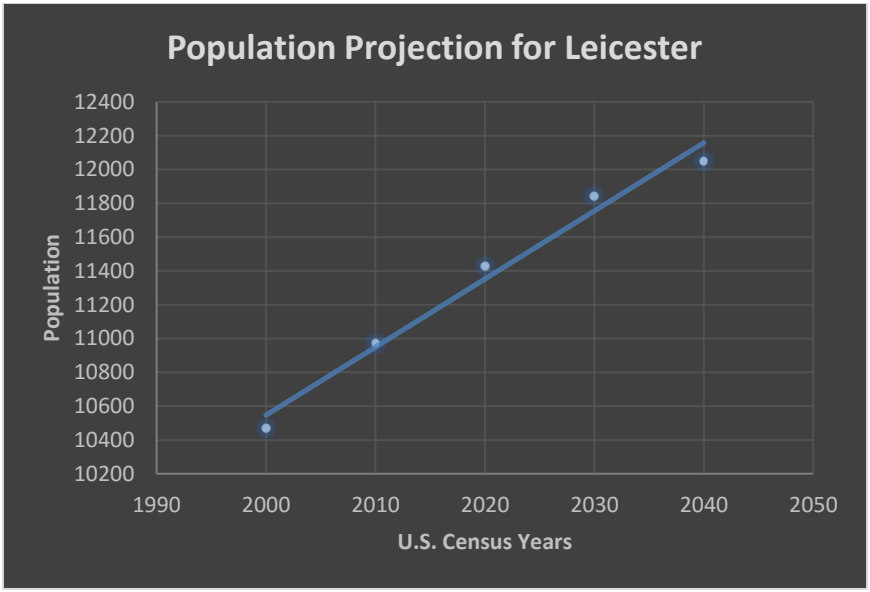

Figure 3: Population projections of Leicester, MA

According to a community snapshot conducted by Central Massachusetts Regional Planning Commission, 72% of land use was open space, whereas 14% of land use was residential and the remaining percentages were from agriculture, water, and built environment (Central, n.d.). Much of the unused land would be prime for commercial businesses and more residents, and would allow for economic growth and development in the town. In 2010, nearly

55% of the population was working. Out of the employed population, 32% of people worked in professional settings, 27% of people worked in sales, 16% of people worked in service industry, and the rest of the employed population worked in either construction, manufacturing, or farming (Central, n.d.). Promoting economic development would most likely increase the percentage of employed residents, but to do so requires adequate and clean water supplies and fire suppression systems.

Consider the cost a maintaining and operating a 1 million gallon treatment facility. Worcester Water department is able to continue their operation because many customers live within a smaller area with triple-decker housing and apartment buildings. As a result, supplying water to a large customer base that is close in proximity of each other reduces costs because the revenue from water bills is large and there is no need for additional piping to reach all the customers (R. Bostwick, personal communication, December 3, 2015). In comparison, Leicester possesses a smaller customer base and the service connections are further apart from each other. Therefore, building and operating a 1 million gallon treatment facility proves to be difficult. To put a million into perspective, a large bathtub can hold about 50 gallons of water, so 1 million gallons of water would fit in 20,000 bathtubs. Imagine the difficulty in maintaining and operating a facility that stores this amount of water on a daily basis.

4.2 The Water Districts

One of the characteristics that makes the Town of Leicester unique is that their public water system is comprised of three water districts. The three districts are the Cherry Valley & Rochdale Water District, Hillcrest Water Supply District, and Leicester Water Supply District (See figure below for a map of the districts).

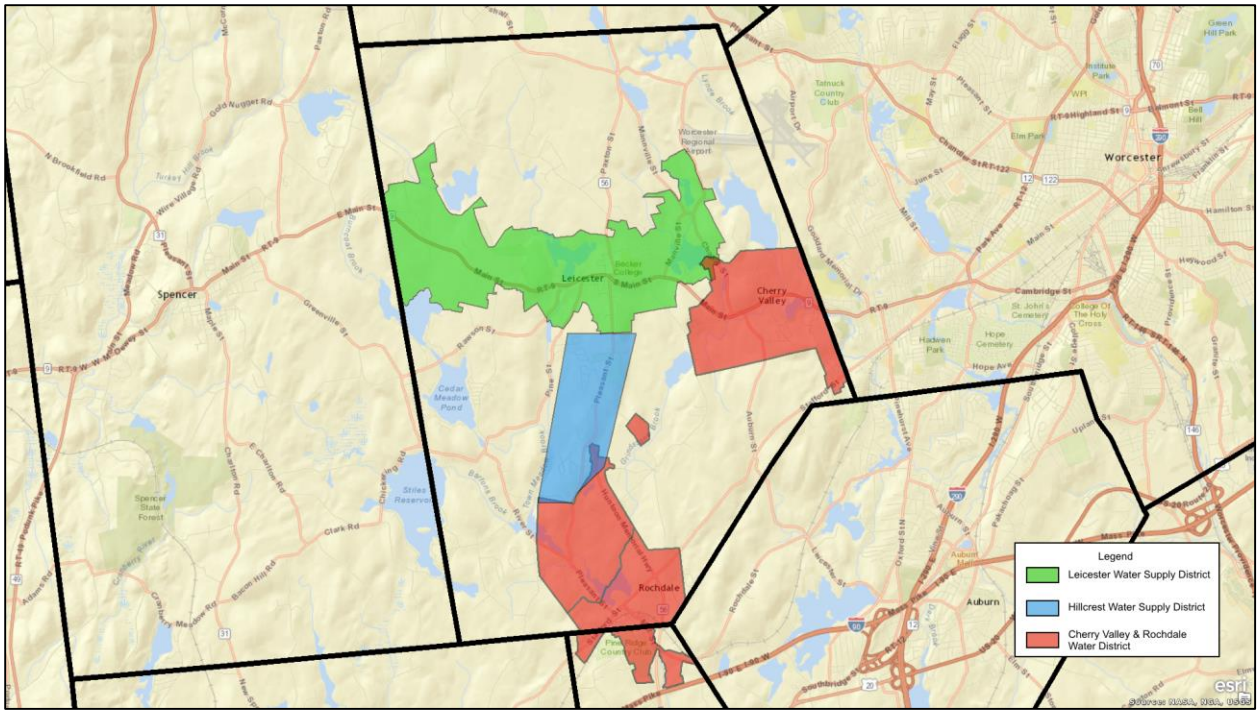

Figure 4: Map of Leicester's three water districts

The water districts operate as enterprise funds so their budgets come directly from their water rate charges. Each district has varied water rates; a comparison between the water districts is shown in Appendix E. Operating as enterprise funds also means they operate independent of the town's control. In addition, the districts do not share resources or provide water outside their district, with the exception of Leicester Water Supply District who supplies water to Hillcrest Water Supply District. The districts have their own boundaries within the town that determine which residents they serve. The regions that the water districts serve, however, do not encompass the entire Town of Leicester, meaning there are other residents outside the districts on well water. The figure below shows the area in Leicester that is not covered by a water district.

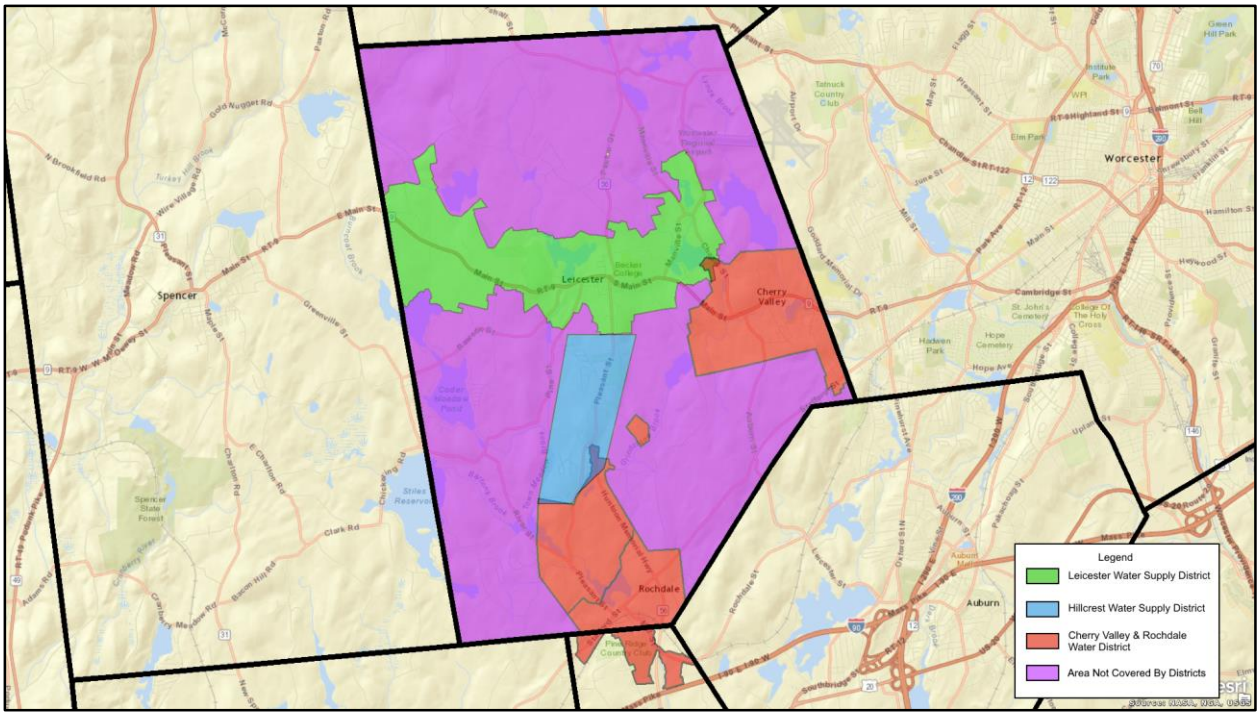

Figure 5: Map of area in Leicester not provided by a water district

According to data from the 2010 United States Census and each water districts annual water quality and statistical reports, we estimated that the districts supplies water to 77% of the 10,970 people in Leicester (Town, n.d.b) Leicester's residents using public drinking water.

4.2.1 Cherry Valley & Rochdale Water District

The Cherry Valley & Rochdale Water District has two water sources: Henshaw Pond and Grindstone Well. The safe yields, the maximum amounts of water that can be withdrawn, obtained from their 2014 Annual Statistical Report are listed in Table 2 below.

Source Name	Safe Yield (MGD)	Active
Henshaw Pond	0.375	Yes
Grindstone Well	0.118	Yes
Total Available Withdrawal Amount	**0.493**	

Table 2: Cherry Valley & Rochdale water source safe yields

There are separate treatment facilities for these sources of water before the water is combined in a clearwell. Water from the Grindstone Well goes through the Grindstone Water

Treatment Facility where the water is treated for removal of radon, uranium, and arsenic before combining with the surface water from the pond in the clearwell. Before the water withdrawn from Henshaw Pond goes into the clearwell, it flows through a slow sand filter that removes particulates and goes through pre-disinfection by chlorine dioxide. After the water leaves the clearwell, treatment ends with disinfection by chlorine gas where the water is then sent through their distribution system (Massachusetts, 2014d).

Based on Cherry Valley & Rochdale Water District's 2014 Annual Statistical Report, the district serves a total of 1,260 service connections, 3 active pump stations, and 3 active treatment facilities. Service connections, again, pertain to houses or buildings that receive water from these districts. The water district has 1,186 residential service connections which use a total of 51.1 million gallons per year (MGY). Based on their 2014 Annual Statistical Report, the Cherry Valley & Rochdale Water District had agricultural or commercial service connections. The different sectors that Cherry Valley & Rochdale Water District distributes water to can be seen in Figure 6 below.

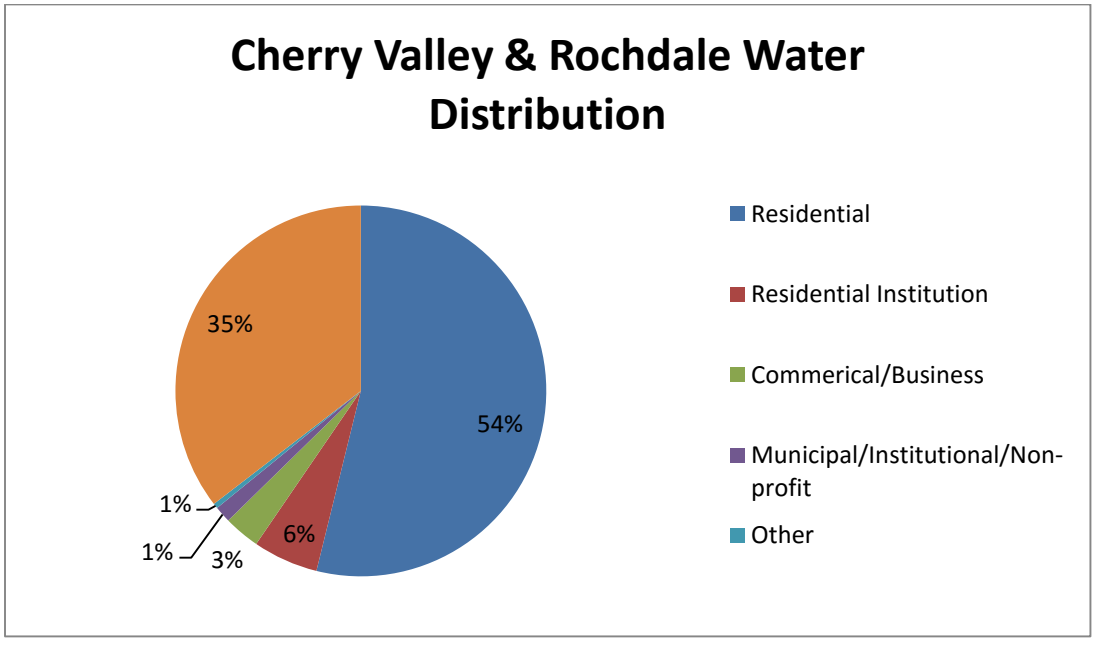

Figure 6: Cherry Valley & Rochdale water distribution (Massachusetts, 2014d)

As shown in Figure 6, 35% of the districts water did not go towards residents, commercial businesses, or industry. Water operators used this water to clean and flush the district's treatment system in the backwashing process. To further explain, flushing the distribution system would rid the pipes of residual chemicals and prevent water from stagnating; therefore, using water for this purpose is necessary to ensure water quality. Mr. Knox, Cherry Valley & Rochdale's Water District's Superintendent, also explained that they were not able to accurately measure the amount of used water during their annually flushing of the water distribution system (personal communication, December 1, 2015). Therefore, the district most likely has a lower percentage of unaccounted/unused water.

The water system would need numerous capital investments to the distribution system. The superintendent of the Cherry Valley & Rochdale Water District provided a list of capital investments needed to improve the operation of the water district (See Appendix I). These improvements, totaling to $2,097,250, include improvements to the hydrants, water mains, and water meters. Of course, these improvements would be costly and the water district could not afford them given its current budget.

4.2.2 Leicester Water Supply District

Leicester Water Supply Department has seven water sources located throughout the towns of Leicester and Paxton. However, only four water sources are in use. The permitted safe yield for each of the water districts sources can be seen in Table 3 below.

Source Name	Safe Yield (MGD)	Active
Paxton Well 1	0.072	No
Paxton Well 2	0.124	Yes
Paxton Well 3	0.131	Yes
Jim Dandy	0.095	No
Whitemore St. Well	0.072	No
Rawson St. Well	0.181	Yes
Pierce Spring Reservoir	0.023	Yes
Total Available Withdrawal Amount	**0.459**	

Table 3: Leicester Water Supply District water source safe yields

In Leicester Water Supply Department's most recent Sanitary Survey, the Massachusetts Department of Environmental Protection (MassDEP) concluded that the Pierce Spring Reservoir was under the influence of surface water. When a source is under the influence of surface water, any contaminants coming from other nearby surface water can affect the water quality of this source. Therefore, the Pierce Spring Reservoir will need to be treated in accordance with surface water treatment regulations (Massachusetts, 2014c).

Based on the district's 2014 Annual Statistical Report, the district has 684 service connections, 7 active pump stations, and 3 active treatment plants. As the Leicester Water Supply District has 583 residential service connections, the majority of their water goes to the residential sector. The percent of water that is distributed to other sectors within the district can be seen below in Figure 7. The Leicester Water Supply District does not have any agricultural or industrial service connections as of 2014.

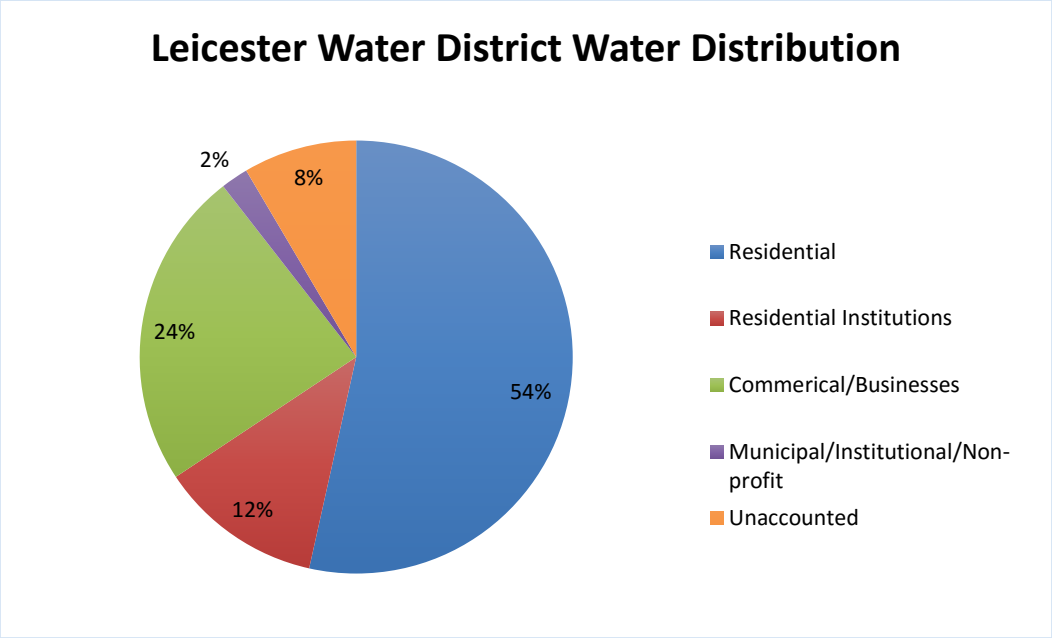

Figure 7: Leicester Water Supply District water distribution (Massachusetts, 2014f)

Not only does Leicester Water Supply District operate their treatment and distribution system, the district also operates the Hillcrest Water Supply District. Kevin Mizikar, the Town Administrator, explained that the treatment and distribution of Hillcrest Water Supply District is overseen by the Leicester Water Supply District operators, but the Hillcrest has its own board of water commission to oversee their management (personal communication, October 27, 2015).

Leicester Water Supply District does not possess a list of capital improvements yet because a published comprehensive study of the water system should come out in 2016. Since this district also handles the operation of the Hillcrest Water Supply District, there is no comprehensive study done for the Hillcrest district as well.

4.2.3 Hillcrest Water Supply District

Hillcrest Water Supply District has two water sources, but only one of them is currently being used. Table 4 below shows the permitted safe yields for the water district.

Source Name	Safe Yield (MGD)	Active
Rock Well 1	0.086	Yes
Rock Well 2	0.144	No
Total Available Withdrawal Amount	**0.086**	

Table 4: Hillcrest Water Supply District water source safe yields

Hillcrest is a small water district containing 379 service connections. The majority of these connections are residential, and the district has two commercial service connections and four municipal service connections. The district has one treatment facility and one pumping station. Since Hillcrest Water Supply only has one active well, the district buys water from the Leicester Water Supply District in the summer months to meet the customer demand (J. Wood, December 4, 2015). According to Hillcrest Water Supplies 2014 Annual Statistical Report, the district bought 850,900 gallons of water from Leicester Water Supply District in 2014.

4.3 Water District Challenges

Throughout our project, we discovered many of the issues that the three districts have faced. Through interviews and sponsor meetings, we came across four major issues that one or more of the districts have dealt with at one point in time. These issues consist of: (i) the limited oversight/staffing available;(ii) quantity and supply issues;(iii) quality issues; and (iv) the inability to take advantage of economies of scale.

In order to maintain and operate a water system, there must be an adequate staff of certified operators. These operators' responsibilities entail measuring the chemical concentrations in the water and monitoring treatment. In the case of the water districts, the district representatives have stated that the treatment facilities are understaffed, relying on the expertise of the few qualified operators. The Superintendent of Cherry Valley & Rochdale, Michael Knox, informed us of how he hires mainly part-time workers due to limitations of the district's budget (personal communication, November 2, 2015). They work in tandem with the 3-

4 district operators. Don Lennerton, Chairman of a Board of Commissioners for Leicester Water Supply District, also discussed how there is only 4 full-time employees who maintain the water facilities (personal communication, November 2, 2015). In terms of quality, there were also quantity issues in the Town of Leicester.

Currently the town has an insufficient supply of water at its disposal, shown in Figure 8. The Cherry Valley & Rochdale Water District is reaching the maximum daily withdrawal limits for its available sources. The district would reach their maximum daily withdrawal limit within the next few years.

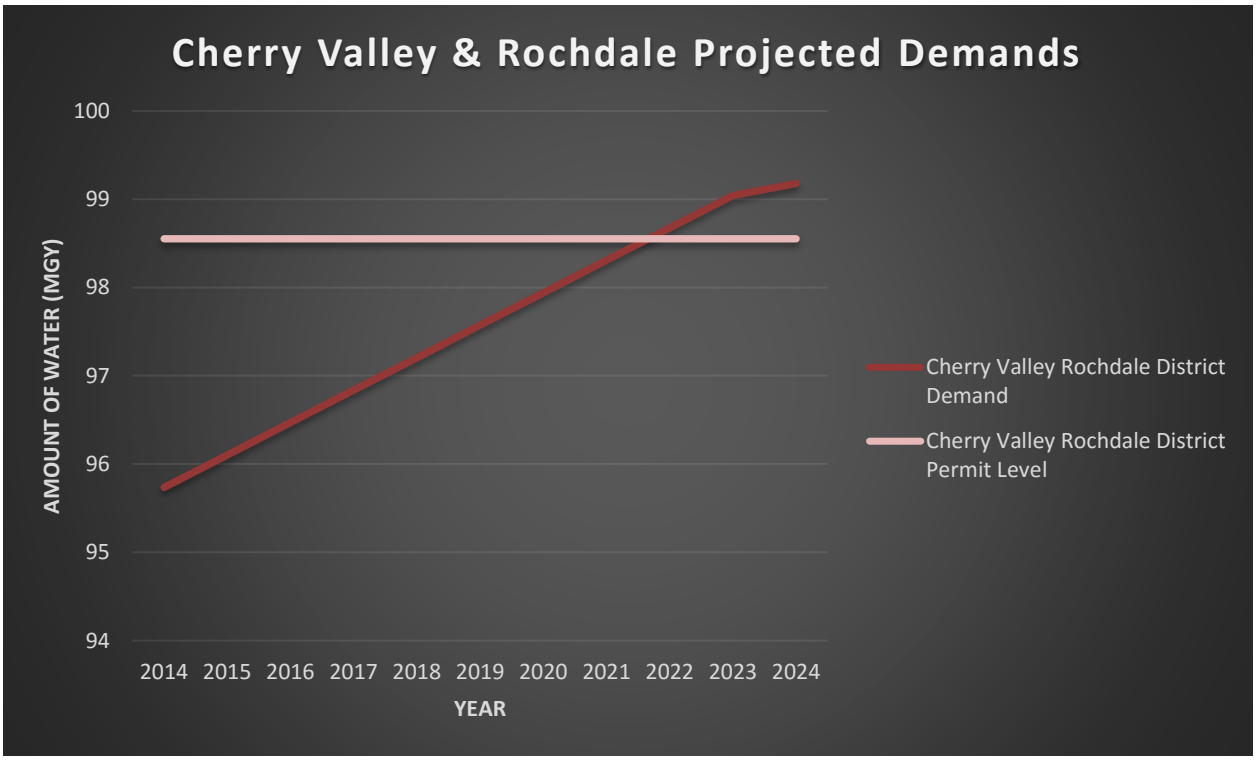

Figure 8: Cherry Valley & Rochdale water district's projected water demand (Massachusetts, 2014d)

Leicester Water Supply District, on the other hand, would have a remaining 36%-37% difference between current and projected usage, as shown below in Figure 9, below. This district is still searching for more water sources to allow for economic growth within the town. For

instance, a new Wal-Mart wanted open in the Town of Leicester; the only obstacle was an adequate fire suppression system that the town would not usually be able to provide. Since Wal-Mart is a Fortune 500 company, the new superstore was able to afford the construction and maintenance of a water tower. This water tower would provide enough water for any fire emergencies (K. Mizikar, personal communication, 29 October 2015). A limited supply of water introduces problems such as an inadequate fire suppression system or lack of drinking water for a large customer base.

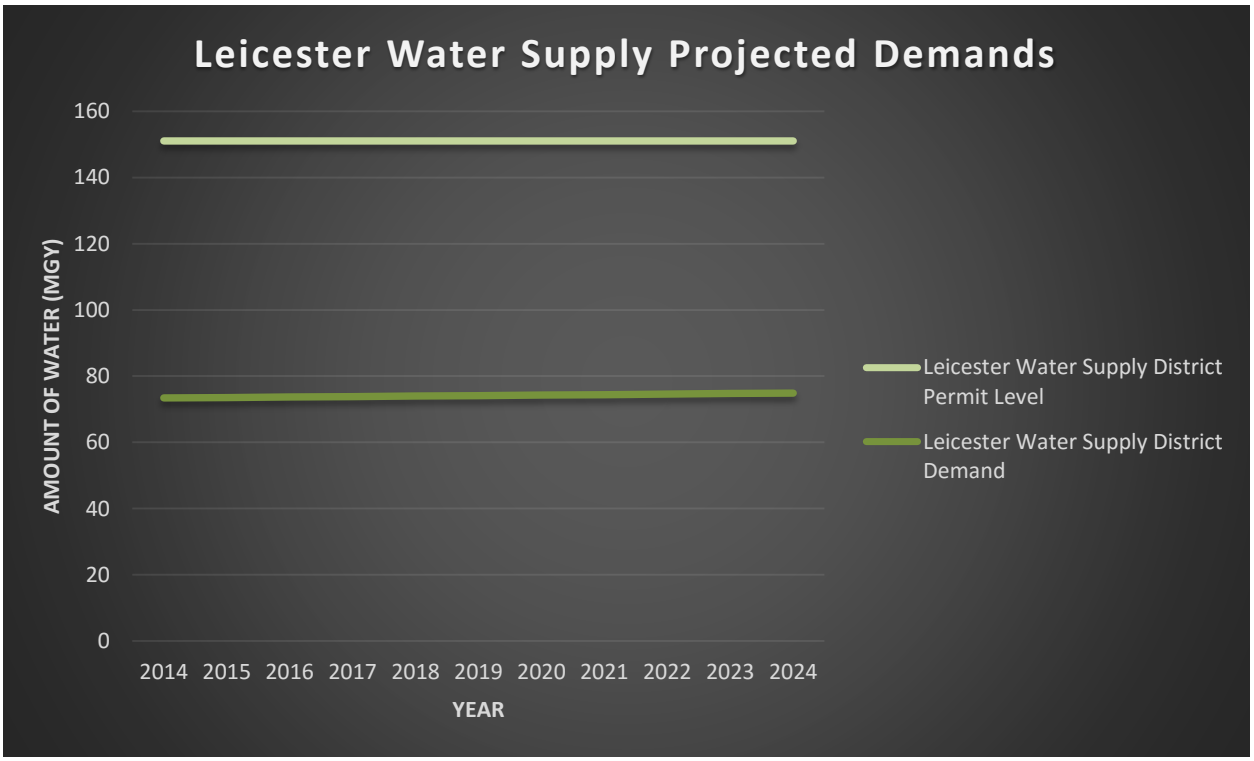

Figure 9: Leicester Water Supply District's projected water demand (Massachusetts, 2014f)

All three of the water districts in Leicester need to resolve arsenic issues. Exposure of arsenic through ingestion can lead to short-term and long-term health effects that can range from vomiting, nausea, and numbness in hands and feet to skin discoloration and increased risk of skin, lung, and bladder cancer (Cerruti, 2015). Long term health effects can be dangerous to residents. In Figure 10 below, Leicester lies above an arsenic belt where arsenic is more

prevalent in ground water sources. This figure indicates that the water from wells is 10%-25% more likely to exceed the Drinking Water Standard of 10 micrograms per liter. Therefore, the treatment facilities within Leicester must consider filtering for arsenic with a higher level of awareness. The entire Town of Leicester is located upon an arsenic belt that passes through the middle of Massachusetts. Figure 10 below shows Leicester's location relative to the arsenic belt.

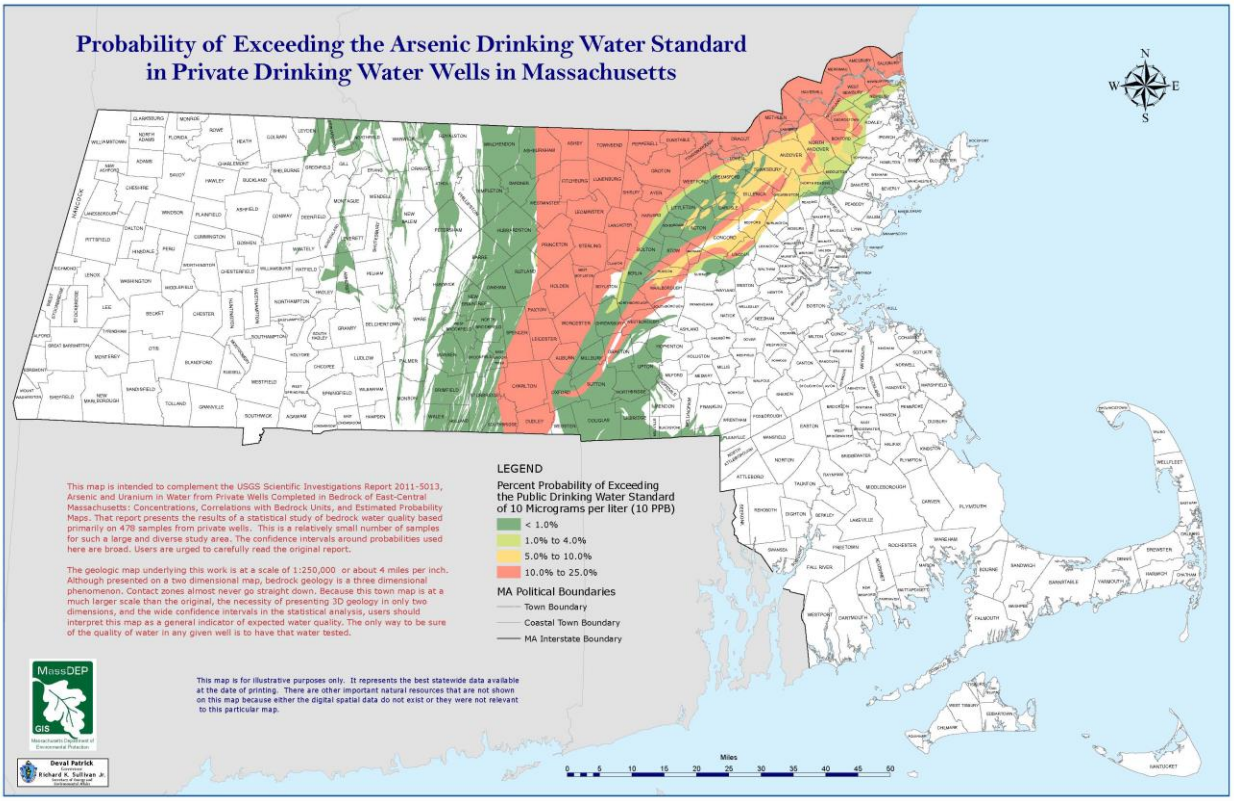

Figure 10: Arsenic map for the state of Massachusetts (Massachusetts, n.d.b)

When describing the quality violations, we leave out names of specific district within this chapter to protect the reputation of the districts. One district, in addition to treating for arsenic, must resolve an issue with a Lead and Copper Violation as well as the level of organics in the source water and finished water. Another water district faces above average levels of radionuclides in one of its sources; this district also must comply with Chapter 6 requirements. Chapter 6 requirements, as explained by WhiteWater consultants, pertains to updated meter

alarm technology that detects the amount of chlorine residuals in the water. Any approach to help these water districts must consider these water quality issues into its planning and design.

As a result of the small customer base, the water districts do not have the ability to utilize economies of scale. Economies of scale refer to the benefits of producing large quantities of the product; doing so decreases the cost per unit of product (Mayhem, 2015). To provide an analogy, economies of scale are the same as products bought in bulk at a warehouse retail store. The cost of bulk buying introduces more savings than if one was to buy from a regular retail store. For the water districts, the water districts serve a total of 2323 service connections where a percentage of them are residential connections. In comparison, the Worcester Water department serves nearly 40,000 service connections (City, 2015). Therefore, there is no reason for the districts to extract large quantities of water. Of course, storage capacity of a facility and permitted yield of a water source also limit the districts on this issue, but the small customer base essentially prevents the districts from taking advantage of economies of scale.

The main issues that are prevalent within the Town of Leicester are summarily the limited oversight, the supply issues, the water quality issues, and the inability to obtain the benefits from economies of scale. Finding solutions to these issues are not clearly outlined by any manual and many water systems in the nation face these challenges as well. However, to overcome these issues, we have outlined several options available to improve Leicester's water management systems.

CHAPTER 5: RESTRUCTURING LEICESTER'S WATER MANAGEMENT SYSTEMS

There are several ways that the Town of Leicester can restructure its water management systems. These approaches exist on a spectrum of restructuring options ranging from internal improvements to a transfer of ownership. Such plans include consolidation of water districts, privatization, interconnections between their water systems and the City of Worcester, and utilization of Moose Hill Reservoir. Figure 11 below illustrates the continuum of approaches we analyzed ranging from significant restructuring to minimal changes to the water management systems in Leicester. In the following sections, we outline each of these options and the associated costs and descriptions for the Town of Leicester to consider for implementation.

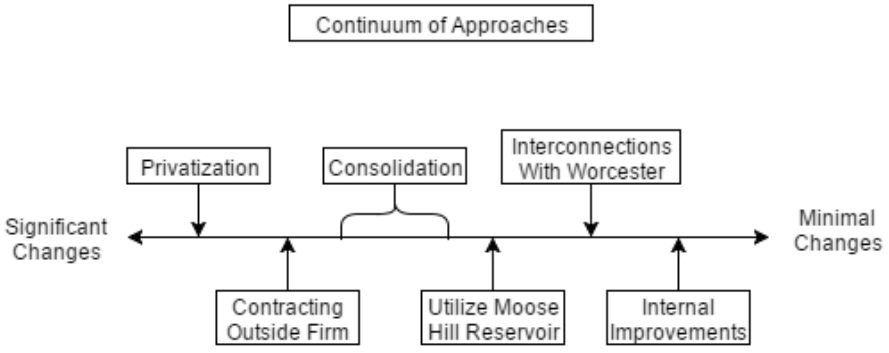

Figure 11: Continuum of potential approaches for water districts in Leicester

5.1 Consolidation

Finding 1: Consolidating the water districts would eliminate redundancy, pull resources together, and reduce operational costs.

There is a wide spectrum of actions that could be taken on the idea of consolidation alone. Andrea Briggs and Robert Bostwick of the Massachusetts Department of Environmental Protection (MassDEP) stated how consolidation could be as minimal as sharing machinery between water districts or as significant as full legal merging of entities. Regardless of the level of consolidation, consolidating would pool resources for the benefit of all the entities involved. Such resources can furnish future upgrades or repairs for expansion of larger customer base. The

New England Water Works Association (NEWWA) Director, Ray Raposa, informed us that smaller water systems do not have a large enough financial base to carry out large infrastructure improvements (personal communication, November 9, 2015). Additionally, several representatives from WhiteWater, Inc., a private water company, explained that many small municipalities cannot afford initial investments on infrastructure improvements (personal communication, November 5, 2015). Consolidation is one option that could expand that amount of capital and resources each of the districts could access to invest in increasing their water supply as to support the demand from customers.

In addition to pooling resources and capital, NEWWA Director Raposa explained that consolidation can reduce operational costs, but to do so the consolidated entities need to eliminate any duplication between the smaller systems (personal communication, November 9, 2015). In Leicester's case, this restructuring option would include consolidating common infrastructures such as water treatment plants, booster stations, or pumping stations within each of the districts. Consolidating these facilities would involve shutting down or reducing the number of treatment plants that are in excess or are not advantageous to keep in operation. Treatment plants that may not be considered advantageous may be geographically isolated from customers. Another method to remove duplicated operations could also include building a new treatment facility to handle the water needs of all residents within the town. The recommendations chapter discusses the assessments that need to be done to determine where the new facilities need to be built. Having common facilities for all the current water district customers reduces operators needed and power consumption. Consolidating these facilities would also require upgrades to the underlying framework of the districts' distribution systems.

For example, the Leicester Water Supply District needs to make improvements so their distribution system can handle a higher water flow through the district's pipes.

Finding 2: Consolidating into one district would require infrastructure overhaul and restructuring of management.

If Leicester's three water districts consolidated into one district, further studies must ensure the system would have sound infrastructure between districts. This infrastructure includes pumping stations, pipes for interconnections between districts, and treatment plants. Based on water district distribution data provided by Tata & Howard, an engineering consulting firm, and Joe Wood, an operator of the Leicester Water Supply District, there are already emergency supply interconnections between all of the districts. These interconnections are apparent on the Geographic Information System (GIS)-generated map we developed, shown in Figure 12 below.

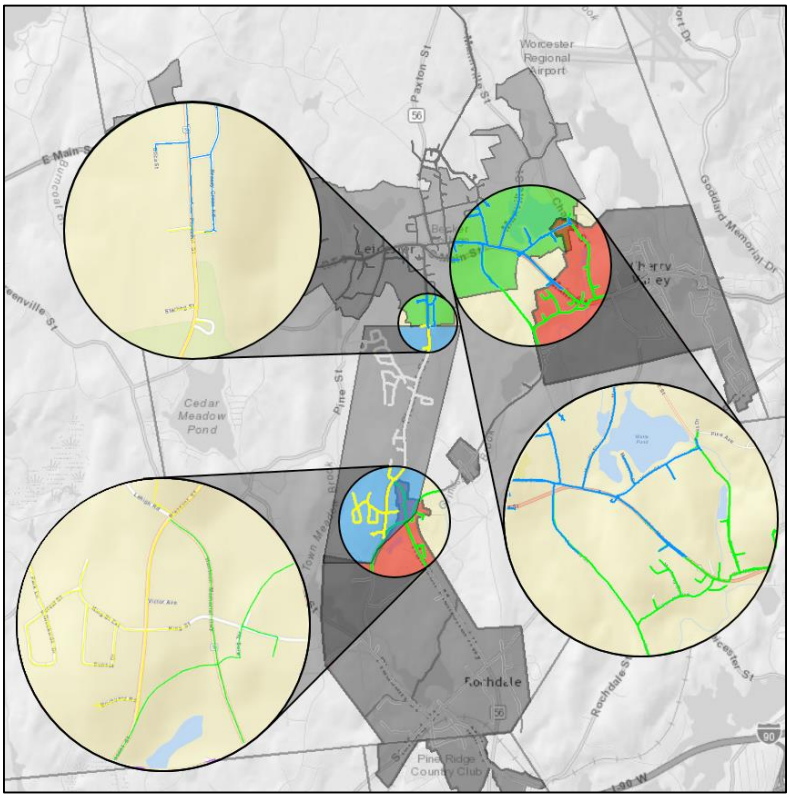

Figure 12: Interconnections between water districts of Leicester, MA

However, if the new consolidated district utilized the interconnections between districts on a daily basis, the water system operators would need to ensure the existing interconnections could support the increased pressure and amount of water that regularly flows through the system. The new system would also require new pipes laid if water from one district would be flowing to another district to help meet the needs of the new consolidated district. Having water flow to all of the town by means of gravity or providing additional treatment before distribution would require pumping stations and treatment plants to be built (M. Knox, personal communication, November 16, 2015).

Another factor to consider before consolidating the three districts is how to manage the new district. After speaking with representatives from each of Leicester's districts, the consensus was that everyone wants to remain involved in the operations and management of their areas. One idea brought forth by Kevin Mizikar, Leicester's Town Administrator, was that if consolidation occurred the management board should include all the elected officials or officials from each of the former water districts. The officials from the former water districts would serve as a part of the single board of commissioners for the new consolidated district, and would provide insight on their former districts at meetings. They would also oversee their area of the town and help coordinate any work between their area and another. With the reorganization of both water system frameworks and management hierarchies in the water districts, consolidation could help unify the districts under one single entity. To take one step further on the spectrum of restructuring options, we also consider privatization as a possible change to the Leicester water systems.

5.2 Privatization

Finding 3: Having a private company take ownership of the water districts was viewed unfavorably by representatives in Leicester.

Throughout the project we spoke with representatives from Leicester's town administration and each of the three water districts. After speaking with Mike Knox from the Cherry Valley & Rochdale Water District, Don Lennerton from the Leicester Water Supply District, and Kevin Mizikar, the town administrator, we learned all parties agreed that complete privatization of the water systems was not in the best interest of the town. Don Lennerton, one of the commissioners on the Leicester Water Supply District's board, spoke passionately about each district's pride in operating their section of town while briefing us on Leicester's history (personal communication, November 2, 2015). According to Lennerton, if a private company was to own and operate the water districts, the local tradition and history would get lost. Leicester's Town Administrator, Kevin Mizikar, explained the importance of keeping the current managers of the districts and the townspeople involved in their water system (personal communication, November 16, 2015). Privatization would limit the local stakeholders' ability to control their water management system.

Finding 4: Privatization may not be a viable option for Leicester's water districts.

Before a private water company takes ownership over a water system, the company assesses the water system to see if it is feasible to make a profit. There are a number of reasons why an acquisition would not take place. These may include poor water quality, geographic location, costs to upgrade the water system, or financial conditions that would not allow any new water rate structures to cover. Each water district has a number of upgrades that need to take place and varying amounts of debt, unfavorable for a private water company in terms of acquisition. An average total acquisition cost for each of Leicester's water districts is shown below in Table 4.

Privatization Acquisition Costs			
Cherry Valley & Rochdale	Hillcrest Water Supply	Leicester Water Supply	**Total**
$6,037,920.00	$1,816,168.00	$3,277,728.00	**$11,131,816.00**

Table 4: Privatization acquisition costs (Source: Townsley Consulting Group, LLC)

Additionally, there are several other drawbacks associated with privatization such as customer support and limited control over their water rates. Customers within each water district are used to having input and representation in the decision process concerning their water districts. Privatization would take away the customers involvement and, as a result, would not be ideal for Leicester (K. Mizikar, personal communication, November 23, 2015).

5.3 Interconnection with Worcester

Finding 5: Interconnections with the City of Worcester would likely not provide a steady and reliable supply for the three water districts for the foreseeable future.

During our interview with Philip Guerin, Director of the Worcester Water Department, we discussed the feasibility and obstacles that towns face when they interconnect with Worcester. Based on the Worcester Water Department's 2014 Annual Statistical Report, their system supplied approximately 22 MGD of water to its customers that include residents in Worcester and the towns of Holden and Paxton. For all of Paxton's residents on the public water system 100% of their water is purchased from Worcester (Town, 2014b). Holden supplements the water they obtain from their five wells with their two interconnections with Worcester (Town, 2014a). Director Guerin informed us that the Worcester Water Department has 24 MGD permit and an additional special permit that allows the City to withdraw an additional 3 MGD that will expire in the next couple of years (personal communication, November 16, 2015). Depending on whether the additional 3 MGD special permit will be approved for renewal, Director Guerin expressed that his main priorities are to provide an ample amount of safe water to all of the department's current customers and honoring its contracts with Holden and Paxton

who already have interconnections in place. Worcester could easily reach 24 MGD. The Town of Holden can increase their demand up to an addition 1.5 MGD according to their contract with Worcester Water Department, and if all of Leicester's water districts were to interconnect with Worcester's water system that would add an additional 0.5 MGD demand (P. Geurin, personal communication, November 16, 2015). At that point the Worcester Water Department would be at the 24 MGD permit and would need to make sure the additional 3 MGD permit was renewed to account for any growth in Worcester or the surrounding towns the department supplies.

However, as illustrated in Figure 1 of the Leicester case study, data points from a CMRPC Population Projection report and a best-fit line indicates a 40 people/year increase for the Town of Leicester. Taking into account this projected population growth in Leicester there would be an additional 1.46 million gallons of water needed per year; therefore the plan to have Worcester supply water to the entire town of Leicester would not be feasible for the foreseeable future especially if the additional 3 MGD permit was not renewed.

Additionally, Director Guerin told us that the quality of water provided from Worcester to Leicester meets all regulations at the point of interconnection, however not after the interconnection. Therefore, each of Leicester's water districts would be responsible for maintaining the quality of water from the interconnection point throughout its distribution systems in Leicester. To do so, pumping stations, chlorine booster pumps, and other infrastructure improvements may be needed to maintain water quality.

Finding 6: There are opportunities to lower the Out-of-City water rates in Leicester.

One of the major limiting factors for Leicester's water districts would be balancing the costs of providing water and subsequent water rates. The Cherry Valley & Rochdale Water District had already begun the paperwork process of completing an interconnection with Worcester. The Superintendent of Cherry Valley & Rochdale Water District, Mike Knox, told us

that the rates for their customer's would increase 136% by interconnecting with Worcester (personal communication, November 2, 2015). Upon speaking with Director Guerin, we learned that Out-Of-Town customers could lower their water rates by providing benefits to the Worcester Water Department. For example, the Town of Holden gave a discount on electricity rates for Worcester's pumping stations located in Holden in exchange for lower water rates (P. Guerin, personal communication, November 16, 2015). The Town of Paxton feeds water from their old reservoir into one of Worcester's water sources in return for lower water rates (P. Guerin, personal communication, November 16, 2015).

The Town of Leicester would have a similar option. Since Worcester has several reservoirs located in Leicester, a water district interested in purchasing water from Worcester could institute or formalize an existing watershed protection plan that could benefit the Worcester Water Department. Protecting Worcester's water sources from contamination would be seen as a significant benefit to the Worcester Water Department. Aside from setting up interconnections for help from Worcester, we analyzed other approaches that involve contracting outside firms for assistance.

5.4 Utilizing Moose Hill Reservoir

Finding 8: Moose Hill Reservoir has an adequate water volume to be the primary source of water for the town.

There is a lot of controversy surrounding the use of Moose Hill Reservoir as a drinking water source for the Town of Leicester. Don Lennerton, a Chairman of the Leicester Water Supply District, said the reservoir would not be capable of meeting the needs of the town because the plan was originally formulated as a means of flood control, but there are several studies that state otherwise (D. Lennerton, personal communication, 2 November 2015). The town has an insufficient supply of water at its disposal, and each district is reaching its maximum

daily withdrawal limit from its available sources. Therefore, these districts must explore other available sources within Leicester, and all signs point to the same place, Moose Hill Reservoir. A study completed by the SEA Consultants, Inc. engineering firm in 1966 on the plan's feasibility concluded the reservoir was a reliable drinking water source for the town. The initial study estimated that Moose Hill could potentially yield 1.5 million gallons of water per day (SEA Consultants, Inc., 1966). In order to do so, however, the town would have had to build a treatment facility with the same capacity. At the time, the calculated cost included the cost of building the dam retention wall for the creation of Moose Hill Reservoir. Since the reservoir has been built, future feasibility studies would no longer have to consider this cost. The total from the 1966 study was roughly 1.1 million dollars. No progress resulted from the study, however, so Moose Hill officials conducted another study in 2008.

Finding 9: Some form of consolidation or agreement must be made between the districts in order for the funding and execution of Moose Hill Reservoir becoming a drinking water source.

In 1997, the Moose Hill Commission formed to look into the different uses of Moose Hill as well as the conservation of the reservoir. The Chair of the Commission is Kurt Parliament and its other members include two other members. In 2008, the Commission began delving into the use of Moose Hill as a drinking water source with the help of the Leicester Water Supply District and the Cherry Valley & Rochdale Water District. They operated under the assumption from the 1966 study and incorporated into their overall costs, the price of a 1.5 million gallon per day treatment plant. The overall costs to build this treatment facility would need to be divided between the three water districts, proportional to their corresponding water use. To calculate the costs to each district, the SEA engineers used the predicted water usage of each district as of 2020, obtaining usages for Cherry Valley & Rochdale Water, Hillcrest Water Supply, and

Leicester Water Supply Districts to 53.2%, 10.7%, and 36.1%, respectively. For the associated costs see Table 5 below.

Districts	Cherry Valley & Rochdale Water	Hillcrest Water Supply	Leicester Water Supply	Totals
Treatment Plant Costs	$1,934,442	$387,324	$1,311,671	**$3,633,437**
Distribution System Costs	$1,496,740	$283,634	$429,626	**$2,210,000**
Totals	**$3,431,182**	**$670,958**	**$1,741,297**	**$5,843,437**

Table 5: District contributions for Moose Hill facility investment (Source: SEA Consultants, Inc. ,1986)

The cost of building the treatment facility had significantly increased in 42 years. An official from WhiteWater, Inc. noted that construction costs for a 1.44 MGD treatment facility in Whitin and a 1.44 MGD treatment facility in Sutton was $1.8 million and $6 million, respectively (WhiteWater, Inc., personal communication, December 8, 2015). Knowing the amount of funds necessary, not one district could afford to do this on their own, leading to the conclusion that some form of consolidation or agreement must occur if all three districts look to use the Moose Hill Reservoir.

Finding 10: To make major progress with the Moose Hill Reservoir, there must be a treatment facility built in compliance with Surface Water Treatment Regulations, as well as a connection to the existing Leicester Water District distribution system

As seen in Table 4, the cost of building a treatment facility is roughly $3.6 million as of 2008. The facility itself would have the capacity to treat on average 1.5 million gallons of water per day; the plant would also have to meet all regulations enforced by the MassDEP regarding the Surface Water Treatment Rule. This rule requires that water systems filter and disinfect water from surface water sources to reduce the occurrence of unsafe levels of contaminants within the water source (USEPA, 2012). The last tests conducted in 1996 confirmed the water quality of Moose Hill Reservoir, the 2008 feasibility study incorporated these tests. In Table 6 we

compared the water quality tests done in 1996 to those tests done in 1965. The majority of the results were relatively similar. The comparison allowed us to conclude that unless there has been a major contamination of Moose Hill since 1996 the results of a test conducted in 2015 will likely yield similar results.

Parameter Tested	Range (1996)	Range (1965)	EPA Reg. Limit
Turbidity	0.5 – 1.5	1	5
Color	50 – 130	55 – 65	15
pH	5.5 – 7	6.0 – 6.3	6.5 – 8.5
Iron	0.07 – 0.7	0.05 – 0.07	0.3
Manganese	0.03 – 0.3	0.02 – 0.04	0.05
Hardness	X	40 – 44	X
Coliform	X	<10 – 10	X

Table 6: Moose Hill raw water quality comparison of 1965 and 1996 to EPA standards (Sanitary, 1986).

Overall the samples had good water quality, except for watercolor. As discussed in Chapter 2.1.1, good water quality has characteristics including but not limited to low turbidity, low total coliform counts, low concentrations of dissolved metals, great taste, and lack of smell. The water also contains low levels of iron and manganese that would require further treatment. The treatment facility would need to be outfitted to treat for the total coliform levels, in order to lower them to levels accepted by the EPA.

Chapter 6: Recommendations

Throughout our project, we created several recommendations for the Town of Leicester and its three water districts. The issues with the water districts management mainly fell under two categories: water quantity and water quality. Our recommendations include options that would address both of these problems and are divided up into short term and long term recommendations. Additionally, we provide recommendations on further studies and necessary research.

6.1 Short-term Recommendations

Recommendation 1: Cherry Valley & Rochdale should consider forming an interconnection with the City of Worcester.

The Cherry Valley & Rochdale Water district is going to need to find new sources of water within the next decade or two in order to meet current and future water demand, the water district should consider temporarily forming an interconnection with the City of Worcester. In doing so, they could halt all water extraction from Henshaw Pond as part of their mitigation process. According to Director Guerin, the Worcester Water Department can make short-term contracts, five years, with outside water systems (P. Guerin, personal communication, November 16, 2015). This short-term agreement would give Cherry Valley & Rochdale Water District an adequate supply of safe drinking water while district officials plan for a long-term solution. The water district would need to ensure that the water quality would not degrade within their distribution system, so this interconnection would require building a chemical booster station. According to Superintendent Knox of the Cherry Valley & Rochdale Water District, forming an interconnection is expected to cost around $750,000-$1,500,000 (personal communication, December 1, 2015).

Recommendation 2: Hillcrest Water Supply District should consider continuing to buy water from the Leicester Water Supply District.

Until the Hillcrest Water District decides on a plan to supply its own water, we recommend the water district continue to buy water from the Leicester Water Supply Department. The Leicester Water Supply Department has enough water in the short-term to provide for the water district. According to Hillcrest Water Supply's 2014 Annual Statistical Report, the district has purchased 850,000 gallons of water from the Leicester Water Supply Department. Hillcrest Water Supply District should also consider creating comprehensive Master

Plan to develop a vision of how the Board of Commissioners and customers want to see their water district grow and operate to the best of their ability.

6.2 Long-term Recommendations

Recommendation 3: The Leicester Water Supply and Hillcrest Water Supply Districts should evaluate the option of hiring a superintendent to manage both of the water districts.

The purpose of a water district superintendent would be to communicate information between the Board of Commissioners and the water system operators. The Cherry Valley & Rochdale Water District is the only district with a superintendent as of 2014. The Leicester and Hillcrest Water Supply Districts currently do not have a superintendent. We spoke with a water operator who represented both the Leicester and Hillcrest Water Supply Districts. Based on our experiences, we were able to acquire more feedback and information from the superintendent of Cherry Valley and Rochdale Water District. Through no fault of any person, there was a delay in our first contact with the water operator.

The main reasons for this delay may have been due to understaffing, as discussed in the Leicester Case Study. We recommend that Leicester and Hillcrest Water Supply Districts evaluate the feasibility and benefits of hiring a superintendent to work with both water districts. As Leicester Water Supply District currently maintains responsibility for the operation of Hillcrest Water Supply District, having one superintendent for both districts would allow the Board of Commissioners of each district to effectively communicate with the water system operators. Additionally, a superintendent would be able to assist the water system operators with management, alleviating part of the understaffing challenge. Therefore, hiring a superintendent for these water districts would allow for accessible representation for information-sharing and decision-making purposes.

Recommendation 4: All of Leicester's water districts should consider having quarterly meetings between their Board of Commissioners and Superintendents.

In order to improve communication between the water districts, we recommend that the districts schedule time for quarterly meetings with the Board of Commissioners and Superintendents. These meetings would work to limit confusion between the districts over where information is stored. During our project, an operator from the Leicester Water Supply District believed maps for their district might be located in the Cherry Valley & Rochdale Water District office. By having these quarterly meetings, they can help each other find information and provide guidance. For example if one water district is facing an issue with the age of their pipes and discusses their challenges at the quarterly meeting, other districts may be able to provide guidance on potential solutions or check to make sure their own district does not have the same issues. Improving communication between the Leicester's water districts would also increase their knowledge base. The meetings between the water districts could be used as an opportunity to share knowledge and brainstorm effective ways to manage and operate the water districts.

Recommendation 5: All of Leicester's water districts should evaluate the possibility of consolidating into one new water district.

There are two options we suggest the water districts' Board of Commissioners and customers consider to consolidate all of Leicester's water districts. The first is to consolidate the water districts management. Shared management responsibilities would include billing, work hour records, and oversight of the water districts' Master Plans. By consolidating management, communication between each of the water districts would improve. This is because the new management board would have knowledge of what challenges and improvements are being addressed in each of the water districts. Therefore the new management board would be able to communicate the improvements and issues that other districts are facing, and perhaps a different district already knows a way to address the issues.

The second option is to consolidate their entire operations. This approach would allow the water districts to pool together their financial resources for capital investment. By consolidating the water district's financial resources, the newly consolidated district would be able to take advantage of economies of scale. There are several fixed costs that could be reduced if the water districts consolidate such as the billing process or the purchase of chemicals. Each of Leicester's water districts have capital improvements that need to be completed for the water distribution systems to be maintained and operating effectively. Through consolidation, the new water district would be able to save money on fixed costs potentially putting the money towards higher cost projects.

Recommendation 6: The newly consolidated water district should consider contracting an on-call employee from a water consulting company.

We recommend that the newly consolidated water district consider hiring an on-call employee from a water consulting company. The water district could negotiate the contract so they have a certified operator available if they are particularly busy or to ensure there is a personnel who can provide guidance on new regulations, compliance, and capital improvements to make sure the water system is functioning optimally. As some of the operators in the water districts are still learning the intricacies of the water system, a certified operator could train them on new regulations and operations.

Recommendation 7: The Town of Leicester should consider working with the Moose Hill Water Commission to certify Moose Hill as a drinking water source.

One of the main issues the Moose Hill Water Commission faced was how to gain support and commitments from all of the water districts. Therefore, we recommend that the Town of Leicester evaluate the benefits of helping the Moose Hill Water Commission fund the initial investment needed to start certifying Moose Hill Reservoir as a drinking water source. Once these new studies and research have been completed, the Commission would be able to tell the

districts that with their commitment of using Moose Hill Reservoir as their main water source it would be very likely that the MassDEP would approve the surface water source. The Commission should communicate to the water districts that a commitment to use the reservoir is necessary to ensure its approval.

Recommendation 8: If all of Leicester's water districts consolidate, the new water district should evaluate the possibility of using Moose Hill Reservoir as a drinking water source.

By consolidating water districts, the Moose Hill Reservoir could potentially be developed into a new drinking water source. Since Moose Hill Reservoir has the capacity to serve the entire town, the Cherry Valley & Rochdale Water District would then be able to stop buying water from the Worcester Water Department once the reservoir was operational. Additionally, Hillcrest Water Supply District would no longer be dependent on Leicester Water Supply District to supply their water demand deficit. This long term goal could then improve the water quality of the entire town. It is important for the water districts to be consolidated before utilizing Moose Hill Reservoir so that the water system would be exempt under the Interbasin Transfer Act.

Recommendation 9: The town should consider financing free lab tests for the residents on private wells.

As stated in the Leicester case study, the town rests above an arsenic and uranium belt. In order to attract more customers towards public water, these residents must be aware of the water quality of their private well water. We recommend that the town consider funding the cost for private well residents to test their water; lab tests for arsenic and uranium cost between $15 to $30 (Cerutti, 2015). Assuming that there are 3,300 and each household shelters 2.5 people, the total costs of providing lab tests for each household on well water ranges between $19,800 to $39,600 annually.

While testing well water for arsenic is not too costly, testing well water for other chemicals or organics requires more funds. A basic profile package costs $150 to test for total

coliform, bacteria, nitrite, iron, manganese, pH, and other substances/characteristics. These packages can reach upwards of $500 depending on targeted contaminants, but all packages include collection and transport of samples by a certified operator (Premier Laboratory, 2015). The lab results may possibly exhibit to private well residents that maintaining a private well requires more expertise and funds than expected. If these lab tests are successful in bringing in some residents onto public water, Leicester's customer base would increase.

6.3 Further Study

The Town of Leicester and the three water districts should meet and discuss all of the potential options for water management available. The residents should be involved in the process of selecting the new water management structure, if any, they wish to implement. Once the town, residents, and water districts have decided on an approach to move forward, there should be more research on different methods of funding as well as specific costs of the approach (provided by consulting firms). We recommend that the use of state grants and Massachusetts State Revolving Fund loans should be explored. Additionally, we strongly recommend that an engineering firm or consultant become involved when researching specific implementation costs for each change to the water system.

6.4 Conclusion

The water districts in Leicester have been working to improve their water systems to meet the quality standards and the demand of their residents, but they need to make larger scale improvements that could help serve the residents of Leicester for the foreseeable future. The approaches we have identified outline long-term and short-term investments that the water districts can decide upon to achieve their goal of improved water quantity and better water quality. These approaches, ranging from consolidation to interconnecting with Worcester for additional water, serve as a means for the districts to work together in various capacities to meet

the needs of their town. In addition to these approaches, we have provided a GIS map of the Town of Leicester's three districts that highlights the key components of the water districts distribution network. This map, and the project as a whole, encourages the water districts to pool resources and work together to strive for the well-being and prosperity of the Town of Leicester.

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APPENDICES

Appendix A: SDWA Monitoring Requirements

Regulation	Monitoring Requirement
Total Coliform	• Samples must be collected at sites that are representative of the water throughout the distribution system based on a sample siting plan that is subject to review by the primacy regulatory agency. • The minimum number of samples that must be collected per month depends on the population served by the system. • For each positive total coliform sample, there are various repeat sampling requirements.
Surface Water Treatment Result and Long Term Enhanced Surface Water Treatment Rules	• Disinfectant residuals must be measured at TCR monitoring sites. • Disinfectant residual must be monitored at the entry to the distribution system. Larger systems (>3,300 population) must provide continuous monitoring. Systems serving less than 3,300 population can take grab samples.
Lead and Copper Rule	• All systems serving a population >50,000 people must do water quality parameter (WQP) monitoring. • Samples must be collected for Pb/Cu at Tier I sites. The number of sample sites for Pb/Cu and water quality monitoring is based on system size.
Stage 2 Disinfectants/Disinfection By-Products Rule	• Standard Monitoring Program requires one year of data on THMs and HAAs. Number of sampling locations based on utility size and source characteristics. Modeling can reduce sampling requirement.

Table 7: Federal Distribution System Water Quality Monitoring Requirements (Drinking, 275)

Appendix B: Water Treatment Process

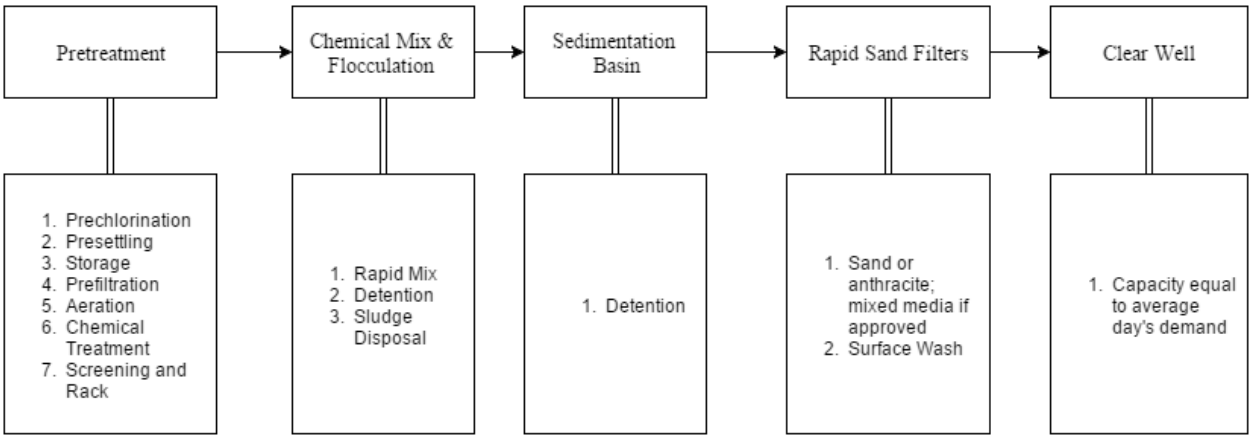

Figure 13: Typical Schematic of Water Treatment Process

Appendix C: Water Districts' Water Usage Distribution and Volume of Usage

District	Cherry Valley & Rochdale Water			Hillcrest Water Supply*			Leicester Water Supply		
	No. of Services	Total Vol. (MGY)	Vol/Service (MGY)	No. of Services	Total Vol. (MGY)	Vol/Service (MGY)	No. of Services	Total Vol. (MGY)	Vol/Service (MGY)
Residential	1186	51.1	0.043	373			583	39.1	0.067
Residential Institutions	4	5.4	1.35				32	8.9	0.278
Commercial/Businesses	60	2.98	0.05	2			64	17.4	0.272
Agricultural	0	0	0				0	0	0
Industrial	0	0	0				0	0	0
Municipal/Institutional/Non-profit	8	1.37	0.171	4			5	1.5	0.3
Other	2	0.42	0.21				0	0	0
Total	1260	61.27			22.736		684	66.9	
*Hillcrest Water Supply District doesn't meet the 100,000 gal/day of water distributed that would require them to report this information									

Table 8: Water usage distribution by sector for each water district in Leicester, MA

Appendix D: Interview Questions

Preamble:

We are a group of students from Worcester Polytechnic Institute (WPI) working on a project with the Massachusetts Department of Environmental Protection and the Town of Leicester. We are conducting this interview in order to learn more about the [X] water district. By participating in this interview, we hope to learn more about [X] water districts water quality and water demand. Your participation is completely voluntary and you can choose to end the interview at any point. If you would like, we can keep your identity confidential. We greatly appreciate your participation. If you would like, we can provide you with our final project report.

Interview Questions for the Moose Hill Water Commission:

1. Could you provide us an overview of the Moose Hill Water Commission?
2. What is your role in the Moose Hill Water Commission?
3. Can you tell us more about what capabilities the water management system at Moose Hill Reservoir?
    a. How much water would the facility be able to provide?
    b. Does the 2008 feasibility study outline more of the information?
4. We have found information about the safe yield that has been estimated for the Moose Hill Reservoir for 2010. Has that prediction changed since 2010, and is there new information about the safe yield for 2015?
5. We know that there have been previous feasibilities studies done on turning Moose Hill Reservoir into a drinking water source. We found a reference to a study done in 2008. Can you provide us with further information on the study?
6. If Moose Hill Reservoir was to be used as a drinking water source, has the commission considered whether it would form another water district in Leicester or combine with another water district?
7. We know that there have been some shortages in water in Leicester's three districts. How do you think Moose Hill Reservoir would best be utilized to help this situation?
8. What do you think are some of the challenges of utilizing Moose Hill Reservoir?
    a. What do you think might be the best situation for Leicester?
9. Did Moose Hill ever receive a Class A certification from the MassDEP? If so, we found out that they expire in 5 years, so would Moose Hill need to reapply?
10. We are trying to get a full sense of the capacity and water needs of Leicester, do you have any other recommendations for anyone else we might connect with?

Interview Questions for the Cherry Valley & Rochdale Water District:

1. What is your role in the CVRWD?
2. Could you tell us about the water district in general?
    a. What are the current water rates?
    b. What are the current operational costs involved in treating, distributing, and acquiring water ?
    c. How many employees are there?
3. Do you have the projected rates and demands?
    a. Projected service connections?
4. Do you face any challenges in meeting this future demand?
5. What would you like to see happen?

6. What still needs to be improved within the district to address compliance issues? How would you implement them?
    a. Conduct updated hydraulic study of the distribution system and resolve any hydraulic deficiencies
    b. Implement corrective actions to prevent chemical addition port manhole located at the Henshaw WTF flooding
    c. Install booster chlorination at water storage tanks according to all applicable standards and with proper Bureau of Resource Protection WS permits (added in chlorine at the top of tank beforehand)
    d. Install 24 mesh screening on storage tank overflows and KOH vent at WTP
    e. In regards to this compliance issue, have there been any changes made to the management system since that water quality test?
    f. What do you think is the underlying cause of these issues? How did they occur?
7. Are there any existing maps containing the water distribution networks, water sources, etc.?
8. What is the annual budget for the water district operations?
    a. What sort of budget or capital requests does the district have in progress for improving the water quality/quantity of the district?
9. Do you have any other recommendations for anyone else we might connect with?

<u>Interview Questions for the Leicester Water Supply District</u>

1. What is your role in the LWSD?
2. Could you tell us about the water district in general?
    a. What are the current water rates?
    b. What are the current operational costs involved in treating, distributing, and acquiring water?
    c. How many employees are there?
3. Would you have the projected rates and demands?
4. Would you face any challenges in meeting this future demand?
5. What still needs to be improved within the district to address compliance issues? How would you implement them?
    a. Submit confirmation that Pierce Spring Source (07G) will be removed from service or that the LWSD intends to comply with filtered SWTR provisions within 18 months.
    b. Submit proper chemical addition reports for sodium hypochlorite addition at all facilities. Monthly chemical treatment reports are required to be submitted by 10th day of following month.
    c. Install air gaps at Paxton Rd. Booster Pump Station (analyzer discharge) and Rawson pump station (floor drain discharge). Submit confirmation upon completion.
6. What would you like to see happen?
    a. What still needs to be improved within the district? How would you implement them?
7. What are your top concerns about the LWSD?
8. Are there any existing maps containing the water distribution networks, water sources, etc.?
9. Can you explain the relationship between LWSD and HWSD?

10. What is the annual budget for the water district operations?
    a. What sort of budget or capital requests does the district have in progress for improving the water quality/quantity of the district?
11. Do you have any other recommendations for anyone else we might connect with?

Interview Questions for WhiteWater Inc.

1. What is your role at WhiteWater, Inc.?
2. In your experiences, are there any strategies or ideologies to follow when working with small town water systems?
    a. What aspects of a town would you consider when dealing with multiple water districts within a town?
3. Several of Leicester's water district representatives we spoke with mentioned the Interbasin Transfer Act. Since Leicester is located on three river basins, if they were to utilize another water source would they be exempt from this act even though there are separate water districts?
    a. If they wanted to sell extra water to another town in a different basin, then would they need to apply for an interbasin transfer?
4. We have considered the cost and impact when brainstorming potential improvements to their system. Are there anything additional aspects of the water district system that we should consider in our proposed changes?
5. [X] is one of our ideas to improve the water management systems. Do you see any holes in our logic that we need to consider?
    a. If this model were to be implemented, what are the steps necessary for its success? What is some of the drawbacks with implementing [X] idea?
    b. Leicester & Hillcrest Consolidation: Hillcrest does infrastructure improvements and then consolidate with Leicester.
    c. Worcester Interconnection with Cherry Valley (either shutting down or keeping open CVRD).
    d. Looking for new water sources for each district.
    e. Consolidating all the water districts, keeping them the same but bringing them all under one management system.
    f. Cost and implementation of improving a groundwater source (Grindstone well).
6. How do you plan for future water source development?
    a. Moose Hill Reservoir Development
7. What do you think the benefits and drawbacks of privatization are?

Interview Questions for Worcester Water Department

1. What is your role in the Worcester Water Department?
2. In your opinion, would the Worcester facilities be able to provide water such that it would be cost-efficient for the Town of Leicester?
    a. Are there any concerns about the quality of water degrading when traveling from the water treatment plant in Worcester to the tap quality provided in Leicester?

   b. Does Worcester have enough water supply to form an interconnection with Worcester?
3. What are some of the obstacles in enacting this proposed plan?
   a. Interbasin Transfer act
   b. Water rates increases
   c. Does Worcester have any infrastructure improvements that would be required of Cherry Valley before supplying them water?
4. Do you have any concerns about the interconnection with all the districts? Why?
5. Would you be able to provide any costs for interconnection between all the water districts or the costs with connecting with Cherry Valley?
6. Can you give us a contact with an engineering firm that would be happy to help students in researching costs?
   a. Consolidation costs? Treatment plant costs? Source costs?
7. Do you have any questions for us?

Interview Questions for Connecticut Water Company

1. Can you provide us with an overview of the Connecticut Water Company?
   a. What are your roles?
2. Tell them about the situation in Leicester:
   a. Three water districts: Leicester, Hillcrest, and Cherry Valley/ Rochdale
   b. No standard approach and each with different challenges
3. What are the benefits of consolidating water systems?
   a. Can you provide any examples of districts that have consolidated and where we could obtain that information?
      i. Actual plans
   b. Is there a general process of consolidation (i.e. steps)?
   c. Was there a general increase or decrease in water rates for residents?
   d. Do you know of the average cost for consolidation?
4. Have you ever worked with small systems who want to remain independent?
   a. Politics/history between districts, don't want to take on infrastructure improvements, etc.
5. What are your opinions on using private water consultants or companies to operate small water systems?

Appendix E: Comparison of Water District Rates

Charges	Hillcrest Water Supply (Rates as of 2012)	Charges	Leicester Water Supply (Rates as of 2015)	Charges	Cherry Valley & Rochdale (Rates as 2012)
Base Charge (0-500CF)	$65.00	**Base Charge**	$45	**Base Charge (0-235CF)**	$32.5
1st Step (501-3000CF)	$3.65/100CF	**1st Step (1-4000CF)**	$2.57/100CF	**1st Step (236-1000CF)**	$7.50/100CF
2nd Step (Over 30001CF)	$7.84/100CF	**2nd Step (4001-12,000CF)**	$4.13/100CF	**2nd Step (1001-1500CF)**	$8.15/100CF
Cost per Quarter	$298.31	**3rd Step (Over 12,000)**	$6.86/100CF	**3rd Step (15001-2000CF)**	$8.80/100CF
Cost per Month	$99.44	**Cost per Quarter**	$181.36	**4th Step (Over 2000CF)**	$9.45/100CF
		Cost per Month	$60.45	**Cost per Quarter**	$440.238262
				Cost per Month	$146.7460873

Table 9: Water rate charges in each district in Leicester, MA

Appendix F: Informed Consent Form

Investigators: Timothy Berube, Yao Yuan Chow, Anna Franciosa, Aditya Nivarthi

Contact Information:

Timothy Berube: Tel. 603-738-5322, Email: tjberube@wpi.edu

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Title of Research Study: Massachusetts Water Resource Outreach Project: Water Management in Leicester

Sponsor: Massachusetts Department of Environmental Protection (MassDEP) & the Town of Leicester

Introduction:
You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study:
The purpose of this study is to identify the challenges the Town of Leicester's three water districts are facing and potential improvements that can be made to the water management systems. We will prepare a comparative analysis for each available solution that will help Leicester improve its water quality and meet its current and future water demands.

Procedures to be followed:
Before each interview or focus group, we will have each of the participants sign a written consent form. During this process, one member of our group will also read our prepared preamble to introduce the participants to the purpose of the activity. Once we have gained permission to continue our research activity from each participant who is willing to participate, we would begin the interview or focus group with any initial questions or brief overview of completed research. The main goal of these interviews and focus group is to obtain their input and answers. If for any reason the participants are unwilling to answer a specific question, they would be free to do so and we would not continue on that subject.

Risks to study participants:
If we uncover any incidental findings that may lead to enforcement action by the MassDEP, these findings may prove to be detrimental to the subject's reputation. Depending on the subject's connection to these findings, risks may include loss of reputation for the subject, the subject's place of work, the Town of Leicester due to any enforcement actions or any other actions to address the situation as the MassDEP sees fit.

Benefits to research participants and others:
Participants in our research will not receive any individual benefits. The Town of Leicester can expect to have solution(s) to choose from when implementing a new water system in their town. These solutions would have the goal of improving system compliance with regulations, and increase the water supplied to the town.

Record keeping and confidentiality:
Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you. If we, the investigators, wish to use your name in our publication or presentation, we will ask for your written consent to do so, which you retain the right to allow or deny.

Compensation or treatment in the event of injury:
This research does not involve any risk of physical injury or harm to the participant. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact:

WPI IRB Chair, Professor Kent Rissmiller: Tel. 508-831-5019, Email: kjr@wpi.edu

University Compliance Officer, Jon Bartelson: Tel. 508-831-5725, Email: jonb@wpi.edu

For contact information of the Investigators, please refer to the top of this document.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the research activities at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ Date: _____
Study Participant Signature

_____
Study Participant Name (Please print)

_____ Date: _____
Signature of Person who explained this study

Appendix G: Written Consent Form

I, _____, give my permission for the Massachusetts Water Resource Outreach Center: Water Management in Leicester project group to identify me by name and position title in their final project report. I reserve the right to withdraw this permission at any time via written and verbal communication with the project investigators.

_____ Date: _____
Study Participant Signature

_____
Study Participant Name (Please print)

Appendix H: Cherry Valley & Rochdale Capital Improvements Needed

A. Recommended improvements as cited in 1989 Water Distribution System Analysis	
1. Main Street (clean and line) from Bottomly Avenue to Chapel Street 2,010 ft. of 12 CIP	$180,900.00
2. Main Street (new) from Bottomly Avenue to McCarthy Avenue 2,170 ft. of 12 CIP	$195,300.00
3. Pleasant Street (clean and line) from Rochdale Standpipe 800ft. of 16 DIP.	$96,000.00
4. Booster Pumps (approx.. 70 homes)	$203,000.00
5. McCarthy Avenue (new) from main Street to Bethel Avenue 660 ft. of 8" DIP.	$46,200.00
6. Watch Street (new) from Mill Street to end of Watch Street 1,000 ft. 8" DIP.	$70,000
B. *Hydrant Upgrades*	$5,500.00
C. *Water Main Upgrades*	
1. Henshaw Street (new) from Virginia Drive to end of Henshaw 1,735 ft. of 8" DIP.	$121,450.00
2. Virginia Avenue (new) from Henshaw Street to end of Virginia Avenue 380 ft. of 8" DIP.	$26,600.00
3. Lillian Avenue (new) from Henshaw Street to end of Lillian Avenue 475 ft. of 8" DIP.	$32,250.00
4. Gold Court (new) 185 ft. of 8" DIP.	$12,950.00
5. Foster Court (new) 200 ft. of 8" DIP.	$14,000.00
6. Dale Court (new) 250 ft. of 8" DIP.	$17,500.00
7. Denny Place (new) 160 ft. of 8" DIP.	$11,200.00
8. Commins Road (new) 1,500 ft. of 8" DIP.	$105,000.00
9. Stafford Street (new) from Oxford town line to Charlton town line 1,725 ft. of 12" DIP.	$155,250.00
10. Green Street (new) 400 ft. of 8" DIP.	$28,000.00

11. Pitcairn Avenue (new) to Peter Salem Road 900 ft. of 8" DIP.	$63,000.00
12. Henshaw Street (new) from #149 to #155 800 ft. of 8" DIP.	$56,000.00
13. Harding Street (new) from Willow Hill Road to end of Harding Street 300 ft. of 8" DIP.	$21,000.00
14. Olney Street (new) from Church Street to end of Olney Street 385 ft. of 8" DIP.	$26,950.00
15. Verona Avenue (new) from Towtaid Street to end of Verona Avenue 170 ft. of 8" Dip.	$11,900.00
16. South Street (new) from Bottomly Avenue to end of South Court 235 ft. of 8" DIP.	$16,450.00
17. Ingram Road from Stafford Street to #11 Ingram Road 350 ft. of 8" DIP.	$24,500.00
18. Folsom Street from Stafford Street to #6 Folsom Street 280 ft. of 8" DIP.	$19,600.00
D. *System Wide Meter Upgrades*	$536,750.00
Total	**$2,097,250.00**

Table 10: Cherry Valley & Rochdale Water District's needed capital improvements and their costs.