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October 4, 2019

Mr. Dennis Deziel, Regional Administrator
EPA New England, Region 1
5 Post Office Square, Suite 100
Boston, MA 02109-3912

Dear Mr. Deziel,

The City of Worcester is pleased to present its Integrated Water Resources Management Plan to EPA Region 1 and the Massachusetts Department of Environmental Protection.

The Integrated Plan identifies and evaluates infrastructure investments for the City's water resources systems, which consist of the drinking water system, wastewater and stormwater systems, and the Upper Blackstone Wastewater Treatment Facility.

The Integrated Plan addresses the most pressing health and environmental protection issues by giving priority to infrastructure investments that result in greater environmental benefits more quickly for each dollar spent. It includes detailed analyses of the City's financial capability to implement the Integrated Plan and its affordability for our residents and ratepayers.

Also accompanying this letter are additional documents to be included in the multi-volume compendium of studies and capital project reports previously submitted. The compendium provides Region 1 with a readily accessible reference set of documents and provides a snapshot of the current state of Worcester's capital improvement program.

We welcome your review and feedback, and look forward to meeting with you to present an overview of the Integrated Plan.

Sincerely,

Paul J. Moosey, P.E.
Commissioner

cc: Martin Suuberg, Commissioner, MassDEP
Mary Jude Pigsley, Regional Director, MassDEP
Edward M. Augustus, Jr., City Manager, City of Worcester

CITY OF WORCESTER
Department of Public Works & Parks

INTEGRATED WATER RESOURCES MANAGEMENT PLAN

October 2019

Clean Worcester WATERS
Planning for practical, affordable solutions

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Executive Summary

Effectively managing the water resources necessary to support healthy and resilient communities has become an increasingly daunting challenge for governments at all levels. Two federal environmental laws, the Clean Water Act and the Safe Drinking Water Act, establish programs to ensure safe and productive natural environments and public drinking water supplies. The costs of meeting the goals of these two laws are astronomical, and local, state and federal officials must work cooperatively and share responsibility for clean, affordable water. The costs associated with maintaining, upgrading and replacing aging water infrastructure in the United States are projected to surpass $1 trillion dollars over the next 25 years.

For Worcester, the costs are particularly sobering. Over the 50-year planning period of this Integrated Plan, the City estimates state and federal mandates related to water resources capital spending could exceed $2.6 billion. That figure does not include a huge corresponding escalation in operating expenses. The capital spending estimate dwarfs the capital costs of all other municipal services combined and is not sustainable or affordable for the City's 187,000 residents and its businesses.

That is particularly true given Worcester's demographics. According to recent data, the median household income was $45,869, more than $25,000 below the State median income of $74,167. Income per capita in recent years has ranked near the 10th percentile among Massachusetts communities. Worcester's per capita income of $20,978 ranked 315 out of 351 municipalities, and its income distribution shows a greater proportion of households at low-income levels and fewer households at high-income levels when compared to the State and country as a whole.

In addition to a comparatively low-income population, the City is home to a number of Environmental Justice communities as defined by the state and the United States Environmental Protection Agency (EPA). Over 70 percent of the population is in an Environmental Justice community.

This Integrated Plan analyzes potential infrastructure investments in the following water resources systems:

- Drinking water supply
- Drinking water treatment and distribution
- Wastewater collection
- Stormwater collection
- Upper Blackstone Wastewater Treatment Facility

EPA's "Integrated Municipal Stormwater and Wastewater Planning Approach Framework" encourages municipalities to address the most pressing health and environmental protection issues first. This Integrated Plan attempts to do exactly that by giving priority to infrastructure investments that will result in greater environmental benefits more quickly for each dollar spent.

A related EPA policy, the "Financial Capability Assessment Framework for Municipal Clean Water Act Requirements," recognizes that the Safe Drinking Water Act obligations of a community can be an important consideration in establishing schedules for implementing integrated plans, and this Integrated Plan includes drinking water costs in the City's financial capability assessment.

Investment in the City's drinking water infrastructure is essential to protecting public health. Therefore, drinking water system investments and associated annual spending are the top priority, as reflected in the Drinking Water System Capital Improvement Plan detailed in this Integrated Plan. The current and projected investment requirements for drinking water infrastructure are well understood and are presented with confidence.

In contrast, the selection and analysis of potential wastewater, stormwater, and Upper Blackstone Treatment Facility infrastructure investments are much more complex. A more detailed approach to identifying and assessing such investments has been followed in preparing the Wastewater and Stormwater Systems Capital Improvement Plan, included herein.

This Integrated Plan allows for significant updates on a continuing basis using adaptive management principles and represents a sound, responsible and realistic strategic plan.

ABOUT

CHAPTER 1. Introduction

The United States Environmental Protection Agency (EPA) has been working in recent years with states and cities to address the overwhelming financial burden of ensuring safe and productive water environments and public drinking water supplies. The huge costs associated with implementing two federal laws — the Clean Water Act and the Safe Drinking Water Act — are borne almost entirely by municipalities and have become unsustainable at the local level.

Two interrelated EPA initiatives attempt to encourage a cost-effective approach that addresses the most pressing public health and environmental protection issues first. EPA's integrated planning policy, endorsed by new federal legislation, recognizes how difficult and expensive it is for cities to complete wastewater upgrades, stormwater improvements, and related projects while providing other necessary municipal services. In conjunction with integrated planning, EPA has developed a framework policy for assessing a community's financial capability to meet its water resource management obligations.

The financial capability policy encourages local governments to consider their needs under the Safe Drinking Water Act as well as the Clean Water Act.

Integrated planning is a tool that allows municipalities to meet multiple Clean Water Act obligations by optimizing infrastructure investments through appropriate sequencing. This approach allows municipalities to schedule investments "so that the highest priority projects come first" and address "the most serious water quality issues first." The integrated planning approach is designed to provide sustainable and comprehensive solutions "that improve water quality and provide multiple benefits that enhance community vitality."[1]

1.1 Integrated Planning

The City of Worcester prepared this Integrated Water Resources Management Plan (Integrated Plan) in accordance with EPA guidance, titled "Integrated Municipal Stormwater and Wastewater

1 EPA Integrated Planning Website

Planning Approach Framework" (EPA integrated planning framework). This framework was enacted into law in January 2019 through the "Water Infrastructure Improvement Act," as Clean Water Act, Section 402(s), 33 U.S.C. 1342(s).

An October 2017 report by a panel of the National Academy of Public Administration, titled "Developing a New Framework for Community Affordability of Clean Water Services," provides an evaluation of EPA's integrated planning framework and highlights best practices in the development of integrated plans. The National Academy of Public Administration recognized the limitations that EPA's framework offers for financial capability analyses, specifically related to accounting for Safe Drinking Water Act requirements. Pitting funding for the Clean Water Act against the Safe Drinking Water Act effectively negates the benefits of integrated planning, and leaves communities struggling to appropriately prioritize investments.

For reference, the National Academy of Public Administration report is included in **Appendix 1.1**, and EPA's integrated planning framework documents, including the Water Infrastructure Improvement Act and the EPA financial capability assessment framework, are included in **Appendix 1.2**.

This Integrated Plan follows EPA's integrated planning framework and the National Academy of Public Administration's recommendations and provides a 50-year management plan for Worcester's water resources infrastructure. By compiling capital and operations and maintenance programs into a comprehensive plan, improvements may be implemented to address the most pressing needs with solutions that offer the greatest benefits.

By establishing metrics for measuring system performance and pursuing benefits that reflect the City's goals, this Integrated Plan provides a road map for management of water resources systems.

1.2 Background

The City was first settled nearly 350 years ago and has grown to be the second largest city in New England. Despite its geographic isolation, Worcester became a major manufacturing center, which led to its rapid development through the 19th century. The Blackstone Canal was constructed in 1828 linking Worcester and Providence and a railroad first opened in 1835 between Worcester and Boston. These transportation improvements made Worcester a crossroads and offered the possibility of large-scale manufacturing. Industry boomed in the 40 years after the Civil War, resulting in population growth from 50,000 to 118,000 as the number of workers and the value of their output doubled. Mechanical innovations in Worcester included machine tools, wire products, and power looms.

This rapid growth affected the natural resources within the City. Development increased impervious surface in the form of roofs, sidewalks, pavement, and other hardscape. Streams that used to serve as drainage for forested land or agriculture carried increased runoff. The City commenced building its wastewater collection system in the mid-1800s, initially with a combined system designed to carry both wastewater and stormwater to the Blackstone River. Some of these system components, a third of which were constructed prior to 1900, continue to serve the City. The City's built and natural environment is further described in **Chapter 2**.

1.3 Demographics

Worcester has a population of 187,000 with a density of approximately 4,915 persons per square mile, compared with the statewide average of 840 persons per square mile. Worcester's population is racially and ethnically diverse. Approximately 21% of residents are foreign-born and over 90 languages are spoken. Seventy-nine percent of the students in the public school system are classified as high needs, which includes students with disabilities and students that are economically disadvantaged. These conditions are important to consider as the City must place a priority on education when establishing annual spending budgets.

Because of its diverse population and low median household income, large portions of the City are designated as Environmental Justice communities. In Massachusetts, Environmental Justice populations are defined as neighborhoods that meet one or more of the following:

- 25% of households have a median annual household income equal to or less than 65% of the statewide median for Massachusetts
- 25% or more of the residents identify as minority
- 25% or more of the residents have English isolation

The locations of Worcester's Environmental Justice communities are shown in **Chapter 7**.

This Integrated Plan seeks to incorporate infrastructure renewal that directly benefits Environmental Justice communities. As an example, Worcester's public bathing beaches are in close proximity to Environmental Justice communities. Therefore, improvement in recreational water quality will directly reduce public beach closures and benefit public health for Environmental Justice communities.

The most flood-prone areas of the City are Environmental Justice neighborhoods. These communities also have the least financial capability to support increased water and sewer rates that will result from major water infrastructure investments.

1.4 Management of City Water Resources Systems

Keeping drinking water, wastewater, and stormwater systems in good working order, and maintaining a high level of service, is demanded by users. Achieving these objectives for a city of Worcester's size and age requires substantial investment and effort.

The drinking water system, which treats and distributes an average of 23 million gallons of clean drinking water a day throughout the City and to adjacent towns and water districts, includes 10 reservoirs and 15 dams.

The wastewater system, dating back over 150 years continues to deteriorate in ways that impact public health and the environment, and interrupt service.

The stormwater system, originally designed to manage runoff from a less urbanized area, has become overwhelmed as impervious cover and development has increased runoff that contributes to widespread flooding.

The drinking water, wastewater and stormwater systems are regulated by EPA and the Massachusetts Department of Environmental Protection (MassDEP) as independent infrastructure. These systems are linked, justifying an integrated management approach.

Major infrastructure investments were completed over the past 40 years to comply with the Clean Water Act and Safe Drinking Water Act. These projects were costly and limited the ability to maintain and improve wastewater and stormwater collection systems. Approximately one-third of these systems were constructed over 100 years ago and have exceeded their service life. Structural condition and capacity of pipelines are a major concern — the approximate cost to upgrade wastewater and stormwater pipelines and pump stations is $700 million. Roughly one-third of maintenance costs address failures or other emergencies. This results in hundreds of street flooding and service disruption calls each year. If the City continues to defer investment in its collection systems emergencies and costly reactive maintenance will increase and threaten public health, safety, and the environment.

The wastewater collection system carries municipal sewage through 400 miles of pipelines, and includes 29 pump stations. Wastewater is conveyed to the Upper Blackstone Water Pollution Abatement District's wastewater treatment facility (Upper Blackstone Treatment Facility).

The combined sewer system, which comprises 15% of the collection system, includes the Quinsigamond Avenue Combined Sewer Overflow Treatment Facility (Quinsigamond Avenue CSO Treatment Facility), which pumps wastewater to the Upper Blackstone Treatment Facility during typical dry weather operation. During significant rainfall events, the Quinsigamond Avenue CSO Treatment Facility stores, treats, and discharges to the Blackstone River.

The stormwater system collects runoff from the City's streets and other drainage conveyance systems and discharges to surface waters through 349 outfalls.

Details of the City's water resources systems, including its drinking water system, are described in **Chapter 3** of this Integrated Plan.

1.5 The Political and Budgeting Processes

Worcester residents and businesses provide funding for municipal services through tax rates, fees and charges, and water and sewer user fees. The tax levy budget and enterprise funds are budgeted separately, but are subject to the appropriation authority of the Worcester City Council.

1.5.1 Budget Procedure

The budget is developed consistent with Massachusetts General Laws Chapter 44, requiring adequate appropriations for salaries, ordinary maintenance, debt service, fringe benefits, and capital outlay. The City of Worcester budget recommendation is developed in a manner consistent with the City's adopted Financial Plan (detailed in the following section).

The City Council has jurisdiction to make reductions but cannot increase the proposed budget without the recommendation of the City Manager.

1.5.2 Property Tax Levy

Worcester's largest source of revenue is the local property tax levy. The property tax levy is the aggregate revenue raised from the annual tax assessment on the value of real (land and buildings) and personal (equipment and machinery) property. When combined with other local receipts (motor vehicle excise tax, licenses and permits, hotels and meal taxes, etc.) Worcester generates 53% of its revenues locally (per the City's FY 2019 budget).

Massachusetts municipalities are limited in their ability to increase property taxes on an annual basis. Proposition 2½ (Mass. Gen. L. c. 59, § 21C) is a Massachusetts statute that limits property tax levy. Proposition 2½ puts constraints on the amount of the levy raised by the City and how much it can be increased each year. A community cannot levy more than 2.5% of the total full and fair cash value of all taxable real and personal property (known as the tax levy ceiling) and can only increase 2.5% year to year excluding new growth (known as the levy limit). The levy limit will always be below or equal to the levy ceiling. The limit for each community is calculated by the Massachusetts Department of Revenue.

An effect of Proposition 2½ is that municipal property tax revenue will decline in real terms whenever inflation rises above 2.5%. Historically, inflation in the United States has been above 2.5% for a significant majority of the years since 1980 (24 out of 37 years according to historic inflation rate data based upon the consumer price index).

1.5.3 Budget Limitations

The budget process requires the City Manager and the City Council to set priorities as they collectively decide how to spend the City's limited resources with a requirement to balance the budget. After education and fixed costs, only 23% of the budget remains for appropriation for public safety, public works and parks, economic development, and the public library.

Worcester, like most municipalities, has unfunded pension and other post-employment benefits obligations, which currently total $1.3 billion.

1.5.4 Enterprise Funds

The water and sewer systems operate through enterprise funds, which establish a "separate accounting and financial reporting mechanism for a municipal service for which a fee is charged in exchange for goods or services." (M.G.L. c. 44, §53F½)

The sewer enterprise is responsible for the collection and conveyance of sanitary sewage and stormwater throughout the City of Worcester. The sewer enterprise fund pays for these services, including costs for wastewater treatment at the Upper Blackstone Treatment Facility. The annual sewer enterprise budget has increased from approximately $15 million in FY 2004 to $44.3 million for FY 2019.

The water enterprise is responsible for the provision of safe drinking water to Worcester residents and businesses. The FY 2019 drinking water enterprise budget is $26.4 million. Annual water and sewer rate recommendations are necessary to ensure that both funds are sufficient to meet the needs of the utilities. Both budgets are expected to rise with the implementation of this Integrated Plan as fixed costs rise and the need for capital improvements becomes more critical.

Although water and sewer enterprise funds are billed separately from City property taxes, the funding sources are the same — residents and businesses.

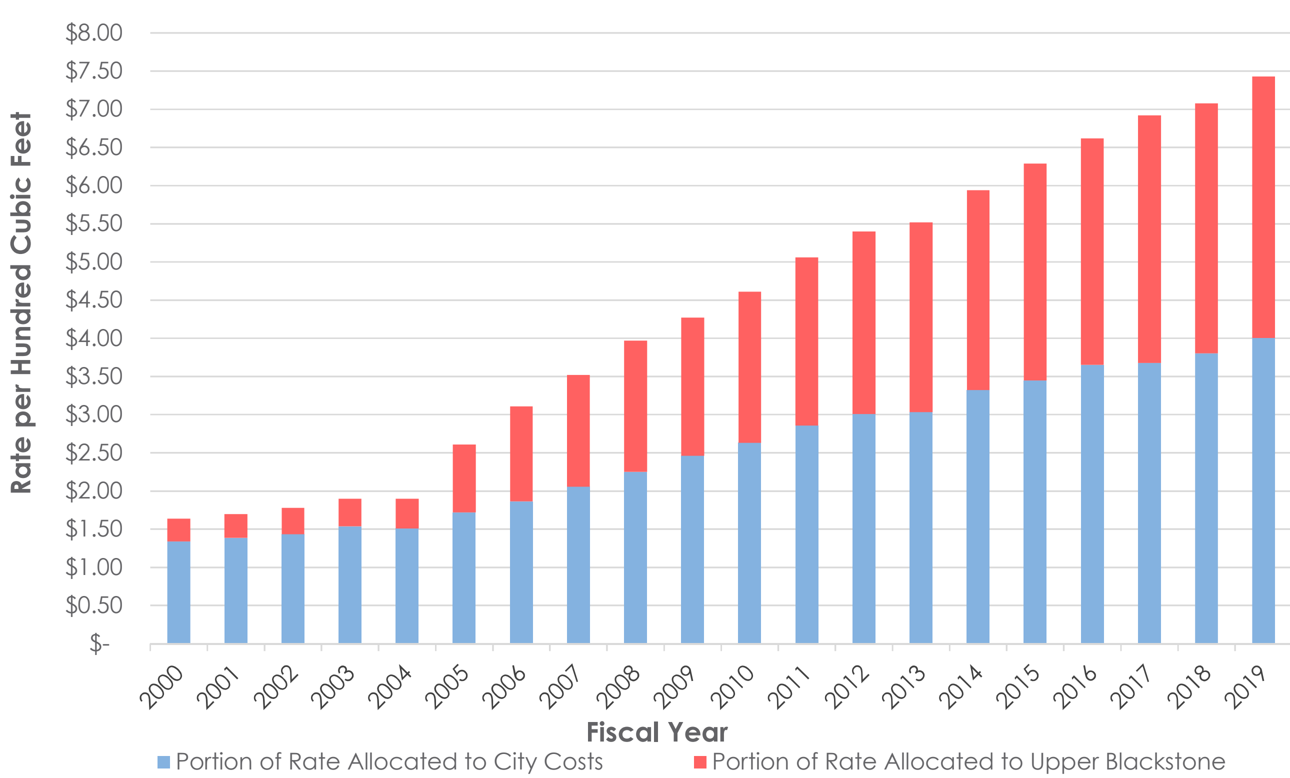
1.5.5 Water and Sewer Rates

Historically, water and sewer rates in Worcester, like other cities in the northeast, were relatively low even as the City continued major improvements to its water resources infrastructure. In the 1980s, with EPA grant assistance, the City focused on major flood reduction and combined sewer overflow elimination. In the 1990s, the City constructed its Water Filtration Plant to improve drinking water quality and meet newly enacted Safe Drinking Water Act standards. This initiative had a major impact on water rates, resulting in reduced investments and lower sewer rates to offset increases in water rates.

By the mid-2000s, the City began paying its share of major upgrades required to meet the 2001 National Pollutant Discharge Elimination System permit for the Upper Blackstone Treatment Facility. These major initiatives limited investments in wastewater and stormwater infrastructure within the City. The latest investments at the Upper Blackstone Treatment Facility resulted in a 350% rate increase over the past 15 years. In 2000, approximately 18% of the sewer rate was allocated to wastewater treatment at the Upper Blackstone Treatment Facility. By 2019, the portion allocated to the Upper Blackstone Treatment Facility increased to 46%, as shown in **Figure 1.1**. Had rate hikes been held at 2.5% per year, similar to property taxes, the FY 2019 rate would be at $2.69. The actual FY 2019 rate of $7.43 is 176% higher.

The City must account for the financial impacts when considering adjustments to water and sewer rates. Given that the City's budget is constrained, and water and sewer funding sources are limited, financial capability is a critical consideration in development of this Integrated Plan. **Chapter 7** details the financial capability assessment that forms the basis for determining affordability and the Integrated Plan's implementation schedule.

FIGURE 1.1: WORCESTER SEWER RATES, FISCAL YEAR 2000-2019



1.6 Worcester's Approach to Integrated Planning — Features and Benefits

The City developed its Integrated Plan to achieve the following goals:

- Protect public health and safety:
  - Maintain high-quality drinking water.
  - Reduce frequency and occurrence of sanitary sewer overflows.
  - Minimize basement backups of sewage caused by wastewater system deficiencies.
- Protect and improve full-contact recreational waters:
  - Lake Quinsigamond, Indian Lake, Coes Reservoir, Bell Pond, and Cook Pond.
- Manage stormwater:
  - Reduce the frequency, duration, and extent of flooding, particularly the Green Island neighborhood.
  - Manage wet weather flows to Upper Blackstone Treatment Facility.
  - Improve quality of stormwater discharges.
- Maintain affordable water and sewer user rates.
- Improve treatment effectiveness and operations at the Quinsigamond Avenue CSO Treatment Facility.

The guiding principles in the development of this Integrated Plan include:

- Use performance trends to help identify needs
- Maximize benefits using Triple Bottom Line (environmental, social, economic) principles
- Balance federal Clean Water Act obligations with other regulatory and non-regulatory responsibilities
- Develop a plan that manages rate impacts
- Consider operation and maintenance costs associated with infrastructure investments
- Include drinking water supply and treatment, drinking water distribution, wastewater treatment, wastewater collection, stormwater management, and flood control in long-term planning
- Identify operation and maintenance, capital projects, and investigations that address system needs
- Manage infrastructure to reduce risk and minimize reactive maintenance
- Use a long-term planning horizon as required to control costs
- Incorporate an adaptive management approach that will continuously update the Integrated Plan
- Develop priorities in a data-driven, transparent, defensible, and repeatable manner
- Maintain regulatory compliance

A benchmarking study was conducted to document system performance and understand system needs. A multi-criteria benefits model was developed to assist with selecting the most beneficial infrastructure investments. The benefits model results consist of numerical scoring to guide development of an implementation plan.

1.6.1 Alternative Spending Scenarios

A long-term financial plan was prepared that evaluated six alternative spending scenarios for wastewater and stormwater system investments using a financial model to project the associated rate increases for the Sewer Enterprise Fund over the first 20 years of the Integrated Plan. The City also evaluated annual spending levels for drinking water system investments and projected the associated rate increases for its Water Enterprise Fund.

1.6.2 Implementation Schedule

This Integrated Plan incorporates the City's Drinking Water System Capital Improvement Plan, which includes infrastructure investments in the drinking water system. It consists of a 50-year planning period starting with FY 2021 at an estimated cost of $538 million.

The Integrated Plan also includes a Wastewater and Stormwater Systems Capital Improvement Plan. It consists of a 50-year planning period starting with FY 2021 at an estimated cost of

$1.27 billion, not including an estimated $811 million required for the City to comply with the draft 2008 National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit, if finalized.

This Integrated Plan gives priority to the following wastewater and stormwater considerations:

- Infrastructure investments with the highest score, using the multi-criteria benefits model
- Addressing backlog of known critical capital reinvestment projects
- Balancing of new capital investment, capital reinvestment, and studies and assessments
- Maintaining wastewater treatment facility operations
- Coordinating and phasing of investments

The sequencing of wastewater and stormwater system maintenance and infrastructure investments is based on the benefits model results. Annual spending is guided by cost determinations from the financial capability assessment. Worcester's financial capability may change along with other factors that impact rates. The implementation schedule is intended to be modified at appropriate intervals throughout the planning period as financial conditions change.

1.6.3 A Plan to Improve the Community

The Integrated Plan addresses local needs while contributing to regional benefits, including:

- Replacing obsolete and failing sewer infrastructure to reduce risk to the community and environment
- Reducing flooding to protect public safety and minimize the potential for surface water contamination
- Removing extraneous flow within the sanitary sewer system to restore capacity and reduce the potential for sanitary sewer overflows
- Reducing high flows in the sewer system during wet weather to improve treatment effectiveness at the Upper Blackstone Treatment Facility
- Implementing best management practices to improve stormwater discharge quality

This approach to integrated planning is consistent with EPA's integrated planning framework, the National Academy of Public Administration report, and Section 402(s) of the Federal Water Pollution Control Act.

1.7 EPA Framework and Elements of the Integrated Plan

This Integrated Plan is organized in accordance with EPA's Integrated Planning Framework, included in **Appendix 1.2**. Each element of EPA's integrated planning framework is outlined with reference to the corresponding chapter(s) of this Integrated Plan.

Element	Chapter
ELEMENT 1. WATER QUALITY, HUMAN HEALTH & REGULATORY ISSUES	**Chapter 2:** Public Health, Water Quality, and Regulatory Challenges
ELEMENT 2. EXISTING SYSTEMS & PERFORMANCE	**Chapter 3:** Existing Water Resources Management Systems Performance
ELEMENT 3. STAKEHOLDER INVOLVEMENT	**Chapter 4:** Public Participation Process
ELEMENT 4. IDENTIFYING, EVALUATING & SELECTING ALTERNATIVES, & PROPOSING IMPLEMENTATION SCHEDULES	**Chapter 5:** Selecting Options for Improving Water Resources Infrastructure **Chapter 6:** Evaluation & Screening of Infrastructure Investments **Chapter 7:** Financial Capability Assessment **Chapter 8:** Development of Integrated Plan
ELEMENT 5. MEASURING SUCCESS	**Chapter 9:** Measuring Success — Post Construction Monitoring Plan
ELEMENT 6. IMPROVING THE PLAN	**Chapter 10:** Adaptive Management Process

The color scheme depicted above is used throughout this Integrated Plan as an aid to the reader in aligning the chapters with the associated elements of the EPA integrated planning framework.

CHAPTER 2.
Public Health, Water Quality & Regulatory Challenges

2.1 Overview

The City of Worcester faces growing challenges in effectively managing its water resources systems to support its growing population, thriving residential, commercial, and industrial sector, and healthy and productive natural environments. The environmental and regulatory challenges summarized in this chapter give context to the City's need for an affordable and cost-effective plan for improving its water resources systems while meeting the needs of its ratepayers, supporting growth, and addressing regulatory requirements.

Protecting public health and maintaining water quality are important functions of the City. The wastewater and stormwater collection systems can threaten public health and safety through deteriorating and failing infrastructure, which can manifest as surface flooding, and sanitary sewer overflows, which result in degradation of water quality.

At the state and federal level, regulatory requirements influence protection of public health as it relates to operation of the wastewater and stormwater collection systems. Policies and guidance establish minimum standards for system operation and maintenance. These standards are useful in establishing metrics for meeting the City's objectives that relate to the water resources systems. It is critical that the evaluation metrics for identifying, comparing and selecting infrastructure investments focus on public health and water quality goals.

Through this Integrated Plan, the City has used these regulatory metrics as a starting point for evaluation of investments focusing on protecting public health and safety, while tailoring the plan to fit the City's infrastructure needs.

Surface water quality is also defined through state and federal laws and policies, which focus on water classifications, designated uses and impairments. All water bodies within Worcester are classified as Class B waters by Massachusetts Surface Water Quality Standards, which are designated for wildlife habitat as well as primary and secondary contact recreation. However, not all water bodies are currently used for primary contact. Further classification of waters is based on the State's Integrated List of Waters, which identifies the cause of water quality impairment — typically pathogens, nutrients and/or total suspended solids.

This Integrated Plan establishes a hierarchy that classifies surface waters based on the actual recreational use they support. This tiered system allows for measurement of water-quality benefits that reflect the broad objectives of protecting public health and maintaining water quality.

2.2 Built Environment and Public Health

Development and urbanization inevitably changed the natural environment in the City over the nearly 350 years since settlement began. The built environment consists of lands altered to better accommodate changing human needs and values, including residential, commercial, and industrial development. This development has caused Worcester to grow to the second largest city in Massachusetts. It is home to approximately 185,000 residents[1] and 104,000 jobs, including 70,000 daily commuters[2].

Land use has evolved dramatically since the City was chartered in 1848. As shown in **Figure 2.1**, most of the City comprises residential development (approximately 40% of land area), with commercial and industrial development concentrated in the central part of the City.

High density development surrounds most water bodies in the City. The largest of these water bodies are Lake Quinsigamond, Indian Lake, and Coes Reservoir.

Development impacts the natural environment, including water bodies and their tributary areas. Development is often characterized by increased impervious surface in the form of roofs, sidewalks, pavement, and other hardscapes. Where streams used to serve as drainage for forested land use or agriculture, they now carry runoff from impervious surfaces. Runoff contributes a significantly greater flow rate, volume, and contaminant loading into receiving water bodies. Worcester's complex topography with numerous and steep hills creates additional challenges for stormwater management and water quality.

As part of the City's growth and development, the water resources systems have changed and expanded. These systems have aged to a point where a significant portion of pipelines and appurtenant components are well beyond their useful life. Failing infrastructure, combined with the effects of urbanization, threatens public health and safety through surface flooding and degradation of surface water quality:

- Aging infrastructure is more prone to failure. Failing infrastructure can collapse and cause sinkholes in the public right-of-way.
- Flooding can lead to injury or death depending on the location and severity.
- Flood waters contain contaminants, and the public's health and property are at risk from direct exposure.

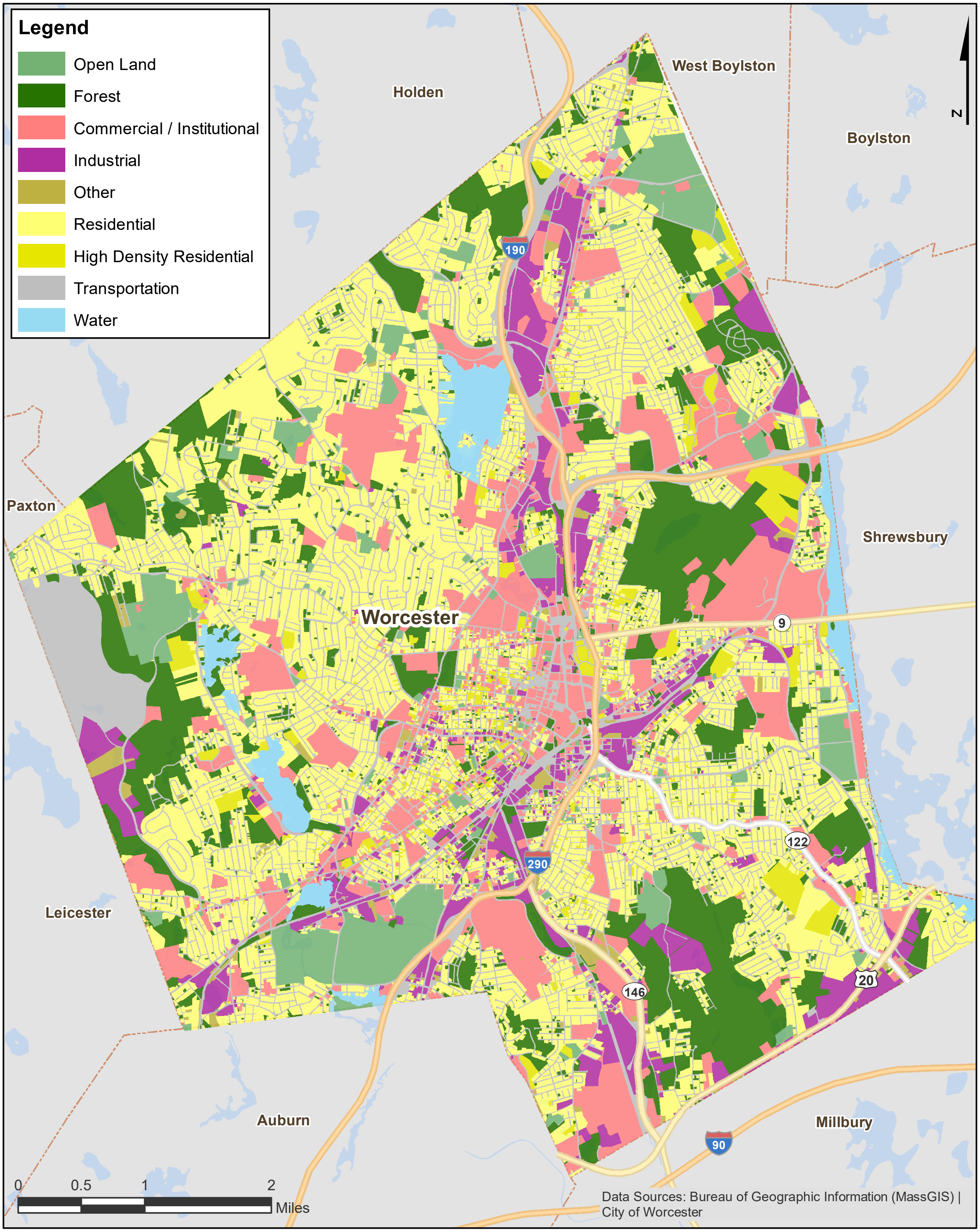
Lake Quinsigamond

Indian Lake

Coes Reservoir

1 United States Census Bureau
2 Worcester Regional Research Bureau

FIGURE 2.1: EXISTING LAND USE (2005 MASSDEP)



- Sanitary sewer overflows and basement backups result in exposure to untreated wastewater.
- Sewer overflows, as well as exfiltration (leaking sewer pipes) have the potential to reach the stormwater system, which discharges into local water bodies.
- Discharge of untreated wastewater into surface waters used for recreation can result in direct exposure and degrade the value of all recreational uses.

2.2.1 Surface Flooding

Impervious surface area and population density contribute to surface flooding, which threatens public health and safety, and the natural environment. Other factors that contribute to surface flooding include wastewater and stormwater system capacity and configuration, topography, and proximity to water bodies.

Flooding on Southgate Street — June 2010.

As Worcester grew into an urban manufacturing center during the mid-1800s, the City built a combined sewer system to convey both wastewater and stormwater from densely developed areas. During dry weather, the combined sewer system conveys only wastewater, but during rain events the system conveys a mix of "combined" wastewater and stormwater. As development moved outward from the City center, separate wastewater and stormwater systems were constructed to serve newer growth areas. Today, a portion (15%) of the wastewater system is still combined. The combined sewer area is in the original urban core of the City, primarily to the east of downtown and in the densely populated Green Island section, as shown in **Figure 2.2**.

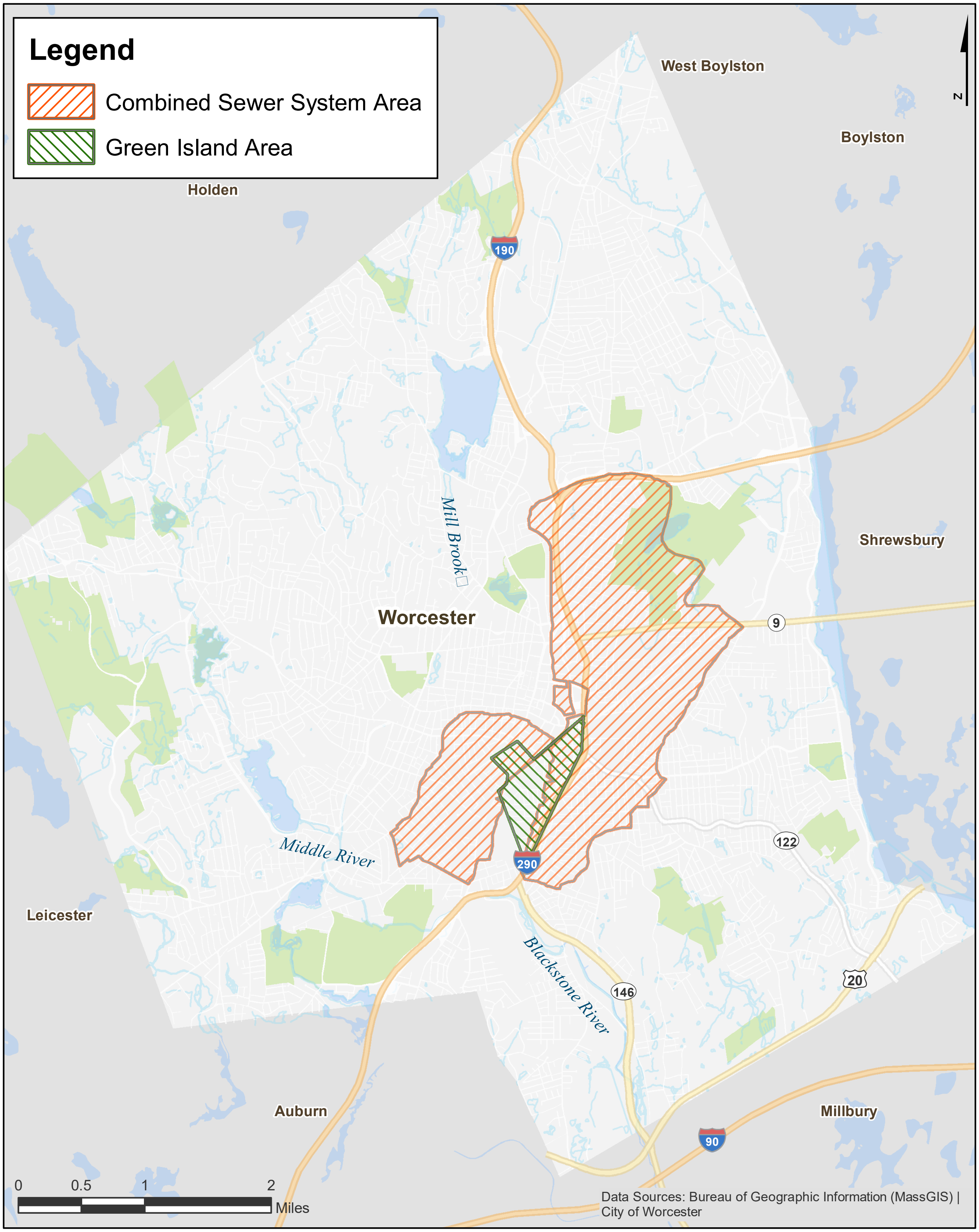
Although surface flooding can occur throughout the City, severe flooding in the Green Island area has been a major problem for residents and businesses for well over a century. Green Island is situated at the lowest elevation in the City, near the confluence of Mill Brook and Middle River (which forms the Blackstone River), and a large portion of the Green Island area is within the Federal Emergency Management Agency flood zone. Because flooding in a combined sewer area has more severe impacts on public health, safety, and the environment than "normal" flooding, the Green Island area continues to be one of the City's highest priorities in terms of flood mitigation and has been the subject of extensive studying over 50 years.

The City occasionally experiences both widespread and localized surface flooding. **Table 2.1** lists flood-prone areas in Worcester. Widespread flooding is typically caused by low-intensity, long-duration rainfall events producing runoff volumes that exceed the hydraulic capacity of the stormwater system. For example, in October 2005, over 12 inches of rain fell during an eight-day period causing rivers and streams to overflow their banks while also inundating the stormwater system and contributing to widespread street flooding.

High-intensity, short-duration rainfall events associated with thunderstorms can also overwhelm the City's stormwater system in areas of vast impervious surface. Examples of the impacts of localized flooding include:

- Flooding on West Boylston Street and Shrewsbury Street caused by topography and inadequate inlet and system capacity; this impacts traffic and businesses along a commercial roadway.
- High water trapped cars and flooded homes in neighborhoods such as Greendale in the northern part of the City as well as Piedmont, Main South, and Green Island in the central and southern parts.
- Flooding caused the closure of 12 streets on October 21, 2016. This is an example of a high-intensity storm event totaling over 4 inches of rain in an eight-hour period, which exceeded the capacity of the stormwater system.

FIGURE 2.2: COMBINED SEWER AND GREEN ISLAND AREAS



All flooding events negatively impact public health and safety, the environment, and the economy. These impacts include:

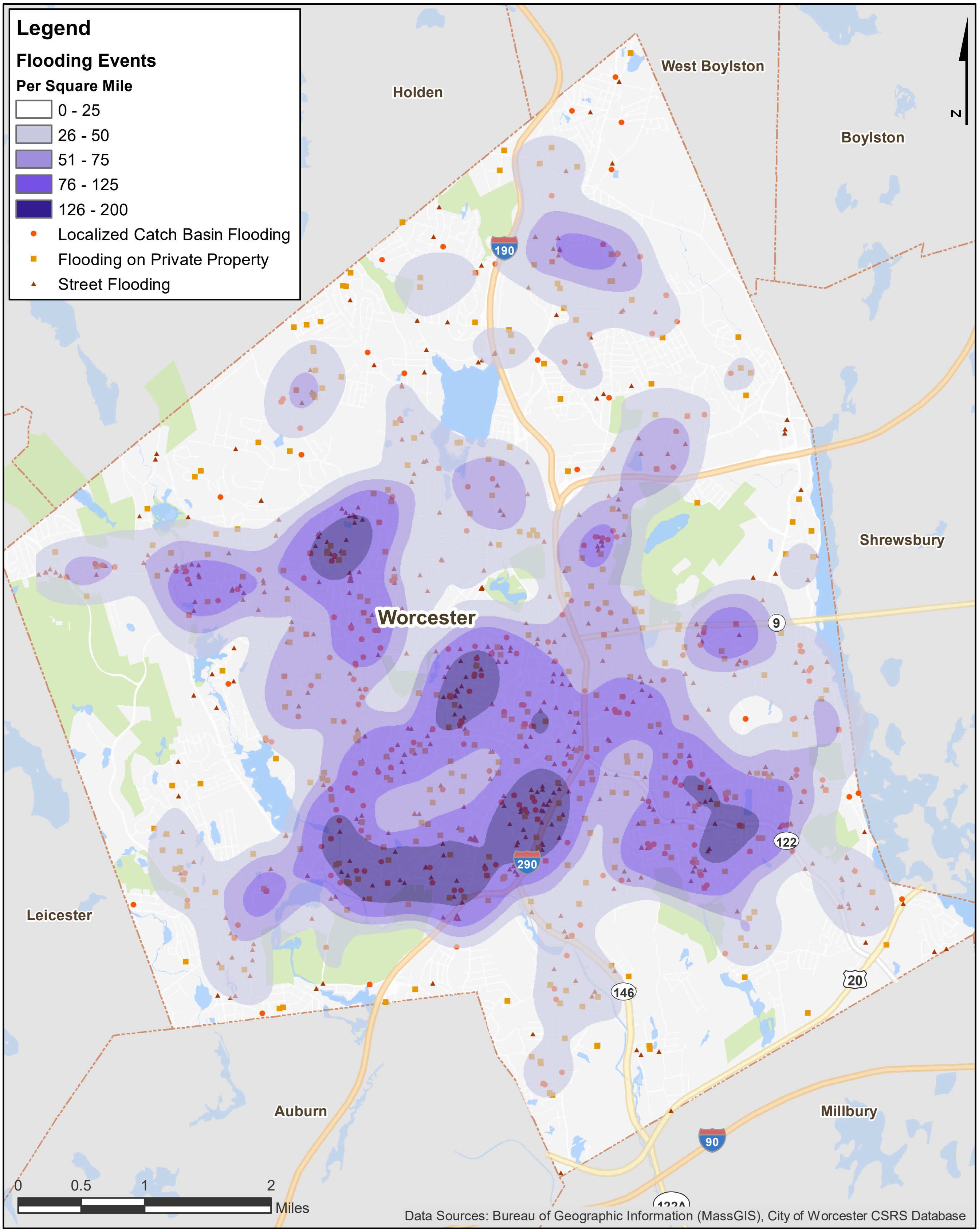
- **Public Health:** Infection, illness, and disease from standing water in streets and on private property, such as basements; flood water, often making direct human contact, carries toxins, bacteria from sewage, and street runoff; mold growth from standing water degrades air quality.
- **Public Safety:** Injuries, drowning, and reduced access to critical services because of flash flooding and high water. Flooding often creates hazardous driving conditions, damage to vehicles, trapped passengers, and closed roadways.
- **Environment:** Degradation of surface water quality because flood water carries toxins, nutrients and solids from sewage, and street runoff. High flow in streams and rivers erodes banks and deposits sediment in lakes and ponds.
- **Economy:** Damage to both residential and commercial buildings and property. Flood waters damage buildings and property resulting in financial costs to homeowners, loss of business and disruptions of commerce and transportation.

The City has developed the Customer Service Request System that allows residents to report issues and request services. Since 2006, over 1,500 instances of either localized catch basin flooding events, flooding in the right-of-way (public streets), and flooding on private property were reported through the Customer Service Request System. **Figure 2.3** illustrates the concentrations of reported flooding events over the past 10 years based on the location data provided with each entry. As expected, most of the areas with a greater concentration of reported flooding events correspond directly to the list of recurring flooding areas, and, in particular, the Green Island area. Additionally, there is a greater concentration of reported flooding events in the South Worcester neighborhoods near Cambridge Street, Main Street, and Park Avenue.

TABLE 2.1: RECURRING SURFACE FLOODING LOCATIONS

Location	Drainage Area
Southbridge Street	Green Island
Southgate Street	Green Island
Cambridge Street	Green Island
Quinsigamond Avenue	Green Island
Pelham Street near Pleasant Street	Beaver Brook
Brownell Street and Calmia Street	Beaver Brook
Creswell Road and Midland Street	Beaver Brook
Paul Revere Drive	Beaver Brook
Mann Street and Lawnfair Street	Beaver Brook
Parker Street and Dewey Street	Beaver Brook
Fitzgerald Brook	Lake Quinsigamond
Brightwood Avenue	Broad Meadow Brook
Dunkirk Avenue	Broad Meadow Brook
West Boylston Street (Greendale Avenue to Quinsigamond Community College)	Weasel Brook
Shrewsbury Street	Mill Brook
Kettle Brook Pond	Kettle Brook
Kettle Brook Pond	Kettle Brook

FIGURE 2.3: CONCENTRATION OF REPORTED FLOODING EVENTS (2006-2016)



Tracking past events has allowed the City to take action to reduce impacts in areas that consistently experience flooding during typical storm events. The Department of Public Works and Parks (DPW&P) has developed several maintenance procedures to help manage and mitigate flooding events, including developing and maintaining multiple databases, consisting of lists of low-lying areas and catch basins that require frequent and priority maintenance; inlets and outlets to be checked and maintained pre-storm; and problematic culverts and choke points in the stormwater system. A sample list is included in **Appendix 2.1**.

2.2.2 Sanitary System Overflows

As with many New England cities and towns, the City's wastewater collection system was built incrementally over the past 150 years. The collection system protects public health by preventing human contact with viruses and other pathogens found in sewage by collecting wastewater from nearly all residential and commercial properties within the City and conveying these flows to the Upper Blackstone Treatment Facility.

Sewer overflow on Wigwam Street.

The wastewater system can fail due to pipe blockages, structural failures, or inadequate hydraulic capacity. If a segment of the collection system fails, untreated sewage can overflow or backup into the natural and built environment causing potential public health impacts, property damage and degradation of water quality. The primary cause of sanitary sewer overflows in the City is the buildup of grease, roots, rags, and other debris — failures unrelated to the capacity or structural condition of the system. These non-capacity related sanitary sewer overflows present challenges in maintaining an aging collection system.

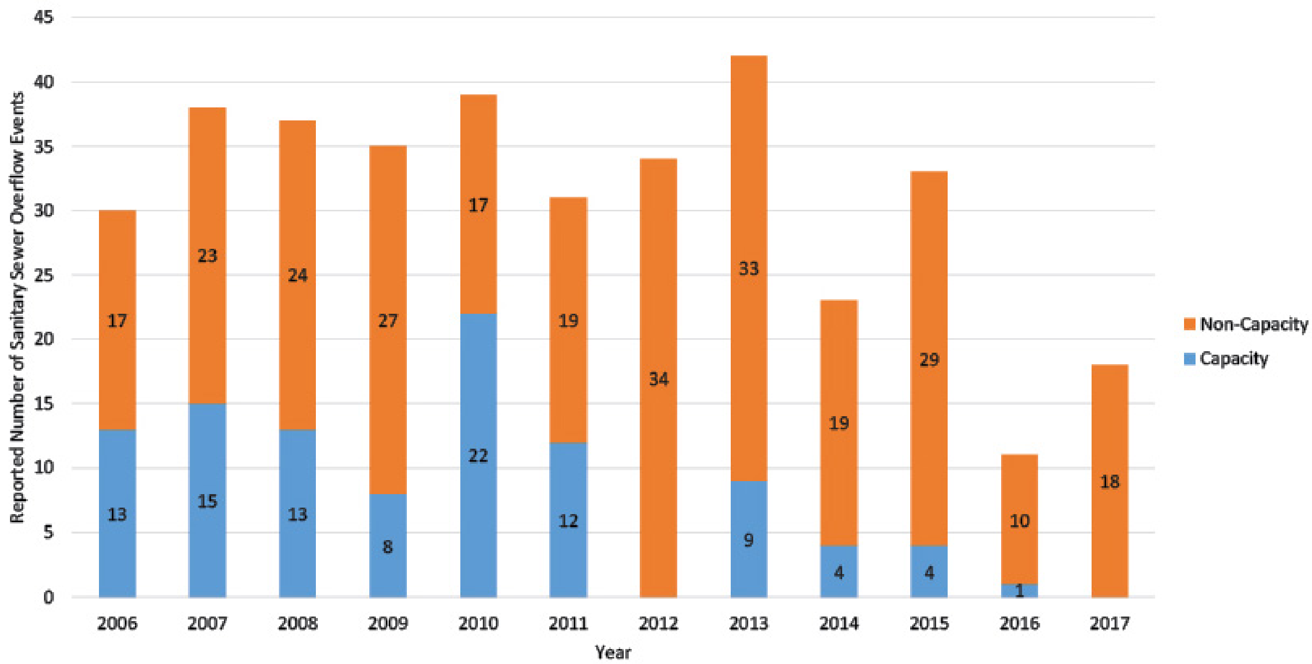
As urbanization and development occurred over many decades, some components of the collection system were not properly upgraded to handle increased flow and provide long-lasting service. Cracked, broken, and failing pipes can lead to debris and root blockages and collapses, as well as introducing groundwater infiltration into the system. Infiltration will occur where groundwater elevation is higher than the sewer pipe and can enter through defects in the pipes.

Extraneous infiltration into the collection system increases the overall volume of flow conveyed to the Upper Blackstone Treatment Facility, which directly increases the cost of treating wastewater. Improper connections such as private roof drain leaders, and sump pumps can introduce extraneous inflow into the wastewater collection system during wet weather. During storms, inflow can far exceed dry weather wastewater flow and the capacity of the system. As an example, the Upper Blackstone Treatment Facility receives 2.5-times the amount of flow during peak wet weather than dry weather wastewater flow. Unlike the combined sewer portion of the wastewater system, which is designed to collect both stormwater and wastewater, infiltration and private inflow sources significantly impact the capacity of the dedicated sanitary collection system throughout the City, resulting in capacity-related sanitary sewer overflows.

Additionally, exfiltration from failing pipes can find its way, directly via the stormwater system or indirectly through the soil mass, into nearby receiving waters. Although not commonly identified as a major source of stormwater pollution, a failing sanitary collection system can be a significant contributor to surface water contamination and degradation.

Figure 2.4 shows the number of capacity and non-capacity sanitary sewer overflows reported per year between 2006 and 2017. The DPW&P continues to work to identify and

FIGURE 2.4: REPORTED SANITARY SEWER OVERFLOWS (2006-2017)



remove infiltration and inflow sources. Since 2010, the City has maintained a downward trend of sanitary sewer overflows attributed to wet weather (capacity related overflows) on an annual basis. Non-capacity related overflows continue to be a challenge to control due to the age of the collection system and the magnitude of maintenance required.

Due to existing wastewater collection system configuration and usage, several localized areas have historically generated sanitary sewer overflows at a higher relative rate. **Figure 2.5** shows locations of sanitary sewer overflow events between 2012 and 2017. Seven localized areas have been identified within the wastewater system that generate overflows on a recurring basis and the typical causes for overflows in those areas (shown in **Table 2.2**).

To reduce these events, problem areas have been targeted with infrastructure improvement projects. The Lake Avenue Pump Station tributary area is an example:

- Between 2006 and 2013, 25 sanitary sewer overflow events, an average of just over three per year, were recorded immediately adjacent to or at the Lake Avenue Pump Station.
- System upgrades completed between 2013 and 2016 included pump station upgrades, infiltration and inflow reduction through pipe and manhole rehabilitation and replacement, and reconfiguration of influent piping to the pump station.
- Since 2013, only one overflow event was recorded in the Lake Avenue Pump Station area.

2.2.3 Twin Invert Manholes

There are over 3,000 twin-invert manholes in the City, through which both wastewater and stormwater pipes enter. These twin-invert manholes are a product of the growth of the infrastructure systems, where development spurred expansion of the wastewater and stormwater systems. During this time, utilizing a single structure for both systems seemingly improved construction efficiency and reduced costs. Although these are separate systems (not part of the combined sewer system), twin-invert manholes represent a potential cross-connection between the two systems. These manholes can allow for cross-flows if either the sewer backs up (due to capacity or non-capacity related issues) and overflows into the stormwater system inside the manhole, or if wet weather storm flow inundates the system and enters the wastewater system, becoming a direct inflow source. Separation plates inside these twin-invert manholes seal the sewer invert so that it does not overflow when the sewer system backs up. These separation plates often require replacement or resecuring.

Detecting contamination caused by twin-invert manholes is often difficult, as is the case with illicit connections, due to the intermittent nature of the cross-flow. Twin invert manholes are being eliminated as their respective sewer mains are replaced, as detailed later in this Integrated Plan. The rate of replacement of these structures will accelerate as the focus of the Capital Improvement Program moves toward collection system (both wastewater and stormwater system) replacement.

2.2.4 Sewer Backups

In addition to sanitary sewer overflows, wastewater backups onto private property are public health threats and also represent a financial liability. In many cases, blockages, failures or inadequate capacity in the sewer system find relief through private sewer service laterals connected to building plumbing. Analysis of the Customer Service Request System database was used to estimate the number of basement backup events.

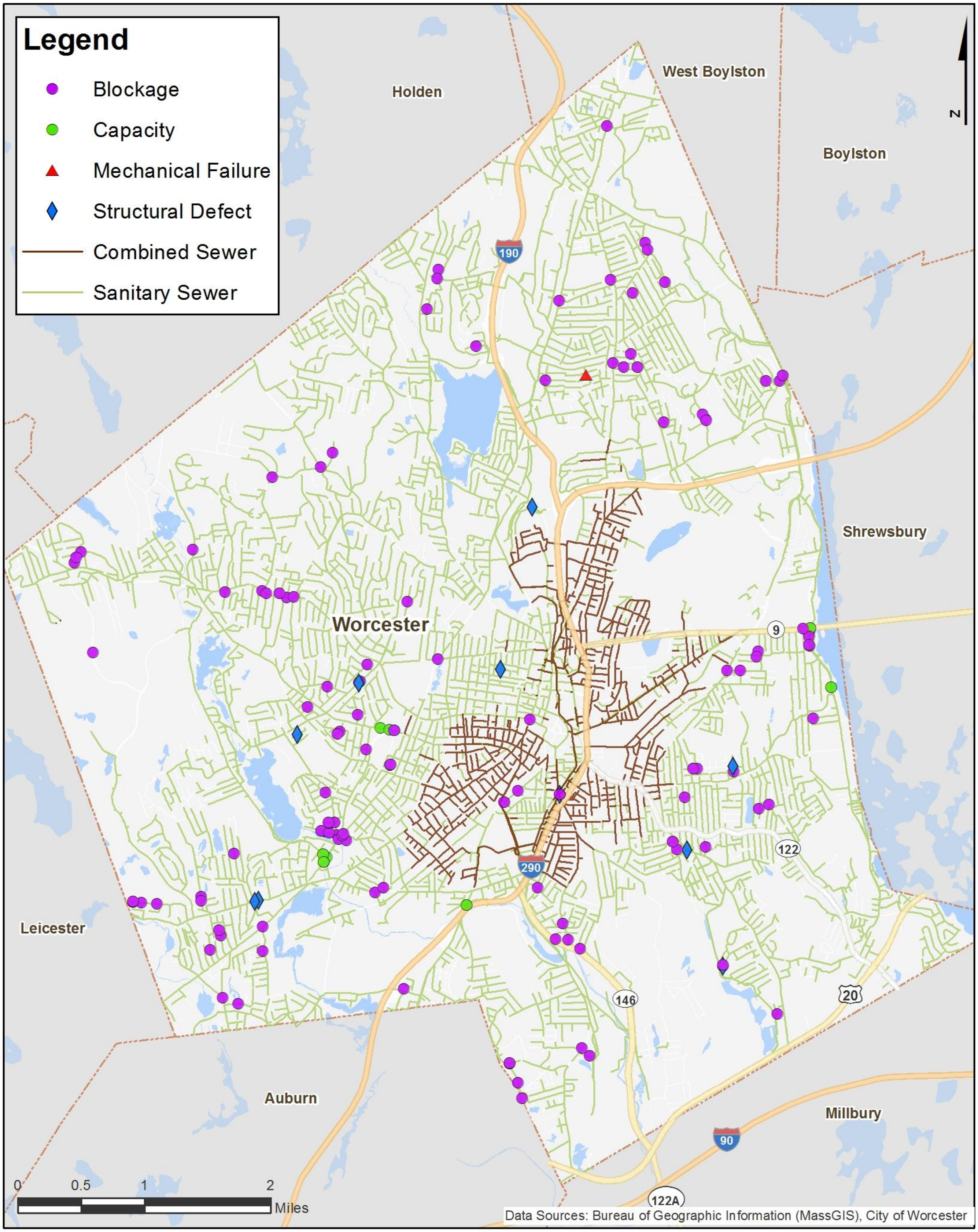
Although reported events are logged in the Customer Service Request System as sewer related, it should be noted this data relies on descriptions provided by residents that are not always confirmed. Therefore, some instances of reported basement backups might have an alternate cause, such as groundwater infiltration or a water service leak. It should also be noted that basement backups and loss of sewer service may be due to failed or blocked sewer laterals, which are the responsibility of the property owner as per City Ordinance. **Figure 2.6** illustrates the concentration of reported sewer backups into basements, and residential and commercial loss of sewer service.

Sewer backup and loss of service can be caused by limited hydraulic capacity of the interceptors during wet weather, backing up wastewater into local collector sewers. The greatest concentration of reported basement backups is in the densely populated neighborhoods between Maywood Street, Cambridge Street, and Park Avenue, where several sewer interceptor pipes converge before conveying flow to the Upper Blackstone Treatment Facility. Other areas with moderate concentration of sewer backups and loss of service correspond to the location of sewer interceptors on Chandler Street and Harding Street.

TABLE 2.2: RECURRING SANITARY SEWER OVERFLOW CAUSES (2012-2017)

Location	Typical Cause	Water Body Impacted	Year of Most Recent Sanitary Sewer Overflow
Vernon Street at Millbury Street	Flushable Wipes, Grease, Debris	Middle River	2016
Upland Gardens Drive	Grease	Blackstone River	2016
Massasoit Road near Crowningshield Pump Station	Grease, Roots	Broad Meadow Brook	2016
Lakeside Avenue and Park Avenue	Grease, Wet Weather — Inadequate Capacity	Beaver Brook	2017
Cherry Valley Area	Roots, Structural Condition, Grease, Debris	Curtis Pond, Kettle Brook	2017
Chandler Street at Foley Stadium	Wet Weather — Inadequate Capacity	Beaver Brook	2016

FIGURE 2.5: RECURRING SANITARY SEWER OVERFLOW LOCATIONS (2012-2017)



The areas of Worcester illustrated in **Figures 2.3, 2.5** and **2.6** face the greatest threats to public health and safety from surface flooding and sewer system backups and overflows, as compared to other areas. Consequently, these areas have historically been the focus of ongoing maintenance and improvement projects. Worcester's Environmental Justice communities reside in most of these densely populated areas (northeastern, central, and southwestern portions of the City) and public beaches are also in these areas. These public health impacts disproportionately affect low-income communities. This Integrated Plan reduces these public health and safety threats by focusing on areas of flooding, sewer backups and overflows, and protecting the most sensitive communities through targeted infrastructure investments.

2.3 Natural Environment and Water Quality

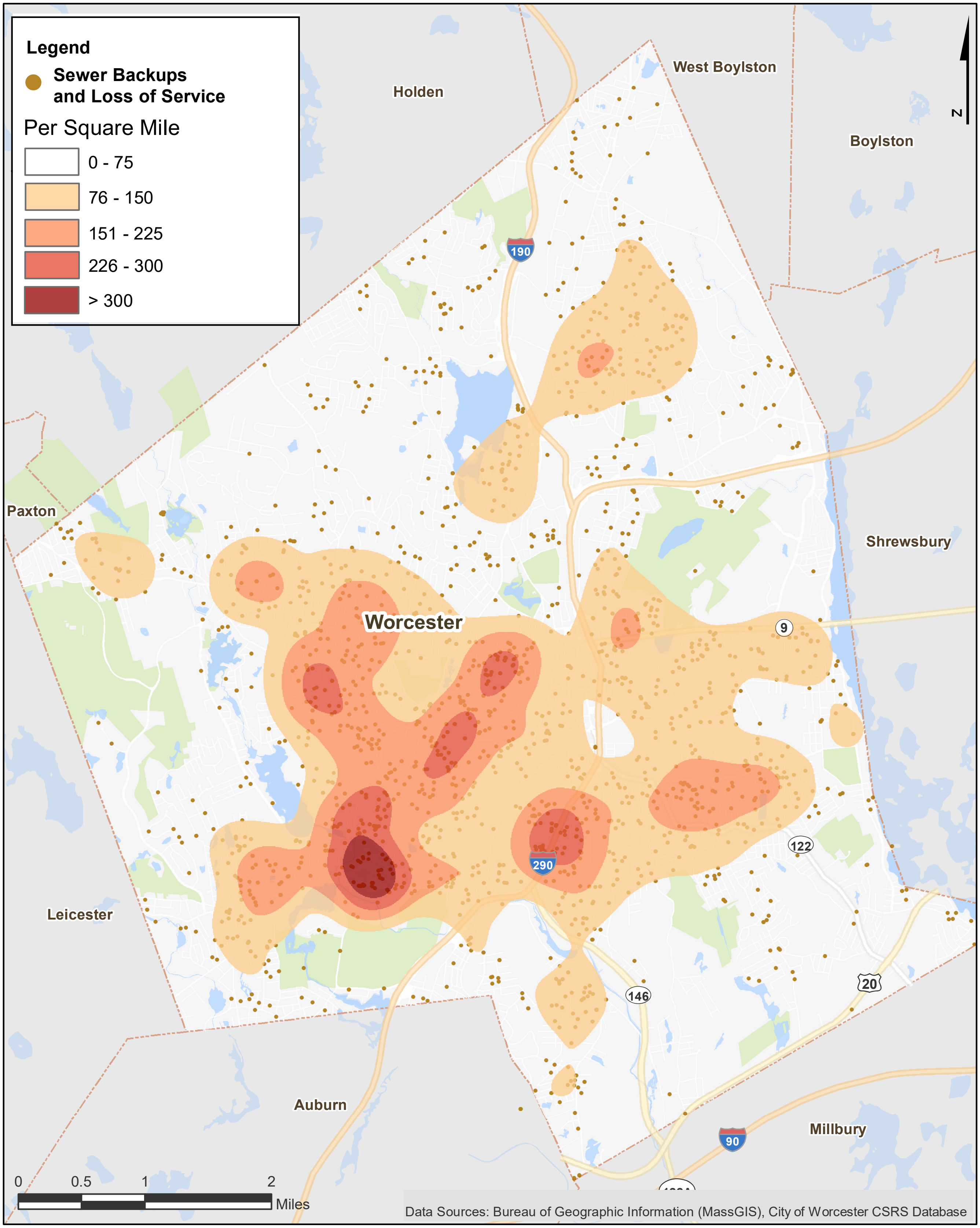
The City's built environment impacts its natural environment. Surface flooding, sanitary sewer overflows, backups, and runoff from impervious surfaces ultimately discharge to the City's surface water bodies — rivers, lakes, and ponds. Many of these water bodies are ideal for swimming, boating, and fishing. Others are part of open space areas that are used for biking, hiking, and picnicking. All are critically valuable resources to the City's social and natural environment.

Surface water bodies receive direct or indirect discharges in the following ways:

- Exfiltration from failing sanitary collection system pipes discharge directly via the stormwater system or indirectly through soils to water bodies.
- Wastewater collected by the sewer system can overflow and either directly or indirectly discharge to water bodies.
- The stormwater system discharges directly to water bodies through its 349 outfalls.
- Overland surface runoff not captured by the stormwater system ultimately discharges to surface water bodies.
- Street flooding from undersized stormwater systems can indirectly discharge to water bodies as overland flow.
- The Upper Blackstone Treatment Facility and the City's Quinsigamond Avenue CSO Treatment Facility treat and discharge wastewater and combined sewage to the Blackstone River.

Flooding in the Richmond Avenue area occurred after a rain event one October.

FIGURE 2.6: DENSITY OF REPORTED SEWER BACKUPS AND LOSS OF SERVICE (2006-2016)



Surface flooding, sanitary sewer overflows, and runoff from impervious surfaces can impact those sensitive areas in the natural environment such as rare species habitats, vernal pools and areas of core habitat, and critical natural landscape. Sensitive environmental areas are primarily located northwest of Coes Reservoir, in the Green Hill Park area, south and southwest of Lake Quinsigamond, and in the Broadmeadow Brook Conservation area, as shown in **Figure 2.7**.

There are no public drinking water supply sources (Class A waters) in Worcester. All of Worcester's public drinking water supplies are outside City boundaries. Also, there are no communities downstream from Worcester that have intakes for public water supply on surface waters that originate or pass through the City, as all depend on groundwater for public water supply. There are no Outstanding National Resource Waters (as defined by the EPA) or waters known to be habitat for threatened or endangered species within the City's limits.

Available water-quality data is summarized in **Appendix 2.2**. Pathogens (e.g., fecal coliform, E. coli or enterococci) and nutrients (e.g., phosphorus, nitrogen) enter surface water bodies from the following:

- Discharge from stormwater outfalls during dry and wet weather events.
- Stormwater runoff from streets and overland flow from parcels or open spaces that may directly enter the water body.
- Illicit sanitary connections to the stormwater system.
- Twin-invert manholes in the collection systems that can cause cross contamination between the wastewater and stormwater systems.
- Sanitary sewer overflows that ultimately discharge to water bodies.
- Increased fertilizer application on residential and commercial parcels that discharge to water bodies.
- Illegal dumping of pet waste into catch basins.
- Waste from pets and wildlife in forested and open spaces that finds its way to the water bodies.

The City strives to maintain the quality of these important waters for recreational use. While it is not possible for surface waters in such urbanized settings to be restored to pristine conditions, the City seeks to identify and mitigate or eliminate threats that may impact the quality of its surface water bodies.

2.3.1 Tier Classifications of the Receiving Surface Water Bodies

For the purpose of this Integrated Plan, the City has developed a tiered system to classify its surface water bodies based on the recreational use they support:

- **Tier 1:** Water bodies that have bathing beaches.
- **Tier 2:** Water bodies that are used for secondary-contact recreation, such as fishing and boating.
- **Tier 3:** Water bodies that are part of open spaces and used for passive recreation, such as picnicking, biking and hiking.

Treated plant discharge water, left, merges with regular Blackstone River water, right.

FIGURE 2.7: LOCATIONS OF ENVIRONMENTALLY SENSITIVE AREAS

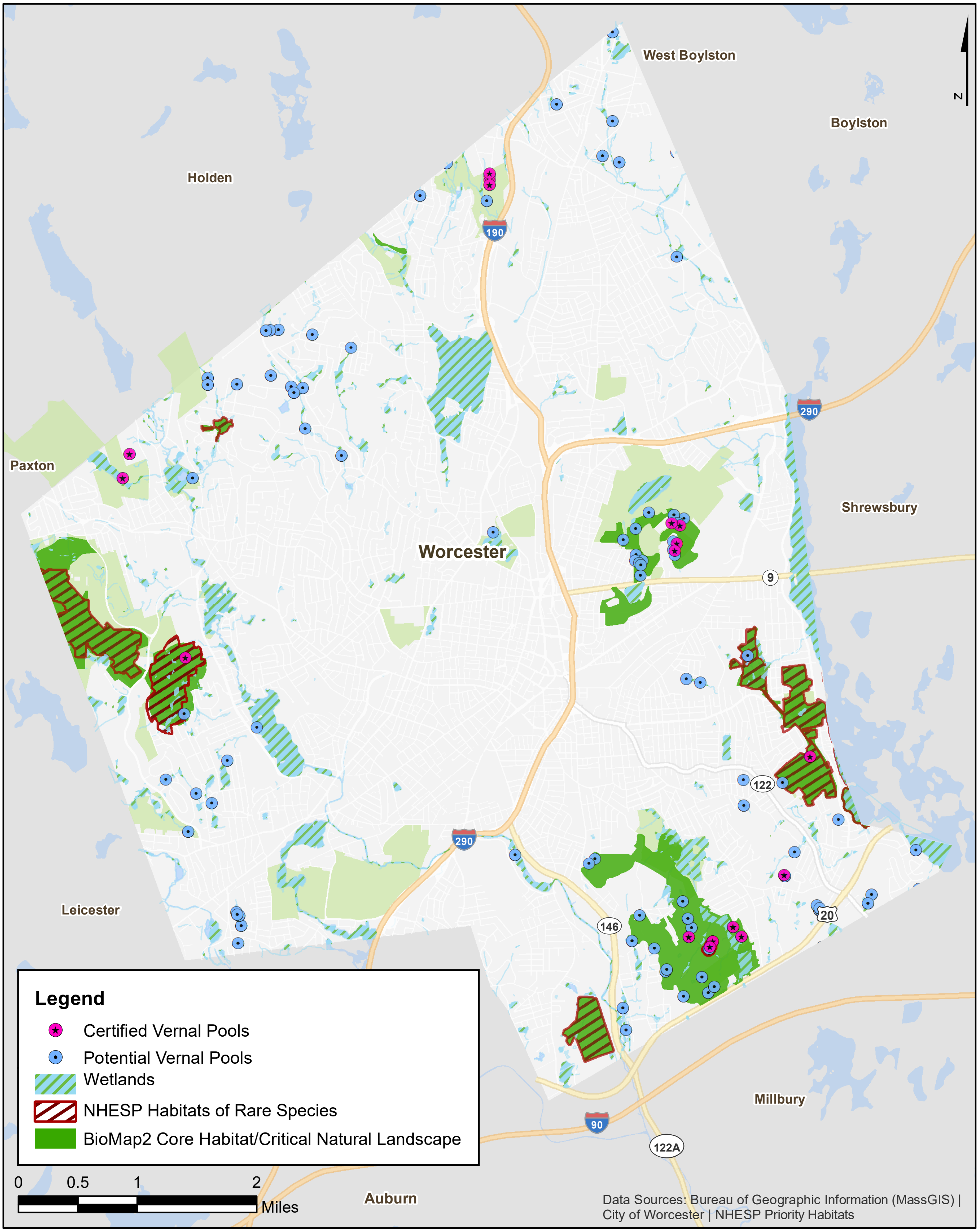


Table 2.3 provides a summary of the surface water bodies by tier and their uses: their surface area or length, and their drainage area[3].

Table 2.3 also identifies if the water body has been designated for fish stocking by the Department of Fish and Game and if it has direct public access[4]. **Figure 2.8** shows the water bodies color-coded by their tier classifications and the contributing drainage areas.

2.3.2 History and Current Status of Water Quality Regulation

The history of water quality regulation and the challenge of funding water infrastructure updates is summarized best in an October 2017 Report by a Panel of the National Academy of Public Administration titled "Developing a New Framework for Community Affordability of Clean Water Services":

"As the regulatory obligations and costs have increased, federal funding has decreased. Local obligations have mounted because of this drop in federal spending and a spike in water-related costs. In the context of compliance with the Clean Water Act, affordability concerns have been driven primarily by the costs associated with combined sewer overflow Long Term Control Plans needed to prevent the discharge of raw sewage and ultimately meeting Water Quality Standards, which reflect the Clean Water Act goals of making our nation's waterways fishable and swimmable, where attainable. In addition to the implementation costs of combined sewer overflow Long Term Control Plans, there are a number of additional costs driving growing concern about water affordability for water utilities providing water services and for their recipient customers."

Additional costs of meeting Water Quality Standards include those of achieving total maximum daily loads, which are established when technology-based effluent levels are not sufficient to meet the standards. Total maximum daily loads are developed for water bodies listed as impaired for each of the pollutants that contribute to the impairment and are allocated among sectors as Waste Load Allocations for individual point sources. These Waste Load Allocations provide the basis for Water Quality Based Effluent Limitations, which are incorporated into National Pollutant Discharge Elimination System (NPDES) permits. Total maximum daily loads also include Load Allocations for non-point sources, but as these are not regulated under the Clean Water Act, they are not incorporated into NPDES permits. Instead, non-point sources are addressed through voluntary incentive programs and may be addressed through state laws.

Among the key costs for meeting NPDES permit obligations are those of reducing discharges from Municipal Separate Storm Sewer Systems. In addition to water quality standard costs, there are also significant infrastructure lifecycle costs, which include deferred maintenance and overdue replacement and upgrading of aging water infrastructure systems. Changes in water use patterns and declining populations in inner cities and small communities reduce the rate base while many of the costs of providing services remain fixed.

2.3.2.1 The Total Maximum Daily Load Program

The Clean Water Act codifies the process by which waters are evaluated with respect to their capacity to support designated uses as defined in each of the states' Surface Water Quality Standards. These uses include aquatic life support, fish and shellfish consumption, drinking water supply, and primary (e.g., swimming) and secondary (e.g., boating) contact-recreation. This process also entails assessing each of these uses for rivers, lakes and coastal waters. Causes and sources of impairment are identified wherever possible.

Under the Clean Water Act, states must identify those water bodies that are not expected to meet Surface Water Quality Standards after the

3 These drainage areas were delineated using the "service drainage areas" obtained from the City of Worcester GIS mapping ("service areas" shapefile) and topographic mapping. They represent contributing land areas that drain to the water bodies through storm drain outfalls and directly by overland runoff for the purposes of evaluating areas that directly impact water quality. The contributing drainage areas are not the same as watershed areas. For instance, the Indian Lake Watershed extends into Holden through connected tributary streams such as Sargent's Brook.

4 MassWildlife Fish Stocking Program, Trout Stocked Waters – Central: https://www.mass.gov/doc/masswildlife-central-districts-trout-stocked-waters

Green Hill Pond is a Tier 2 body of water; public access is allowed, with fishing, picnicking and hiking permitted.

implementation of technology-based controls and to prioritize and schedule them for the development of total maximum daily load. A total maximum daily load establishes the maximum amount of a pollutant that may be introduced into a water body and still ensure attainment and maintenance of water quality standards. A total maximum daily load must also allocate that acceptable pollutant load among all potential sources.

Section 303(d) of the Clean Water Act, and EPA's regulations at 40 CFR Part 130, require states to develop total maximum daily loads for water bodies that are not meeting designated uses under technology-based controls. The process establishes the maximum allowable loading of pollutants that a water body can receive and still meet the Surface Water Quality Standards established for protecting public health and maintaining the designated beneficial uses of those waters. A specific time frame for developing these loads is not set forth in either the statute or regulation governing the total maximum daily load program.

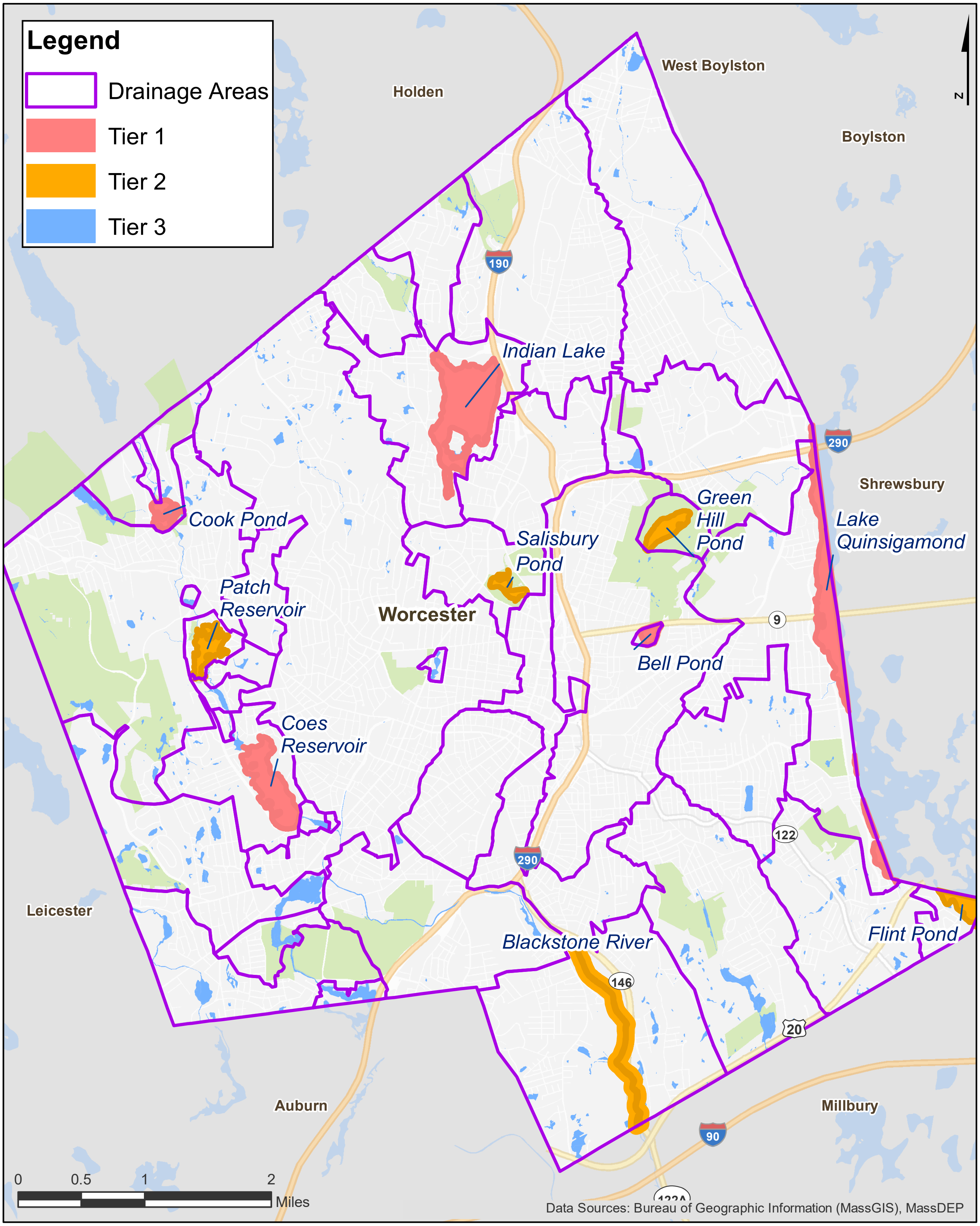
2.3.2.2 Surface Water Quality Standards

States adopt water quality standards that ascribe goals in the form of beneficial uses that are assigned to specific defined water bodies. For example, waters may be designated for the support of aquatic life, recreational use, and fish and shellfish consumption. Water quality standards also specify criteria that water bodies must meet to support their assigned uses. Criteria may be expressed as numerical values that should not be exceeded in ambient water, such as the geometric mean of all E. coli samples shall not exceed 126 colonies per 100 milliliters (ml), or a minimum instream dissolved oxygen concentration of 5 milligrams per liter (mg/l). Alternatively, water quality standards may include narrative statements that waters shall be free from constituents in concentrations that would impair their intended uses.

TABLE 2.3: CITY OF WORCESTER TIER CLASSIFICATIONS OF WATER BODIES

	Water Body	Water Body Use							
		Public Access	Swimming	Fishing	Boating	Picnicking	Biking	Hiking	Fish Stocking
Tier 1	Bell Pond	♦	♦	♦				♦	♦
	Coes Reservoir	♦	♦	♦		♦			♦
	Cook Pond		♦						
	Indian Lake	♦	♦	♦	♦	♦			
	Lake Quinsigamond	♦	♦	♦	♦	♦		♦	♦
Tier 2	Blackstone River	♦			♦	♦	♦	♦	
	Flint Pond	♦		♦	♦	♦			
	Green Hill Pond	♦		♦		♦		♦	
	Patch Reservoir			♦	♦			♦	
	Salisbury Pond	♦				♦		♦	
Tier 3	Beaver Brook	♦							
	Broad Meadow Brook	♦						♦	
	Burncoat Park Pond	♦		♦					
	Coal Mine Brook	♦						♦	
	Lower Coes Pond								
	Curtis Pond North								
	Curtis Pond South	♦							
	Elm Park Pond	♦				♦			
	Fitzgerald Brook								
	Kettle Brook								
	Leesville Pond								
	Middle River	♦						♦	
	Mill Brook								
	O'Hara Brook								
	Patch Pond								
	Poor Farm Brook								
	Tatnuck Brook								
	Weasel Brook								

FIGURE 2.8: MAP OF CITY'S TIER CLASSIFICATIONS OF WATER BODIES IN WORCESTER



All water bodies within the City are designated as Class B waters, as defined by the Massachusetts Surface Water Quality Standards (per 314 CMR 4.00). Class B refers to waters "designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation."

The Massachusetts Surface Water Quality Standards are found at 314 CMR 4.00 and are available online. The Surface Water Quality Standards assign all inland and coastal and marine waters to classes according to the intended beneficial uses of those waters. For example, Class A waters are waters designated as a source of public water supply and their tributaries. They should also be suitable for supporting aquatic life, recreational uses such as swimming and boating, and fish consumption. Class B waters are not water supplies, but are designated for all other uses previously cited for Class A. Finally, Class C waters should be suitable for aquatic life and recreational uses where contact with the water is incidental, such as boating and fishing, but may not be suitable for swimming, diving or water skiing. Inland waters are also subcategorized as to fishery type (cold water fishery, warm water fishery or aquatic life) based on their natural capacity to support these resources.

All water bodies within the City are designated as Class B waters, as defined by the Massachusetts Surface Water Quality Standards (per 314 CMR 4.00). Class B refers to waters "designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation."

There are no public drinking water supply sources (Class A waters) in Worcester. All of Worcester's public drinking water supplies are outside City boundaries. Also, there are no communities downstream from Worcester that have intakes for public water supply on surface waters that originate or pass through the City, as all depend on groundwater for public water supply. There are no Outstanding Natural Resource Waters or waters known to be habitat for threatened or endangered species within the City's limits.

The adoption of water quality standards is a public process and the Clean Water Act specifies that states hold public hearings at least once every three years (i.e., triennial review) to review and, where appropriate, revise their water quality standards. The MassDEP adopted the most recent revisions to the Surface Water Quality Standards on December 29, 2006. These were subsequently submitted to EPA for review in January 2007, and on March 26, 2007, EPA approved some revisions while indicating that the remaining revisions proposed by the MassDEP were still under review.

The process of assessing surface waters and listing impairments is linked to the Surface Water Quality Standards, as they define the uses that are to be evaluated for any given water body as well as the criteria for determining whether those uses are, in fact, supported.

MassDEP's Integrated List of Waters assesses the condition of all waters in the State every two years. The assessment is referred to as the "Integrated List of Waters" (Proposed Listing of the Condition of Massachusetts' Waters Pursuant to Sections 305(b), 314 and 303(d) of the Clean Water Act).

The objective of the federal Clean Water Act is to "restore and maintain the integrity of the Nation's waters." MassDEP assesses uses for rivers, lakes and coastal waters. Causes and sources of impairment are identified wherever possible. This assessment relies upon data and other information and classifies waters as either meeting designated uses or not meeting designated uses as previously explained.

Waters that allegedly do not meet designated uses are considered impaired and appear on MassDEP's Integrated List of Waters. They may be determined to be impaired by pollutants, or by other factors such as habitat alteration, and the presence of noxious or invasive plants, among other factors. Waters that are impaired by pollutants are then the subject of total maximum daily load studies that determine how much of the specific pollutant of concern the impaired water body may receive by the various sources of that pollutant while still meeting water quality standards. The following are the definitions of the water quality categories:

- **Category 1:** Waters attaining all designated uses
- **Category 2:** Attaining some uses; other uses not assessed
- **Category 3:** No uses assessed
- **Category 4A:** Impaired — total maximum daily load is completed
- **Category 4B:** Impairment controlled by alternative pollution control requirements
- **Category 4C:** Impairment is not caused by a pollutant – total maximum daily load not required
- **Category 5:** Impaired — total maximum daily load required

Table 2.4 provides a summary of MassDEP's characteristics for each water body in Worcester, including the impairment category and number of impairments according to the latest final list published by MassDEP in 2014. The Massachusetts Year 2016 Integrated List of Waters was still in draft form at the time this report was written. This table is organized by the City's Water Body Tier Classifications presented in the previous section. The table also lists those water bodies subject to the 2008 Draft Total Maximum Daily Load for Pathogens and 2002 total phosphorus total maximum daily load. **Figure 2.9** shows the same information in map form.

For two pollutants, there are either draft or final total maximum daily loads, as indicated in **Table 2.4**. At present, total maximum daily loads issued for Worcester's water bodies consist of the following:

- Phosphorus:
  - Indian Lake (Final)
  - Lake Quinsigamond and Flint Pond (Final)
  - Leesville Pond (Final)
  - Northern Blackstone Lakes — includes Curtis Pond North and South, Green Hill Pond (Final)
  - Salisbury Pond (Final)
- Pathogens:
  - Blackstone River Watershed — includes Kettle Brook, Middle River, Blackstone River, Beaver Brook and Mill Brook (Draft)

All the phosphorus total maximum daily loads for the lakes and ponds in the City were finalized by the MassDEP in 2002. However, the methodology used to establish these are based on a prescriptive approach rather than a demonstrative one. A prescriptive approach sets certain percent reduction targets for the pollutant of concern that are based on empirical relationships. A demonstrative approach is based on detailed numeric modeling, and hence provides a stronger basis for the allocated loads. Originally issued in 2008, the pathogen total maximum daily loads were expected to be finalized in FY 2012-2013, but their status still shows as draft.

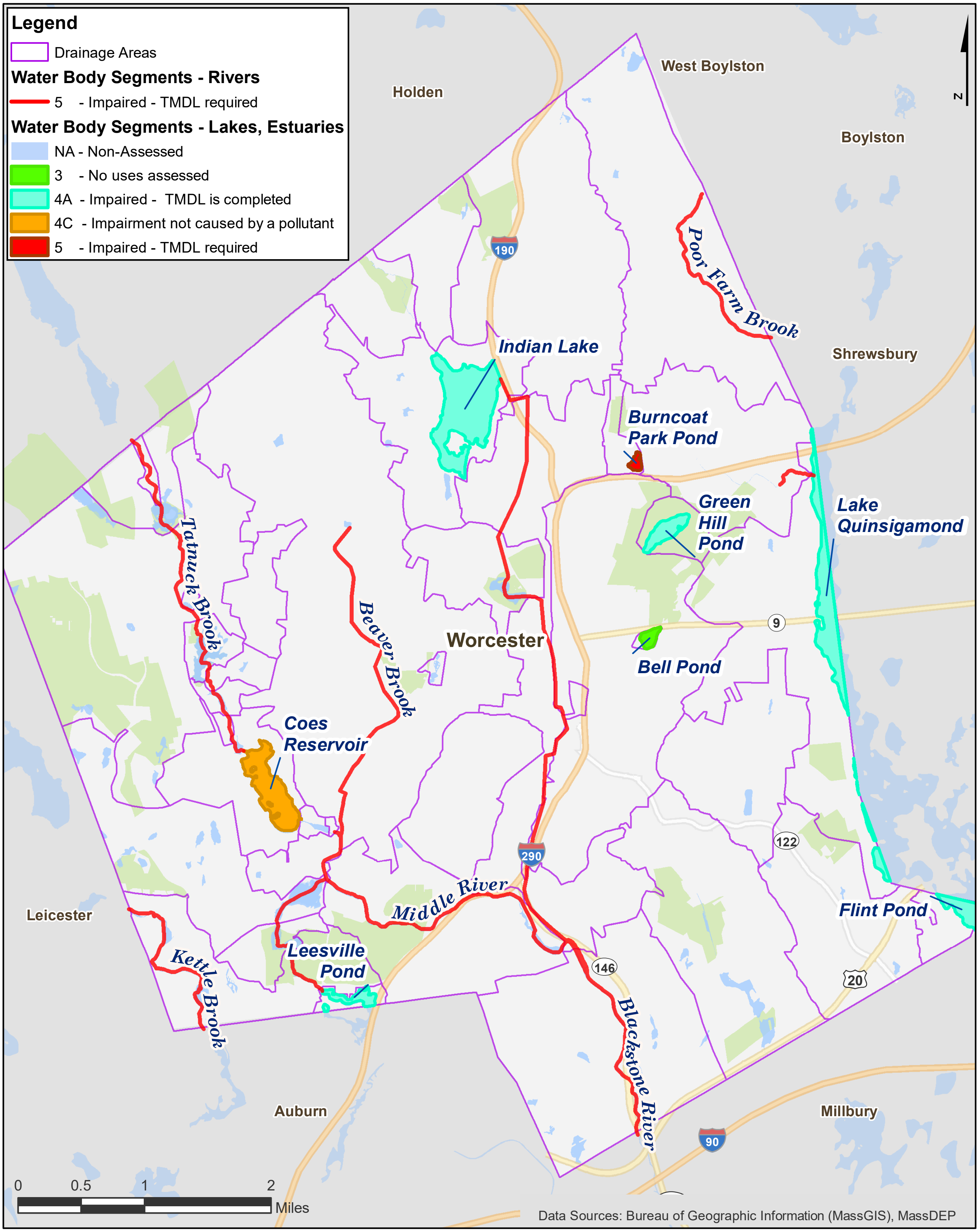
Beaver Brook, part of the Blackstone River Watershed, is subject to the 2008 Draft Total Maximum Daily Load for Pathogens.

TABLE 2.4: LIST OF WORCESTER WATER BODIES WITH MASSDEP'S LISTED IMPAIRMENTS AND TOTAL MAXIMUM DAILY LOADS

	Water Body	Impairment Category as of 2014	# 303(d) Impairments as of 2014	Draft Pathogen Total Maximum Daily Loads (2008)	Total Phosphorus Total Maximum Daily Loads Established (2002)
Tier 1	Bell Pond	3			
	Coes Reservoir	4C	1		
	Cook Pond	Not Assessed			
	Indian Lake	4A	3		♦
	Lake Quinsigamond	4A	4		♦
Tier 2	Blackstone River	5	17	♦	
	Flint Pond	4A	3		♦
	Green Hill Pond	4A	1		♦
	Patch Reservoir	Not Assessed			
	Salisbury Pond[1]				♦
Tier 3	Beaver Brook	5	6	♦	
	Broad Meadow Brook	Not Assessed			
	Burncoat Park Pond	5	2		
	Coal Mine Brook	5	4		
	Lower Coes Pond	Not Assessed			
	Curtis Pond North	Not Assessed			♦
	Curtis Pond South	Not Assessed			♦
	Elm Park Pond	Not Assessed			
	Fitzgerald Brook	Not Assessed			
	Kettle Brook	5	8	♦	
	Leesville Pond	4A	3		♦
	Middle River	5	7	♦	
	Mill Brook	5	11	♦	
	O'Hara Brook	Not Assessed			
	Patch Pond	Not Assessed			
	Poor Farm Brook	5	3		
	Tatnuck Brook	5	6		
	Weasel Brook	Not Assessed			

1. Salisbury Pond was categorized as impaired Category 5 in the 303(d) lists up until and including 2008.

FIGURE 2.9: WATER BODIES IN WORCESTER AND MASSDEP'S LISTED IMPAIRMENTS



2.3.2.3 Problems with Total Maximum Daily Load Reports

There are significant problems with the final total maximum daily loads for the pollutant total phosphorus for six water bodies:

Curtis Pond (North & South) — Curtis Pond's total maximum daily load issued in 2002 (part of Northern Blackstone Lakes total maximum daily load report) was based in part on a 1994 "synoptic survey" by MassDEP during which no samples were tested for total phosphorus. The report mentioned that two samples with conflicting results were collected and tested in 1985. The Curtis Pond total maximum daily load does not use actual test data but relies entirely on a watershed export model to predict total phosphorus loading and a theoretical estimate of what a pond in this area should naturally have for total phosphorus concentrations. The modeled loading, using 1985 land use data, indicates the pond contains 26-27 parts per billion (ppb) of total phosphorus while the theoretical estimate and target suggests the pond should have (naturally) about 25 ppb. The 2008 draft NPDES Municipal Separate Storm Sewer System permit proposes a reduction of total phosphorus loads to Curtis Pond by 5% from residential areas and 7% from commercial/industrial areas by implementing best management practices. This would then help to achieve a 1 ppb reduction in total phosphorus concentrations in the pond. No samples were ever collected to verify the accuracy of the loading model.

Indian Lake

Indian Lake's 2002 total maximum daily load indicates that the Lake receives 383 kg/year of total phosphorus from watershed runoff (stormwater) but can only handle 206 kg/year. Thus, total phosphorus input to the lake from the watershed would need to be reduced by 46%. These conclusions were based partly on a Diagnostic/Feasibility Study completed in 1989 and earlier studies and partly on modeled total phosphorus loading using land use data. Any actual total phosphorus testing data considered in this total maximum daily load is 20 or more years old. Any efforts undertaken over the past 20 years that may have reduced total phosphorus loading, including paving of private streets, upgrades to sewage pumping stations and improved stormwater best management practice implementation, like street sweeping and catch basin cleaning and installation of hydrodynamic separator units, have not been considered. The total maximum daily load uses 20-year-old results and assumes that no stormwater improvements have occurred in the watershed over the past two decades.

Lake Quinsigamond/Flint Pond

Lake Quinsigamond/Flint Pond total maximum daily load issued in 2002 is based almost exclusively on studies and data from 1980 and 1981. This total maximum daily load takes 22-year-old data and analysis and transfers it to 2002. The 2008 draft NPDES Municipal Separate Storm Sewer System permit uses the same information and transfers it to 2008 along with a proposed requirement that the City achieve the 28-year-old phosphorus reduction targets (52% reduction in available phosphorus). Nowhere in the process does it consider any of the work performed in the prior 28 years that likely reduced total phosphorus loading to Lake Quinsigamond, including the Belmont Street Vortechs unit, rehabilitation of sanitary sewers and sewer pump stations, private street paving and other projects. The Quinsigamond total maximum daily load is predicated on reducing mean available in-lake phosphorus by 4 parts per billion.

Green Hill Pond

The Green Hill Pond total maximum daily load, like that for Curtis Pond, was part of the 2002 Northern Blackstone Lakes total maximum daily load report. The only investigation of the pond was a 1994 "synoptic survey" by MassDEP during which no samples were tested for total phosphorus. This survey noted that aquatic plants were sparse, but the pond was very turbid. Using 1985 land use data, a model was generated to estimate total phosphorus loading to the pond. It was noted that the Green Hill Golf Course is adjacent to the pond and it was assumed that total phosphorus loading would be higher than that from typical "open land." Therefore, the model was adjusted to make total phosphorus export rates equivalent to that from a pasture. The adjusted model then predicted a total phosphorus concentration in the pond that would need to be reduced by 38% to meet the theoretical level of total phosphorus "typical" for ponds in the region. The 2008 draft NPDES permit calls for achievement of this level of total phosphorus reduction in the stormwater discharge to the pond by implementing practices at the golf course. There are, however, no stormwater outfalls to the pond.

Previous studies of Indian Lake and its total maximum daily load implicated carp as a source of total phosphorus. Carp tend to stir up phosphorus-rich sediments releasing the nutrient into the water while also creating turbidity. Many Worcester residents recognize Green Hill Pond as being famous for one thing: carp. Feeding the carp has been an entertaining activity for Worcester area children for decades. However, the total maximum daily load for Green Hill Pond makes no mention of carp. Rather, it places the blame for turbidity entirely on assumed fertilizer runoff from the golf course. The 2008 draft NPDES permit then determines the solution to this impairment is for the City to control phosphorus use at the golf course so that it does not enter the pond through a non-existent stormwater collection system.

The City cannot embrace these total maximum daily loads as valid or as a true guide as to the level of effort and cost needed to improve local receiving waters. Scientifically, total phosphorus can induce the growth of aquatic plants and algae, thereby making a water body less suitable for recreation and possibly having negative impacts on fish and aquatic wildlife. Reducing total phosphorus is an appropriate goal. However, the ability to cost-effectively reduce total phosphorus in stormwater and the lack of current and valid data used in total maximum daily loads clearly shows that specific percent reduction requirements for total phosphorus called for in these reports are highly suspect. Given the questionable nature of these studies, the City should not be held to meeting these total phosphorus reduction requirements and they must be rejected. Instead, for discharges to DEP-listed impaired waters with approved total maximum daily loads for total phosphorus, reasonable best management practices (e.g., street sweeping, catch basin cleaning, leaf collection, structural stormwater controls) to reduce total phosphorus loading to the maximum extent practicable standard is appropriate. The total maximum daily loads lack the specificity and accuracy to be used as absolute target levels for stormwater management decision-making.

2.3.3 Public Health and Recreational Uses

The impacts of water-quality impairments to public health and recreational use is of the utmost concern to the City. Pathogens such as fecal coliform, E. coli or enterococci that are present in street flooding, stormwater runoff, and sanitary sewer overflows ultimately discharge to water bodies. This is a public health and safety issue.

Any time a sanitary sewer overflow occurs, public beaches in the vicinity are likely to be closed to swimming. **Figure 2.10** summarizes the number of sanitary sewer overflows reported each year during the summer months from 2006-2015 in areas tributary to public beaches in Worcester, and shows the risk to public health and the potential for beach closures during the summer season due to impacts from sanitary sewer overflows.

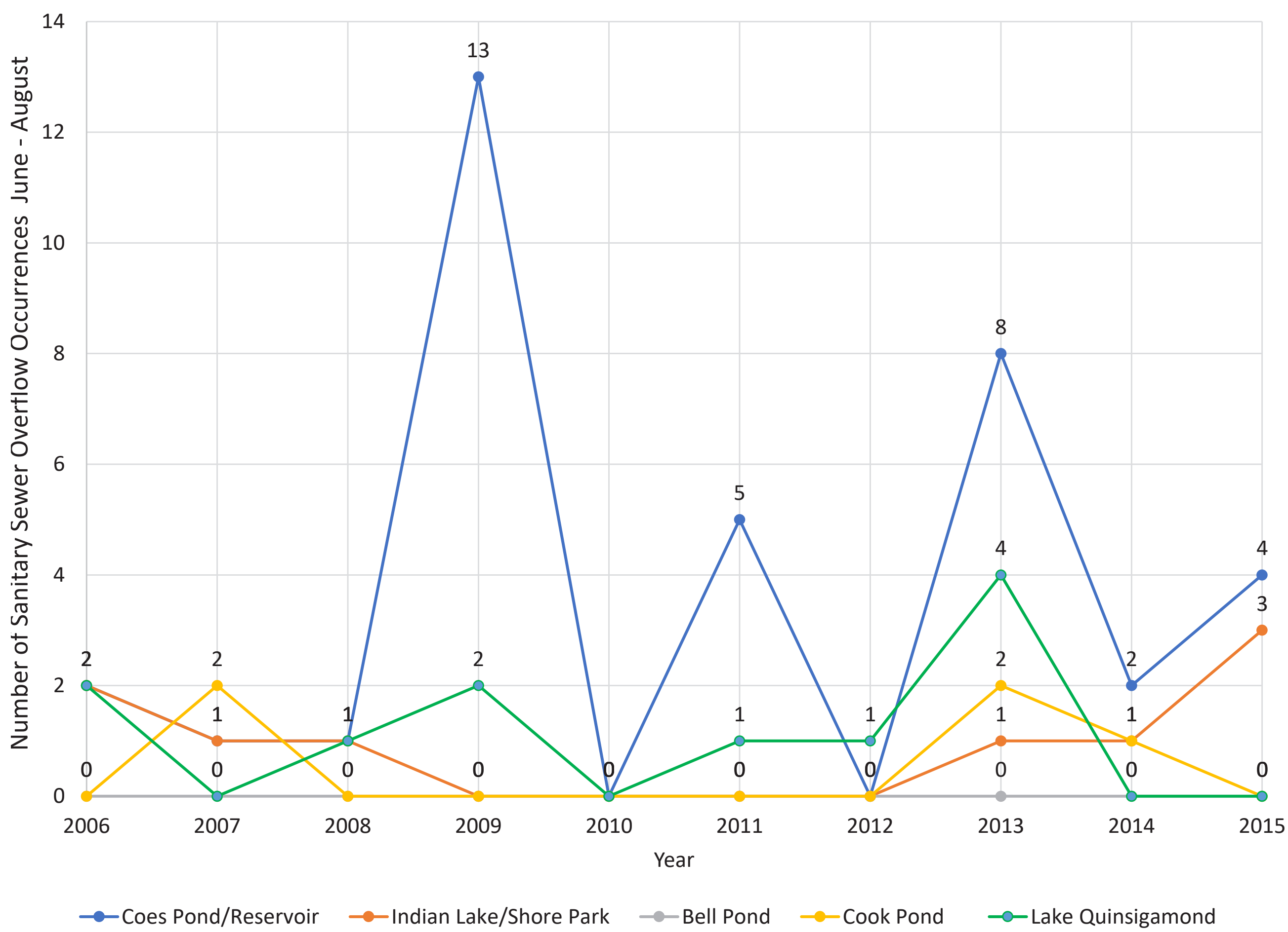
Beach sampling results for the public beaches in Worcester show a similar trend. **Table 2.5** summarizes public beach sampling results in terms of percent samples in compliance with the current Massachusetts E. coli water quality standard for swimmable beaches (less than 235 cfu/100 mL). It is important to note that the beach sampling standard is based on using E. coli as the indicator for pathogens, whereas the City's instream sampling data uses fecal coliform as the indicator for pathogens. As previously mentioned, a fecal coliform concentration of 200 cfu/100 mL was the water quality standard prior to the use of E. coli. **Table 2.5** indicates the following:

- Overall, the sampling at public beaches in Worcester has averaged over 93% compliance over the last 12 years.
- Smith Pond sampling has achieved the highest average compliance score of 98%, while Lake Quinsigamond has the lowest average compliance score of 86%.

Note that the public beaches at Lake Quinsigamond are owned and maintained by the Massachusetts Department of Conservation and Recreation, and as such, the City does not perform sampling at those beaches.

Excessive nutrient loading, such as phosphorus and nitrogen, from stormwater runoff can cause harmful algal blooms in water bodies. Not

FIGURE 2.10: SANITARY SEWER OVERFLOW OCCURRENCES TRIBUTARY TO SAMPLED BEACHES — JUNE THROUGH AUGUST



technically classified as algae, cyanobacteria (commonly referred to as blue-green algae) are very harmful. The toxins found in cyanobacteria have several harmful effects, including skin and eye irritation, asthma-like symptoms, neurological damage if exposed to large amounts, and even death for pets and livestock. This is a significant public health threat and is becoming an increasingly common one in Massachusetts and many other states. In Worcester, Indian Lake is the only water body historically known to have cyanobacteria.

When this occurs, the Worcester Division of Public Health issues advisories that prohibit any primary or secondary contact recreation activities such as swimming and fishing, and closes the beaches.

Other water quality impacts to the City's water bodies include:

- In Tatnuck Brook, moderate nutrient loading causes excessive eutrophication that has restricted recreational activities and made the Brook aesthetically displeasing.
- In Salisbury Pond, suspended sediment load and increased turbidity have caused excessive sedimentation, buildup and filling of the waters. This is most commonly observed downstream of major outfalls and tributary brooks and streams that convey a significant amount of stormwater runoff during rainfall events.

The City recognizes the challenge of protecting and maintaining water quality within its recreational waters. The City's goals are to protect public health and water quality of the tiered classified receiving waters, described in **Section 2.3.1**.

Fact sheets for each tier classified water body are provided in **Appendix 2.3**. These fact sheets provide an overview of the water body and details about the contributing drainage area, percentage of drainage area that is served by the stormwater system, land use and percent impervious cover for each drainage area, and water-quality data related to category, number, and source of impairments for each water body.

2.4 Challenges in Meeting Current and Future Clean Water Act Regulatory Requirements

Clean Water Act requirements include:

- Protection of surface waters.
- Compliance with stormwater regulations.
- Operation and maintenance of wastewater collection systems.

TABLE 2.5: PUBLIC BEACH E. COLI SAMPLING COMPLIANCE (% OF SAMPLES < 235 COLONIES/100 ML)

Water Body	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Overall
Lake Quinsigamond	N/A	N/A	72	100	78	88	94	N/A	N/A	N/A	N/A	N/A	N/A	**86**
Coes Reservoir	100	91	89	78	100	88	88	100	80	70	100	100	100	**91**
Indian Lake	100	100	95	100	94	100	88	100	93	83	90	94	100	**95**
Bell Pond	90	100	100	100	100	100	88	100	100	78	100	100	100	**97**
Smith Pond	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	92	100	100	100	**98**

- Compliance with NPDES permit at the Upper Blackstone Treatment Facility.

The water resources systems are regulated by four separate NPDES permits issued by the EPA. Each of these permits requires compliance with specific water quality parameters as well as implementation of operations and maintenance programs.

Escalating regulatory demands make it increasingly difficult to adequately invest in, maintain and renew these systems.

2.4.1 National Pollutant Discharge Elimination System (NPDES) Permits

The four NPDES permits cover discharges to waters of the United States from:

- Quinsigamond Avenue CSO Treatment Facility
- Upper Blackstone Treatment Facility
- Municipal Separate Storm Sewer System
- Water Filtration Plant

Each of these permits requires compliance with specific water quality parameters as well as implementation of operations and maintenance programs.

2.4.1.1 Quinsigamond Avenue CSO Treatment Facility

The Quinsigamond Avenue CSO Treatment Facility provides treatment of combined sewage from the City's combined sewer system during wet weather that is then discharged as necessary to Mill Brook, a tributary to the Blackstone River. The NPDES permit for this facility became effective in August 2005 and was administratively extended in 2010 (a copy of the current permit is included in **Appendix 2.4**). The permit establishes pollutant limits with respect to discharge water quality for total chlorine and fecal coliform bacteria, pH and flow, and limits the annual number of treated discharge events.

The City's Long Term Control Plan was completed in 2004 and outlined recommendations for system improvements aimed at reducing the frequency and magnitude of treated discharges from this facility. To date, all system improvements have been implemented except for the requirement to reduce the number of annual treated discharges. This was to be achieved by increasing the pumping capacity at the Quinsigamond Avenue CSO Treatment Facility. During wet weather, increased flow is pumped to the Upper Blackstone Treatment Facility for treatment and discharged into the Blackstone River. Increasing the pumping capacity reduces the discharges to Mill Brook.

The City, in conjunction with the Upper Blackstone District, reevaluated the operational relationship between the two facilities in the context of the proposed pump upgrades and concluded that the benefits of this upgrade are uncertain and should be further evaluated. The City's review of treated discharge water quality from the Quinsigamond Avenue CSO Treatment Facility suggested that the quality could be equal to the quality of the primary effluent discharged from the Upper Blackstone Treatment Facility. Therefore, overall water quality in the Blackstone River might be better if the pumps were not upgraded and the Quinsigamond Avenue CSO Treatment Facility continued to treat and discharge to Mill Brook rather than pump to the Upper Blackstone Treatment Facility. This issue requires further study.

Another challenge of this permit is that it does not provide flexibility for meeting the annual treated discharge limits. The permit does not include information regarding conditions during which treated discharges would be acceptable or unavoidable. Typically, the maximum number of discharges cited under a NPDES permit would be qualified by a "Typical Year," which defines a certain number or size of storms during which a discharge event would be counted toward the permit limit for both treated discharge activation and volume. The NPDES permit for the Quinsigamond Avenue CSO Treatment Facility does not include this qualification, and therefore leaves little flexibility for compliance during wetter years. The lack of a Typical Year also does not allow accounting for the documented changes in rainfall patterns in the Northeast now and in the future.

Designing a system to meet an undefined limit is cost prohibitive, could harm the Upper Blackstone Treatment Facility by increasing flow and nutrient load, and may result in reduced water quality in the Blackstone River, which is pathogen impaired and a Tier 2 water body. The City recognizes that wet weather impairments should be addressed and believes that investments in stormwater controls will yield greater benefits than further investments in combined sewer overflows controls.

2.4.1.2 Upper Blackstone Water Pollution Abatement District

The Upper Blackstone District treats wastewater from the City of Worcester and other neighboring communities at the Upper Blackstone Treatment Facility, with Worcester representing approximately 85% of the overall flow, and budget. The facility provides primary clarification and secondary treatment through biologic nutrient removal. Treated wastewater is disinfected prior to discharge to the Blackstone River.

The 2001 NPDES permit required nearly $180 million in upgrades to reduce phosphorus, an effort that has been highly effective in lowering the total phosphorus loading to the river as demonstrated in **Figure 2.11**.

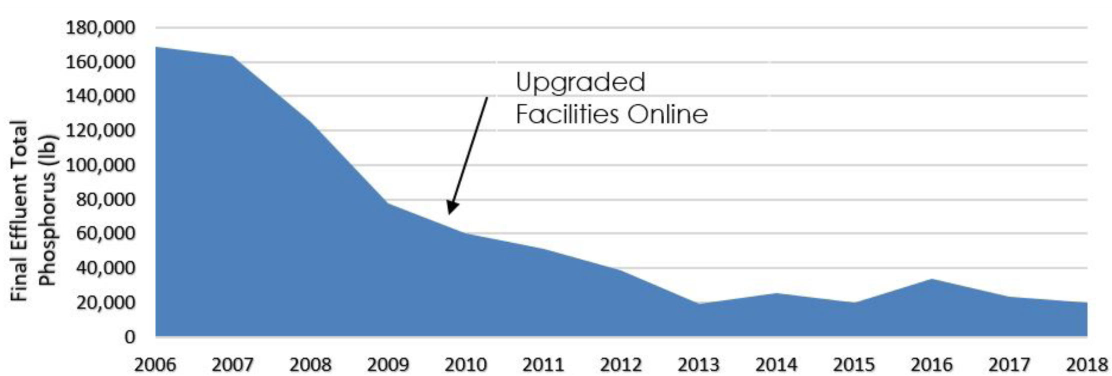
The current permit was issued in 2008 and was appealed by the Upper Blackstone District. The permit imposed more stringent effluent phosphorus and nitrogen limitations and required communities that send their wastewater to the facility to become co-permittees. This would make them responsible for proper operation and maintenance of their system, including inflow and infiltration removal plans.

A determination on remand from EPA Environmental Appeals Board upheld the nutrient removal requirements, but required the local region to provide a “more comprehensive factual and legal rationale” for regulating the satellite collection systems. EPA chose to reissue the permit without the co-permittees requirement and that, too, was appealed and subsequently upheld by the EPA. The Upper Blackstone District remained aggrieved by the permit’s nutrient limits, believing them to be onerous and without scientific basis. In April 2011, the permit appeal was then advanced to the First Circuit Court of Appeals in Boston. In August 2012, that Court upheld the permit as written, citing extreme deference to EPA’s authority and discretion in such matters. The permit then went into effect in October 2012.

The current permit includes limits on effluent water quality discharges to the Blackstone River for phosphorus, nitrogen, metals, pH, and other parameters, as well as overall flow. These permit limits were established to cover all flows from the plant that do not result in a discharge from Outfall 001A, which is used during high-flow events to bypass secondary treatment processes. A copy of the current permit is included in **Appendix 2.4**.

In May 2014, the Upper Blackstone Treatment Facility was issued an administrative order that establishes a schedule for the facility to comply with the 2008 permit, as well as interim limits to be met until compliance is achieved. This schedule, subsequently modified in August 2016, is presented in **Table 2.6** for reference, and includes three nutrient removal upgrade projects (Phases A-C) and development of a program to manage wet weather flows. The Upper Blackstone Treatment Facility is currently in full compliance with the administrative order.

FIGURE 2.11: POUNDS OF PHOSPHORUS IN UPPER BLACKSTONE TREATMENT FACILITY DISCHARGE



As part of this compliance, the Upper Blackstone District submitted a report in 2016 titled Integrated Planning Report for Wet Weather Management in the Upper Blackstone Treatment Facility and the City. The report studied the necessary upgrades and evaluated the financial capability of the facility and member communities. Through the preparation of the report, the Upper Blackstone District recognized the significant financial burden that the NPDES permit compliance will impose on the City of Worcester as the majority member. The City's socioeconomic characteristics and financial capability are a significant driver of the Upper Blackstone District's financial capability. This Integrated Plan considers modification to the schedule for the nutrient removal requirements of the NPDES permit. Those requirements are identified as to be determined, or TBD, in **Table 2.6**.

To better understand the water quality in the Blackstone River and the effects of the discharges from the Upper Blackstone Treatment Facility on the River, the Upper Blackstone District initiated a water-quality study in 2004. The University of Massachusetts (UMass) Amherst, supported by CDM Smith, developed a hydrologic and water quality computer model of the rivers. The model simulated over 10 years of hydrologic and water-quality conditions and evaluated potential water-quality improvements. The study included a field sampling program to provide wet- and dry-weather water-quality data from locations at the headwaters and in the main stem of the river. It also evaluated and modeled dynamic water quality conditions incorporating daily, monthly, seasonal, and interannual variability to develop a year-round understanding of conditions. The modeling analysis also incorporated point source and non-point source pollutant loads to the river. Since initiating the river study in 2004, the Upper Blackstone District has invested well over $2 million in this scientific investigation and has continued with the study annually. As the Blackstone River water quality is better understood, the study has adjusted its focus to include other parameters of significance including periphyton and macroinvertebrates. Information on this water quality modeling effort, and a fact sheet describing it, is included in **Appendix 2.5**.

Extensive model simulations revealed the following:

- Despite the best efforts to improve the quality of discharges from the Upper Blackstone Treatment Facility, the reduction in nutrients dictated by the 2008 NPDES permit would not achieve water quality targets for mitigating algae growth in the Blackstone River.
- The key factor contributing to algae growth was found to be the downstream impoundments, which govern the water quality of the entire river.

Even complete elimination of nutrients from the Upper Blackstone Treatment Facility discharge would not achieve water quality targets until the impoundments are removed.

2.4.1.2.1 Blackstone River Water Quality Monitoring

Since upgrades came online in 2009, the nutrient loads to the Blackstone River from the Upper Blackstone Treatment Facility have decreased significantly. The loads have been even lower since 2013 when Upper Blackstone began implementing interim measures, which focused on optimizing the plant's biological nutrient removal process. The biological nutrient removal process is operated year-round to remove nitrogen and phosphorus.

Figure 2.12 shows the annual and seasonal total phosphorus and total nitrogen effluent loads. The average 2017 and 2018 loads to the river were 85% and 39%, respectively, lower than the pre-upgrade (2006 through 2008) loads.

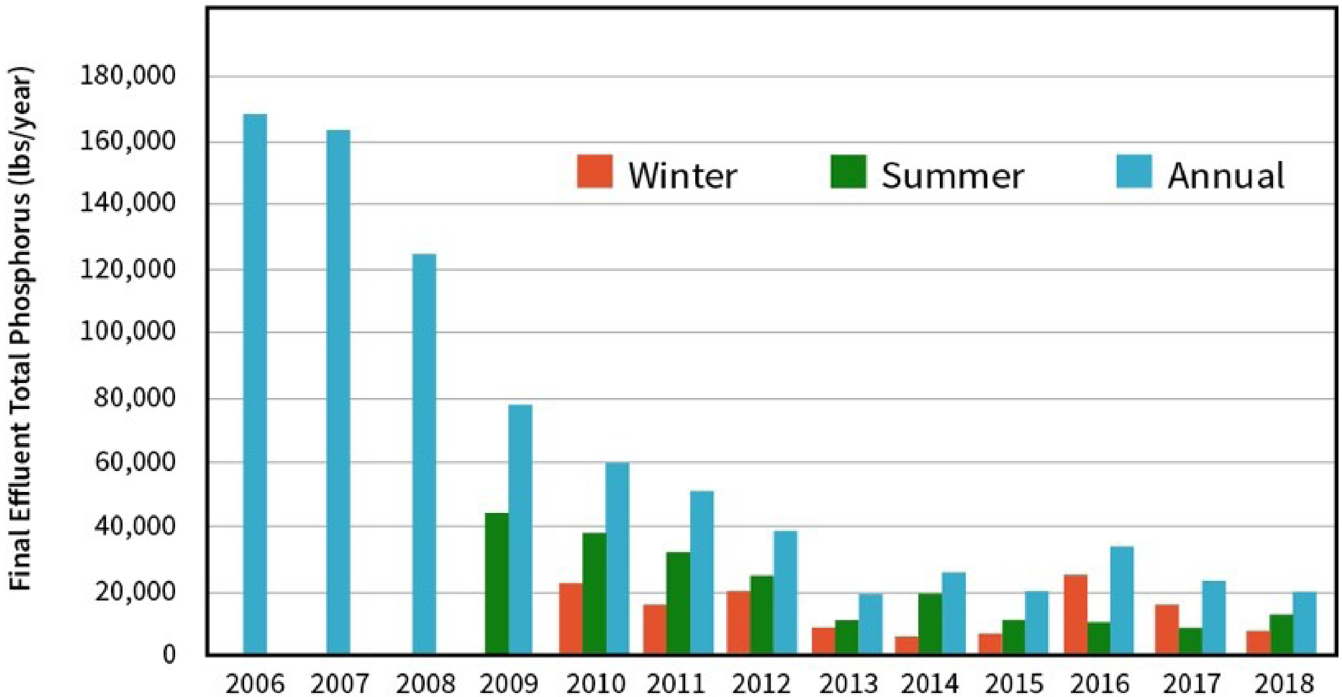
The Upper Blackstone Treatment Facility operates under seasonal nutrient discharge limits. Environmental conditions that could cause algal blooms are much more likely to occur during the summer months than during the winter. Due to this, winter nutrient limits are much less stringent than summer nutrient limits.

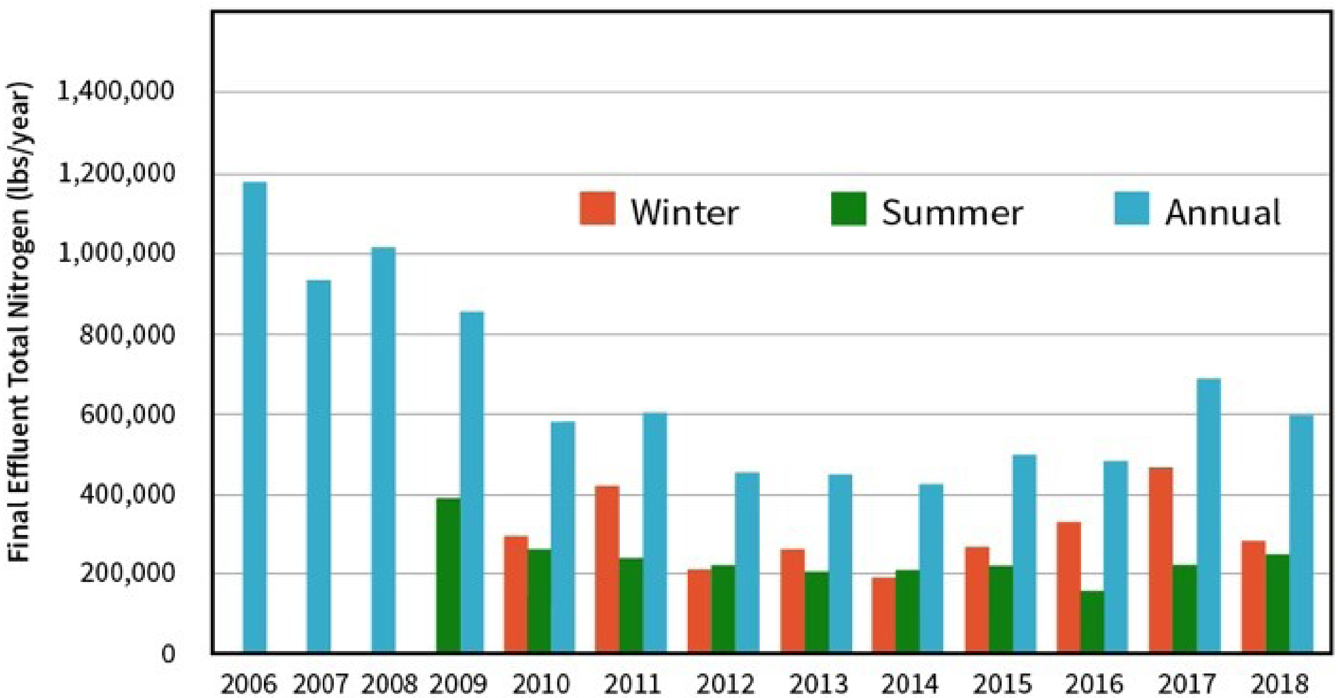
Since plant upgrades were initiated in 2007 and completed in 2009, the Upper Blackstone District has conducted water quality monitoring of the Blackstone River to assess the river's response to reduced nutrient concentrations in its treated effluent. The river monitoring program provides

TABLE 2.6: MODIFIED ADMINISTRATIVE ORDER SCHEDULE

Requirement	Due Date	Status
Commence pilot testing of measures recommended in the Interim Improvements Evaluation Report	April 1, 2014	Complete
Submit Nutrient Removal Alternative Screening Report	June 30, 2014	Complete
Submit Interim Improvements Pilot Testing Results Report	June 30, 2015	Complete
Submit Nutrient Upgrade Facilities Plan	December 31, 2015	Complete
Submit Integrated Planning Report for Wet Weather Management in the Upper Blackstone District and the City	December 31, 2015	Complete
Submit and Report on Pilot Testing of Phosphorus Removal Upgrade	February 1, 2017	Complete
Submit plans and specifications for Nutrient Upgrade Phase B — Phosphorus	September 30, 2018	Complete
Complete construction of Nutrient Upgrade Phase A	June 30, 2019	Complete
Initiate construction of Nutrient Upgrade Phase B	July 31, 2021	TBD
Complete construction and commence operation of Nutrient Upgrade Phase B	July 31, 2023	TBD
Obtain operational levels and comply with the total phosphorus effluent limit in 2008 Permit	Oct. 31, 2023	TBD
Submit plans and specifications for Nutrient Upgrade Phase C — Nitrogen	July 31, 2023	TBD
Initiate construction of Nutrient Upgrade Phase C	July 31, 2024	TBD
Complete construction and commence operation of Nutrient Upgrade Phase C	Oct. 31, 2026	TBD
Obtain operational levels and comply with the total nitrogen effluent limit in 2008 Permit	Oct. 31, 2027	TBD
Quarterly Reporting	Ongoing	TBD

FIGURE 2.12: ANNUAL PHOSPHORUS AND NITROGEN LOADING (2006-2016)



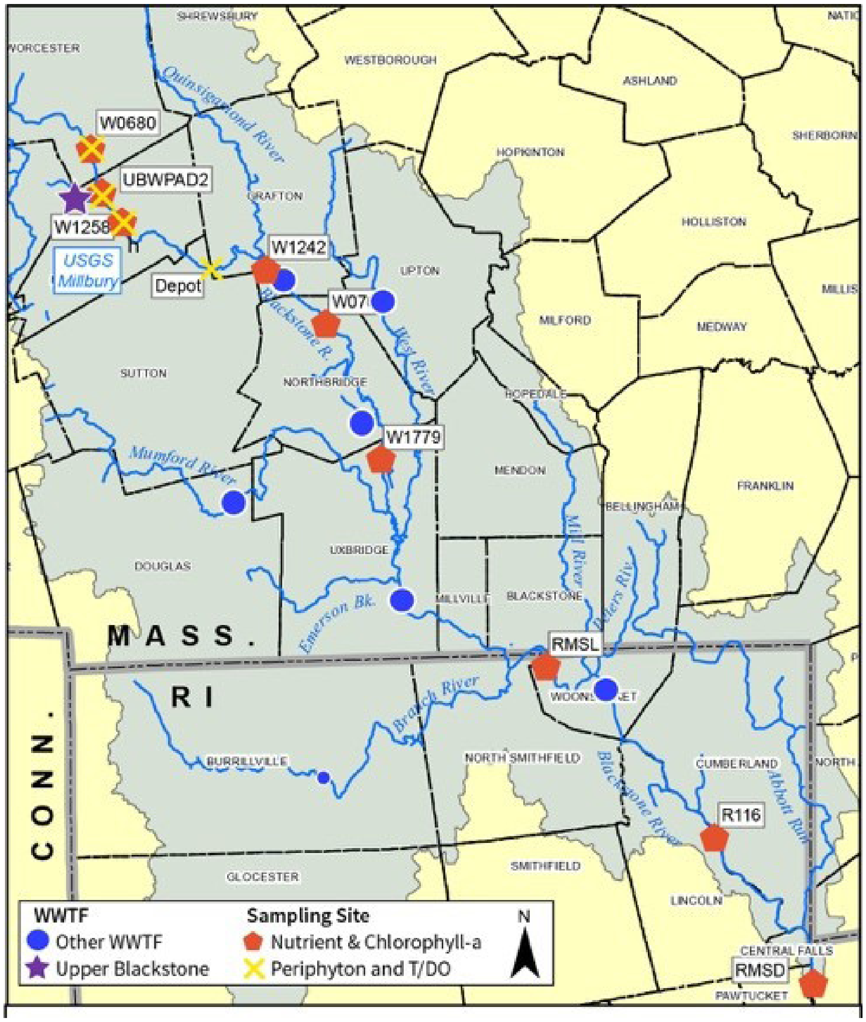


Notes:

1. Summer refers to the period between April 1 and October 31 for TP and May 1 and October 31 for TN for the year noted. Winter refers to the period between November 1 of the prior year through March 31 of the current year for TP and April 30 of the current year for TN.
2. Annual loads are on a calendar year basis, January 1 - December 31

consistent year-to-year monitoring at the same river sites to build a multi-year data record. In 2015 and 2016, the river monitoring program included monthly water quality sampling for nutrients and chlorophyll-a as well as periphyton surveys. Additionally, a macroinvertebrate survey was completed in 2015 to compare to river conditions observed by MassDEP in a 2008 survey. The 2015 macroinvertebrate survey indicated a noticeable improvement downstream of the Upper Blackstone Treatment Facility. Additional details on the river monitoring program are included in **Appendix 2.5**.

FIGURE 2.13: BLACKSTONE RIVER SAMPLING LOCATIONS

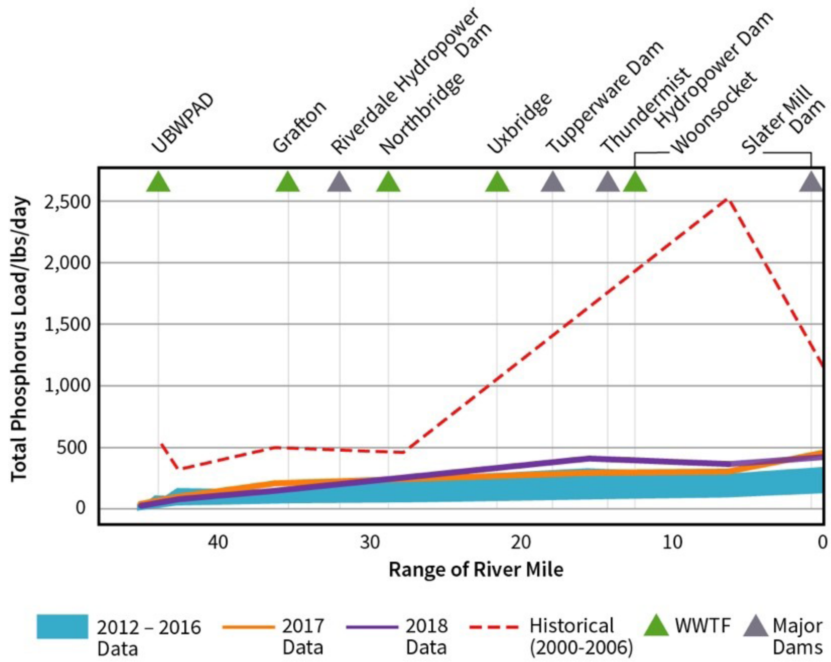


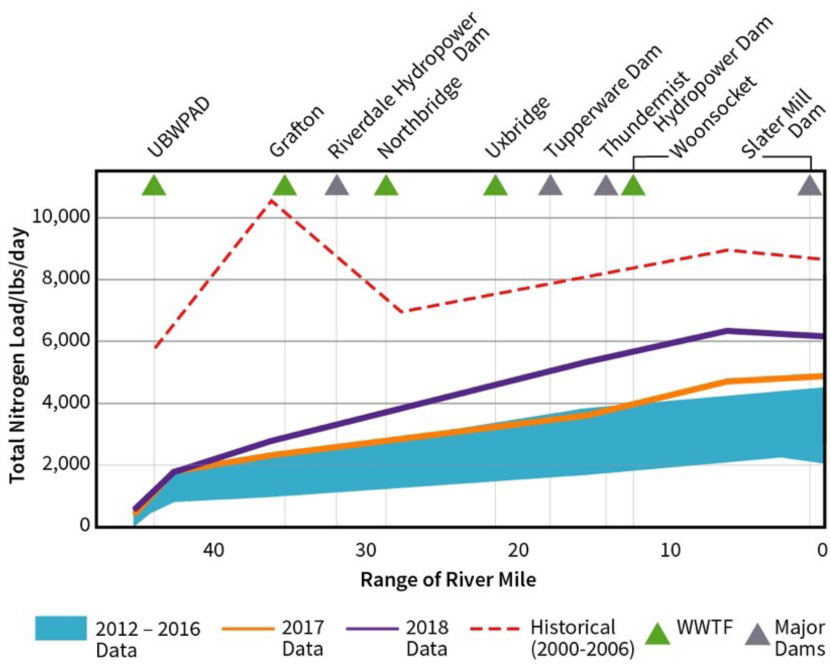
The most recent river monitoring data, from 2017 and 2018, is summarized below. Monitoring locations are shown in the map in **Figure 2.13**.

River sampling for nutrients and chlorophyll-a was conducted from April through November at nine Blackstone River mainstem sites located in Massachusetts and Rhode Island. The Rhode Island stations were co-sampled with the Narragansett Bay Commission's ongoing monitoring program (snapshot.narrabay.com). Streamflow during most sampling dates in 2017 was at or below average, whereas during most sampling dates in 2018 streamflow was at or above average.

Reductions in the total phosphorus and total nitrogen load leaving the Upper Blackstone Treatment Facility are reflected in lower river concentrations. An analysis of 2012 to 2018 concentration data found decreasing concentration trends at three out of the nine monitoring locations for total phosphorus and six out of the nine monitoring locations for total nitrogen. **Figure 2.14** shows total phosphorus and total nitrogen loads in the river using reported concentrations for sampling days. In these graphs, total phosphorus and total nitrogen loads in the river are presented from upstream of Upper Blackstone in Millbury, MA (left side of graph) south to the river outlet at Slater Mill in Pawtucket, RI (right side of graph). Locations of other wastewater treatment facilities and major dams, by river mile, are indicated in the top portion of each graph. These locations are included because these facilities may also influence river water quality. The graphs show that nutrient concentrations downstream of the Upper Blackstone Treatment Facility have decreased; however further downstream, concentrations have increased along some stretches of the river. These increases are not related to the quality of the water leaving the Upper Blackstone Treatment Facility. It is important to note that water quality along the entire river has improved drastically compared to historical data (2000-2006).

FIGURE 2.14: PHOSPHORUS AND NITROGEN LOADING ALONG BLACKSTONE RIVER (2000-2018)





The decrease in river nutrient concentrations due to improvements at the Upper Blackstone Treatment Facility have also resulted in lower chlorophyll-a concentrations, particularly in Rhode Island where most of the large impoundments exist. Chlorophyll-a concentrations are representative of algae growth, which is supported by higher nutrient loading. A comparison of historical summer (June through September) chlorophyll-a concentrations with the average 2017 and 2018 data is shown in **Figure 2.15**.

Chlorophyll-a concentrations were below the 16 µg/L MassDEP screening guideline in 96% samples in 2017 and 90% of samples in 2018. The highest mean chlorophyll-a concentrations typically occur just downstream of Rice City Pond (site W1779) and in the Rhode Island sampling locations. In addition to nutrients in the water column, other factors such as water temperature and increased exposure to sunlight make conditions within impoundments and low river velocity stretches more amenable to algal growth, which is reflected in higher chlorophyll-a concentrations. In 2017, streamflow and precipitation were below average and air temperatures were above average, likely influencing the observed chlorophyll-a concentrations. Similarly, July 2018 was hot with low streamflow.

Periphyton is the micro-community that lives on or attached to the rocks and other submerged surfaces in a river. The 2017 and 2018 sampling program included periphyton surveys in July, August, and September, collected during low streamflow conditions. The surveys were performed at four river locations, including three sites sampled by MassDEP in 2008. The range of reported periphyton concentrations from the 2012–2018 survey results are shown in **Figure 2.16**. Overall, 71% of the periphyton samples collected in 2017 and 2018 were below the MassDEP guidance value (200 mg/m^2).

Year to year periphyton concentrations vary, not only in response to nutrient levels in the river water, but also in response to shading, water temperature and river streamflow conditions.

FIGURE 2.15: CHLOROPHYLL-A SUMMER (JUNE-SEPTEMBER) CONCENTRATIONS (2012-2018)

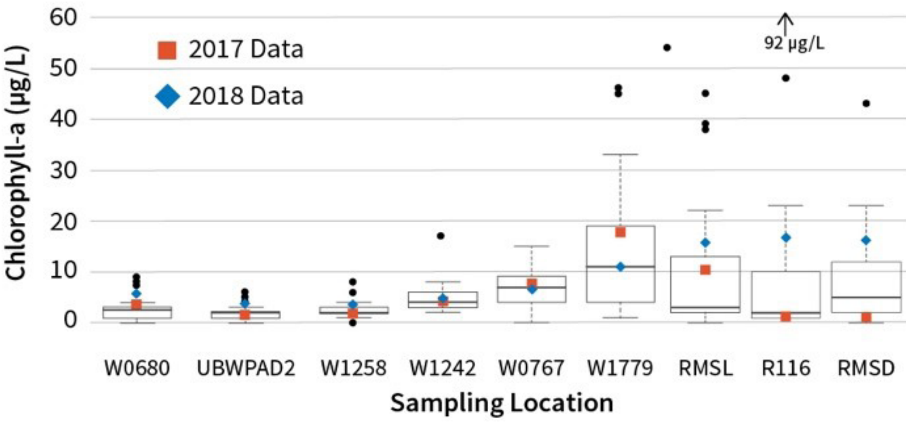


FIGURE 2.16: PERIPHYTON SUMMER CONCENTRATIONS (JULY-SEPTEMBER, 2012-2018)

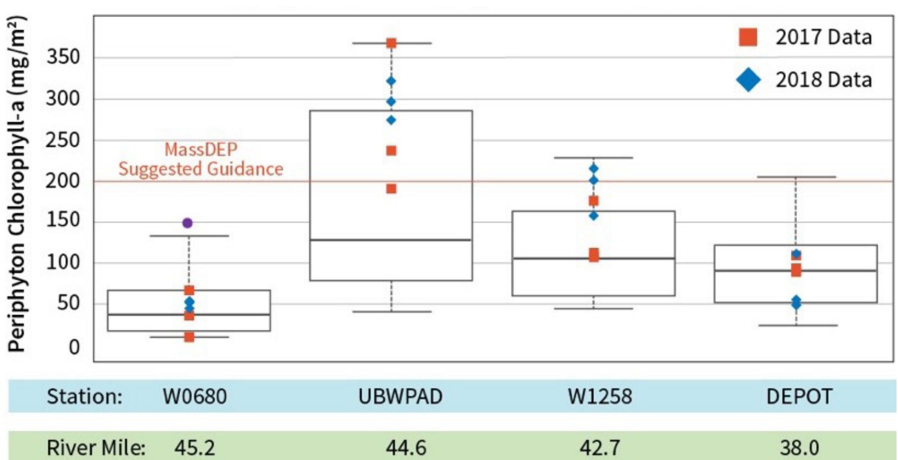
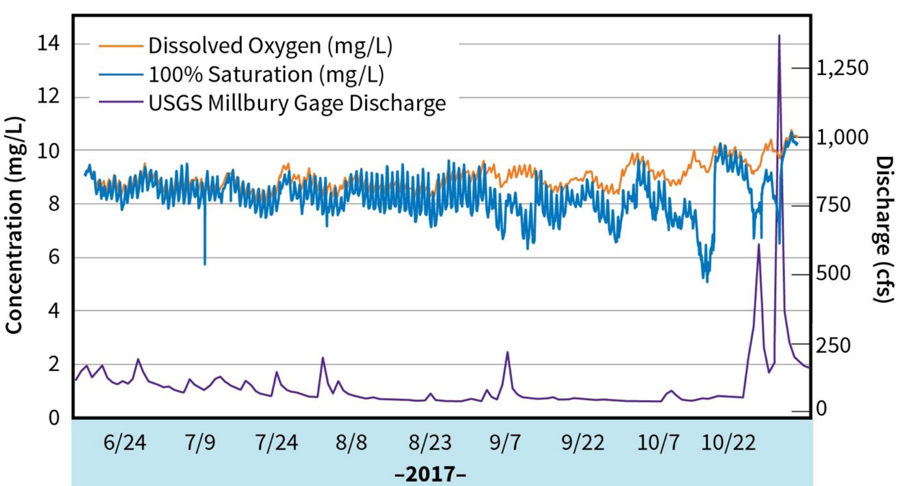


FIGURE 2.17: CONTINUOUS DISSOLVED OXYGEN CONCENTRATIONS AT DEPOT SAMPLING LOCATION (2017)



While data collected during the regular monthly sampling program provide important information on the Blackstone River's health, this data does not provide any information about water quality between sampling events. To help fill this gap, in 2017 the Upper Blackstone District collaborated with MassDEP to deploy and manage four continuous temperature and dissolved oxygen probes in the Blackstone River between June and November 2017. The probes were installed at the periphyton survey locations. In 2019, Upper Blackstone purchased four temperature and dissolved oxygen probes to perform monitoring at the same four locations surveyed in 2017.

MassDEP requires a minimum dissolved oxygen level of 5 mg/L to protect sensitive aquatic life. As temperature increases, the amount of dissolved oxygen that the river can hold decreases. Therefore, measuring both metrics helps evaluate whether dissolved oxygen levels are healthy relative to the temperature of the river. Continuous temperature and dissolved oxygen data collected during 2017, downstream of the Upper Blackstone Treatment Facility, indicates that the Blackstone River is healthy. Observed dissolved oxygen data met Massachusetts state standards nearly all of the time, with occasional low measurements at one sampling location, as shown in **Figure 2.17**.

As the river monitoring data above, and summarized at **Appendix 2.5**, show, the water quality of the Blackstone River has continued to improve since plant upgrades came online in 2009. Reduced nutrient loadings from the Upper Blackstone Treatment Facility effluent correlates to reduced nutrient, chlorophyll-a, and periphyton levels, increasingly meeting MassDEP river quality guidelines for the Blackstone River. The Upper Blackstone District plans to continue river water quality monitoring activities.

Considering the significant cost to Upper Blackstone District, and ultimately to the City, it is prudent to evaluate watershed solutions to improving water quality in the Blackstone River as alternatives to implementing additional nutrient removal improvements at the Upper Blackstone Treatment Facility.

2.4.1.3 Municipal Separate Storm Sewer System

Congress enacted the Clean Water Act "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." 33 U.S.C. §1251(a). Clean Water Act Section 301(a) prohibits "the discharge of any pollutant" by any person, except as authorized by the Act. 33 U.S.C. § 1311(a). To regulate these discharges, Clean Water Act Sections 301 and 304 authorize EPA to establish "effluent limitations," defined as restrictions placed upon pollutants that "are discharged from point sources into navigable waters." Id.§§ 1311, 1314(b), 1362(11)(emphasis added); see also id. § 1342(a)(1).

Under Clean Water Act Section 301, EPA must develop effluent limitations for "pollutants." 33 U.S.C. § 1311. The term "pollutant" has a specific meaning that is not open-ended, but limited, according to statutory language and relevant case law. See, Colautti v. Franklin, 439 U.S. 379, 393 n.10 (1978); National Wildlife Federation v. Gorsuch, 693 F.2d 156, 172 (D.C. Cir. 1982). Clean Water Act Section 402 provides an exception to Clean Water Act Section 301's pollutant discharge prohibition by establishing the NPDES permit program, provided that the pollutant discharges meet appropriate "effluent limitations" contained in an NPDES permit. 33 U.S.C.§ 1342(a). The NPDES permit program limits pollutant discharges from "point sources" into U.S. waters through various practices or technologies. 33 U.S.C.§§ 1311(b)(2), 1314(b), 1316(b)(1)(B).

Originally, Congress exempted some sources of water pollution from the Clean Water Act and NPDES permit program, including municipal stormwater discharges. In 1987, Congress added Clean Water Act Section 4.02(p), which established a phased approach to regulating certain stormwater discharges. In Phase I, Congress required NPDES permits for stormwater discharges "associated with industrial activities" and "from" certain large and medium Municipal Separate Storm Sewer Systems (33 U.S.C. § 1342(p)(1)(4)). The industrial permit program mirrored the existing NPDES permit program for industrial and sanitary wastewaters. The new Municipal Separate Storm Sewer System program was intended to have a more limited scope than traditional NPDES permits.

From the start, Congress recognized that municipal stormwater presented unique challenges and that different practices and technologies should apply than those of other NPDES permit programs.

For Phase II, Congress instructed EPA to study all remaining stormwater discharges to determine the nature of pollutants in those discharges and establish "procedures and methods to control stormwater discharges to the extent necessary to mitigate impacts on water quality." Id. §1342(p)(5). Based on that study, EPA was required to promulgate regulations designating any additional sources of stormwater discharges to be regulated and to establish a "comprehensive program to regulate such designated sources." Id. §1342(p)(6).

From the start, Congress recognized that municipal stormwater presented unique challenges and that different practices and technologies should apply than those of other NPDES permit programs. Municipalities must manage enormous quantities of diffuse stormwater runoff, complex flood control management infrastructure, and the addition of pollutants from within and sometimes even outside their jurisdictional boundaries. Therefore, Congress limited EPA's NPDES permitting authority over municipalities to controlling the discharge of pollutants from the stormwater system to the maximum extent practicable (the maximum extent practicable standard). 33 U.S.C.§ 1342(p)(3)(B)(ii)-(iii).

Federal courts have consistently ruled that the maximum extent practicable standard is the only standard that discharges are required to meet, exempting them from the requirement to specifically meet water quality-based standards. Natural Resources Defense Council, Inc. v. U.S. EPA, 966 F.2d 1292, 1308 (9th Cir. 1992) (Clean Water Act §402(p)(3)(B)) "retained the existing, stricter controls for industrial stormwater discharges but prescribed new controls for municipal stormwater discharge); Defenders of Wildlife v. Browner, 191 F.3d 1159, 1165 (9th Cir. 1999) (Clean Water Act §402(p) (3)(B)) "replaces" the requirements of § 301 with the maximum extent practicable standard for discharges, and it creates a "lesser standard" than § 301 imposes on other types of discharges); Environmental Defense Center v. EPA, 319 F.3d 398 (9th Cir. 2003), vacated, rehearing denied by, and amended opinion issued at 344 F.3d 832 (9th Cir. 2003) (Clean Water Act "requires EPA to ensure that operators of small stormwater systems reduce the discharge of pollutants to the maximum extent practicable"); Mississippi River Revival, Inc. v. City of St. Paul, 2002 U.S. Dist. LEXIS 25384 (N.D. Minn. 2002) ("the Clean Water Act specifically exempts municipal stormwater permittees" from the requirement to ensure that water quality standards are met).

EPA's NPDES permitting authority is limited to controlling the discharge of pollutants from the system to the maximum extent practicable. Stormwater "flow" is not a "pollutant" and it cannot be regulated as a "proxy" or "surrogate" to effect levels of pollutants already present within a water body. Virginia Department of Transportation v. U.S. Environmental Protection Agency, 2013 U.S. Dist. LEXIS 981 (E.D.Va. Jan. 3, 2013).

The City holds a Phase I NPDES permit for their Municipal Separate Storm Sewer System that regulates discharges from the stormwater collection system to various receiving waters. The current permit became effective in 1998 and a draft renewal permit was issued in 2008 (copies of both permits are included in **Appendix 2.4**). The draft 2008 permit has not been finalized; therefore, the 1998 permit remains in effect. In 1999, the City developed a Stormwater Management Plan to comply with the requirements of the 1998 permit. The Stormwater Management Plan was updated in 2015 and referenced in the administrative order issued in August 2016.

The Stormwater Management Plan includes a variety of best management practices that are intended to improve the water quality of stormwater runoff within the City. Examples include street sweeping and catch basin cleaning, both of which require a significant maintenance investment by the City. Stormwater management activities typically consume approximately 60% of the sewer enterprise annual maintenance budget — more than the amount spent on managing the wastewater system.

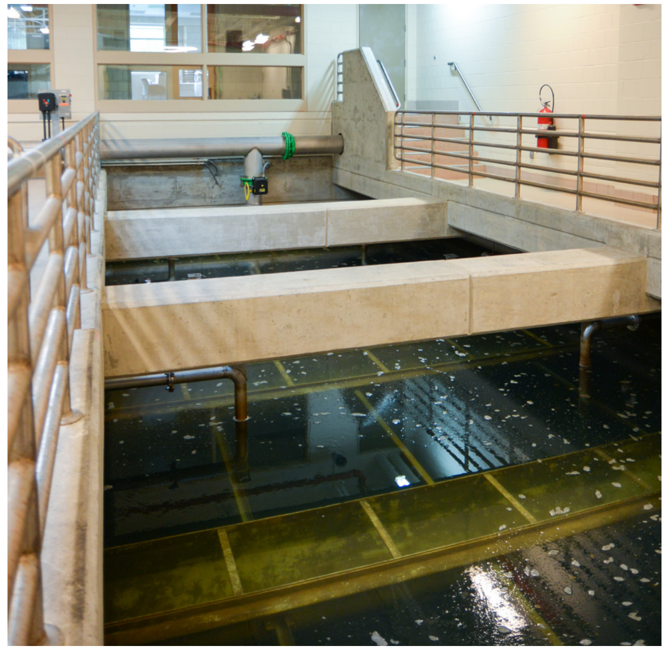
The draft 2008 NPDES Municipal Separate Storm Sewer System permit would impose even more onerous stormwater management requirements. In a study performed in 2012, the City found that compliance with the full requirements of the draft 2008 permit would cost approximately $962 million (2010 dollars). Nearly 76% of that cost is related to stormwater treatment through green infrastructure. Funding these improvements would preclude investment of any significance in maintenance and renewal of the wastewater system. Furthermore, this would significantly reduce the ability of ratepayers to fund other water infrastructure system improvements and maintenance.

2.4.1.4 Water Filtration Plant Backwash

Worcester's public drinking water supplies are treated at its 50 million gallons per day Water Filtration Plant. Treatment includes the introduction of alum to coagulate, creating floc, which is then filtered out of the finished drinking water through dual media filters. The filters require periodic backwashing — cleaning by reversing the flow of fluid through the filter — and the settled backwash water is discharged to Holden

Reservoir No. 2. The City's current general NPDES permit governing this discharge was issued in 2001. A copy of EPA's transmittal letter from May 2001 is included in **Appendix 2.4**. The City applied for coverage under the 2009 General Permit, but the application was denied.

In 2017 EPA issued a new Potable Water Treatment Facility General Permit (MAG640000). Initially it was determined that Worcester was ineligible for coverage under this general permit. After further consideration, EPA found that the discharge from the Worcester Water Filtration Plant did not have reasonable potential to exceed water quality standards and it could be covered by the General Permit. A Notice of Intent was submitted in June 2019 and the City awaits EPA action. The 2017 General Permit does not have specific aluminum limits but does require best management practices to reduce aluminum levels in the discharge. That permit is set to expire in 2022. Beyond that permit it is unclear if aluminum will be regulated in potable water treatment facilities in the future. EPA has included aluminum limits in many recent wastewater treatment plant permits in Massachusetts and continues to set limits based on an 87 ug/L water quality standard. EPA also acknowledges that this standard is likely to change as Massachusetts pursues a state standard and EPA modifies the criteria for setting aluminum standards. It is likely that aluminum will be regulated in permits going forward but it is uncertain what standard will be applied. Through 2022 Worcester does not face any major hurdles regarding permit compliance for the Water Filtration Plant discharge. However, alum is used in the coagulation process, and the filtration backwash water typically contains 700- 800 µg/L of aluminum. Meanwhile, the natural (background) levels of aluminum in the Holden Reservoir No. 2 watershed often exceed the 87 µg/L standard, sometimes by a factor of 20. Meeting future aluminum discharge limits would be challenging as the options to achieve compliance are cost-prohibitive.



The Water Filtration Plant treats the City's public drinking water.

Achieving compliance would require either discharging to the wastewater system, changing coagulant, or installing a separate backwash water treatment facility. Each of these options presents its own technical and financial challenges to reduce aluminum discharge:

- Discharging to the sewer system would exacerbate existing downstream sanitary sewer overflows.
- Changing coagulants could negatively impact drinking-water quality and introduce constituents that may be regulated by future NPDES permits.
- Construction of a separate backwash treatment facility would be costly to construct and would result in significant additional operation and maintenance costs.

The Water Filtration Plant processes have already been optimized to improve residuals handling, which has reduced the backwash water discharge to approximately 0.2 million gallons per day (2010 DMR), significantly less than the 1 million gallons per day discharge allowed under the permit.

2.4.2 Administrative Orders

An administrative order is a non-judicial enforcement action — taken by EPA or a state agency under its own authority — directing an entity to take specific action to come into or to maintain compliance. Administrative orders may be challenged in court, but are often accepted without challenge, or are settled by a negotiated administrative order on consent between the parties.

The following section is a summary of relevant administrative orders concerning the City:

2.4.2.1 EPA Region 1 Docket No. 00-115

This administrative consent order was negotiated with EPA and MassDEP and involved the development by the City of its second Combined Sewer Overflow Long Term Control Plan. The new plan, which included reviewing all options for combined sewer overflow control, recommended building upon, improving and optimizing the system that was constructed in the 1980s. These recommended improvements and optimization steps included:

a. Removing drainage flow from the Green Hill Pond from the combined sewer system
b. Reconfiguration of four regulators to maximize in-line storage
c. Rehabilitation of the Kelley Square Leaf Gate System to maximize in-line storage
d. Increased pumping capacity of Quinsigamond Avenue CSO Treatment Facility to reduce discharge frequency and volume

Improvements “a” through “c” were implemented in 2006-2008, but the final item, increasing the pumping capacity of the Quinsigamond Avenue CSO Treatment Facility from 19 million gallons per day to 54 million gallons per day, has been on hold. The reason for this is that the underlying premise of this specific recommendation was the “conventional wisdom” that wet weather flows were better handled by being pumped to the Upper Blackstone District for treatment, as opposed to the screening-settling-disinfection process offered at the facility. However, shortly after filing the Part II Long Term Control Plan, the City and the District collectively began to question this strategy and concluded that the issue should be examined in a more holistic fashion, with the desired result being a determination of what is best for the receiving water, in this case the Blackstone River. A presentation on the issue was made at a meeting held with regulators, the District and Worcester Department of Public Works & Parks on December 20, 2007 (Note: EPA Region 1 was invited but chose not to attend). A key part of the presentation was the finding that treatment effectiveness at Quinsigamond Avenue CSO Treatment Facility was essentially the same as at the Upper Blackstone District during wet weather conditions. Because Quinsigamond Avenue CSO Treatment Facility influent was mostly stormwater, the equivalent level of treatment on a much-diluted inflow results in better water quality from the facility than from the Upper Blackstone District in wet weather. A March 25, 2008, letter from Worcester to EPA Region 1 requested an extension on the compliance dates for design and construction of the additional pumping capacity at the facility, and further suggested that the project be held pending more analysis and discussion on the efficacy of added pumping capacity. The City has yet to receive a response to the letter but expects that this Integrated Plan will result in further examination of these issues.

2.4.2.2 EPA Region 1 Docket No. 5-21

On September 30, 2005, EPA Region 1 issued an administrative order with numerous requirements to address sanitary sewer overflows. Key provisions include:

- A Capacity, Management, Operations and Maintenance (CMOM) Self-Assessment and Implementation Schedule
- Structural Integrity Investigations of the Sewer Collection System
- Fats, Oils and Grease Program
- Long Term Preventative Maintenance Program
- Sewer System Evaluation Survey investigations of the Chandler and Mann Streets Sanitary Sewer Overflows
- Priority Cleaning Program

The City has complied with the requirements of this administrative order, although EPA has yet to formally approve submittals made by the City.

2.4.2.3 EPA Region 1 Docket No. 92-15

This administrative order was issued in 1992 in response to samples indicating the presence of wastewater measured from the Fitzgerald Brook in quantities that exceeded Massachusetts Water Quality Standards. The order required the City to submit a map of the drainage area for the outfall, inspect manholes, submit a report for securing twin invert manholes and develop a monitoring plan for the drainage area. To date, the City has completed the requirements of the order, including expending significant resources identifying illicit connections through ongoing sampling.

2.4.2.4 EPA Region 1 Docket No. 16-16

This administrative order requires the City to complete an Integrated Plan by February 2019, implement its revised Stormwater Management Plan (SWMP), and provide annual progress reports. A copy of the City's Draft 2015 Stormwater Management Plan is provided in **Appendix 2.4**. EPA and the City agreed to extend the February 2019 date to October 1, 2019. The City is currently in compliance with this order, and the submission of the Integrated Plan will conclude the City's obligations under the order.

2.4.3 State Regulations

In addition to the City's obligations under its NPDES permits, Massachusetts regulatory requirements are applicable. The Commonwealth of Massachusetts, despite not being delegated to implement the NPDES permitting program, has its own regulatory approaches to water resources management that directly and indirectly impact Worcester. These regulatory programs are overseen by MassDEP.

2.4.3.1 Stormwater Regulations

The majority of the stormwater regulations are included in the City's NPDES Municipal Separate Storm Sewer System permit as detailed previously in this section. The City's approach to meeting the permit obligations are contained in its Stormwater Management Plan. Other stormwater regulations in Massachusetts to which the City is subject include:

- 314 CMR 4.00: Massachusetts Surface Water Quality Standards
- 310 CMR 9.00: Stormwater Management Standards for projects requiring a water quality certification
- 310 CMR 10.00: Wetlands Protection Act

MassDEP also publishes the Massachusetts Stormwater Handbook as guidance on the stormwater policy.

Identification of areas with excessive infiltration and inflow requires system-wide subarea metering and follow up closed-circuit television inspections of prioritized subareas.

2.4.3.2 Infiltration/Inflow Control

The State's regulations under 314 CMR 12.00: Operation, Maintenance, and Pretreatment Standards for Wastewater Treatment Works and Indirect Discharges includes a requirement that all sewer system owners develop and implement an ongoing plan to control infiltration and inflow to their sewer systems. Worcester operates a partially combined system; however, these regulations apply to both its combined and separated sewer systems. MassDEP requires a plan for rehabilitation of subareas of sewer systems that exhibit infiltration rates greater than or equal to 4,000 gallons per day per inch-diameter-mile of sewer pipe. Removal of infiltration at lower rates is encouraged provided it can be removed in a cost-effective manner. Inflow sources should be removed unless technically infeasible.

Identification of areas with excessive infiltration and inflow requires system-wide subarea metering and follow up closed-circuit television inspections of prioritized subareas. The closed-circuit television inspections can identify specific pipelines requiring rehabilitation and assist in locating sources of inflow to be removed. The Department's challenge with completing a full-scale infiltration and inflow program is simply the size, age, and condition of its collection system. In many cases, pipelines were constructed over 100 years ago, and nearly 70% of the system has reached or exceeded its useful life. Pipe renewal remains a priority for the Department to maintain service to its users and provides the benefit of removing infiltration sources. The magnitude of the effort to renew the collection system is significant and requires commitment to a full system inspection and assessment program.

2.5 Regulatory Compliance Through Integrated Management

EPA introduced its integrated planning framework in 2012 ("Integrated Municipal Stormwater and Wastewater Planning Approach Framework," May 2012). This framework recognized that municipalities often address Clean Water Act requirements individually, leading to inefficiencies and the unintended consequence of constraining a municipality from addressing its most serious water quality issues first. EPA's integrated planning framework is intended to provide communities with flexibility to prioritize and sequence needed infrastructure investments so that limited public funds can be invested in ways the municipalities find most valuable. The integrated planning framework was adopted by the "Water Infrastructure Improvement Act" to serve as the foundation for an Integrated Plan under the Federal Water Pollution Control Act, as amended on January 14, 2019. (Federal Water Pollution Control Act, Section 402. S.)

The National Academy of Public Administration report, "Developing a New Framework for Community Affordability of Clean Water Services," issued in October 2017, highlights best practices in applying EPA's integrated planning framework for the development of an Integrated Plan. The report recognized the limitations that EPA framework offers for financial capability analyses, specifically related to accounting for Safe Drinking Water Act requirements. Pitting funding for the Clean Water Act against the Safe Drinking Water Act effectively negates the benefits of integrated planning, and leaves communities struggling to appropriately prioritize investments. The National Academy of Public Administration report recommends guidelines for establishing flexibilities to accommodate both sets of regulatory requirements "within a time frame that correlates with well-defined prioritization of community objectives, statutory and regulatory requirements, and integrated planning activities."

This Integrated Plan follows the National Academy of Public Administration report, included in **Appendix 1.1,** and EPA's integrated planning framework, included in **Appendix 1.2**.

Creating an integrated approach to water resources management allows the City to better prioritize and manage its utilities. This effort will ultimately create more reliable systems and an improved environment that is financially sustainable.

CHAPTER 3.
Existing Water Resources Systems Performance

3.1 Overview

Worcester's water resources systems date back to the mid-1800s. Many system components still in use today were constructed during that time. Given the expected design life of these parts, it is clear that significant portions of the City's water resources systems have reached or exceeded their intended service life and require assessment, maintenance, renewal, and upgrade to provide continued, long-lasting service, protection of public health and the environment, and regulatory compliance. The overall aim of this Integrated Plan is to prioritize infrastructure spending to most effectively address City needs. A first step is to characterize the performance of the existing water resources systems and identify where improvements are needed to maximize function and achieve the City's desired performance.

This chapter describes each water resources system considered under this Integrated Plan, and the methodology used to characterize performance. These systems include the following:

- Wastewater collection system
- Stormwater collection system
- Upper Blackstone Treatment Facility
- Drinking Water System

As part of this Integrated Plan development, system performance was benchmarked to quantify the variation between desired and actual levels of operation. This analysis included:

- Review of system operations and crucial areas of performance, referred to as Key Performance Indicators. These Key Performance Indicators are quantitative performance metrics and may be used for comparison with typical national averages.
- Identification of objectives and industry standards to establish benchmarks, or desired performance metrics.

- Documentation of current system performance, or baseline conditions.
- Analysis of performance data to document the differences, or gaps, between benchmarks and baseline conditions. This gap analysis revealed the system needs within critical areas of operation.

Benchmarking is an important step in the Integrated Plan process because it provides the City with greater understanding of system needs prior to identifying and prioritizing infrastructure investments to address those needs. Benchmarking highlights gaps between the current performance of the system and the level of service standards that the City strives to achieve. Understanding performance gaps allows the City to set priorities for closing those gaps. The results inform the subsequent evaluation and screening process used to prioritize capital investments.

3.2 Wastewater Collection System

The wastewater collection system collects and transports domestic sewage and commercial/ industrial wastewater from connected homes and businesses to the Upper Blackstone Treatment Facility for treatment. A small portion of the system utilizes combined sewers, which collect and convey stormwater runoff in addition to sewage. The movement of sewage through the wastewater system generally follows this pattern:

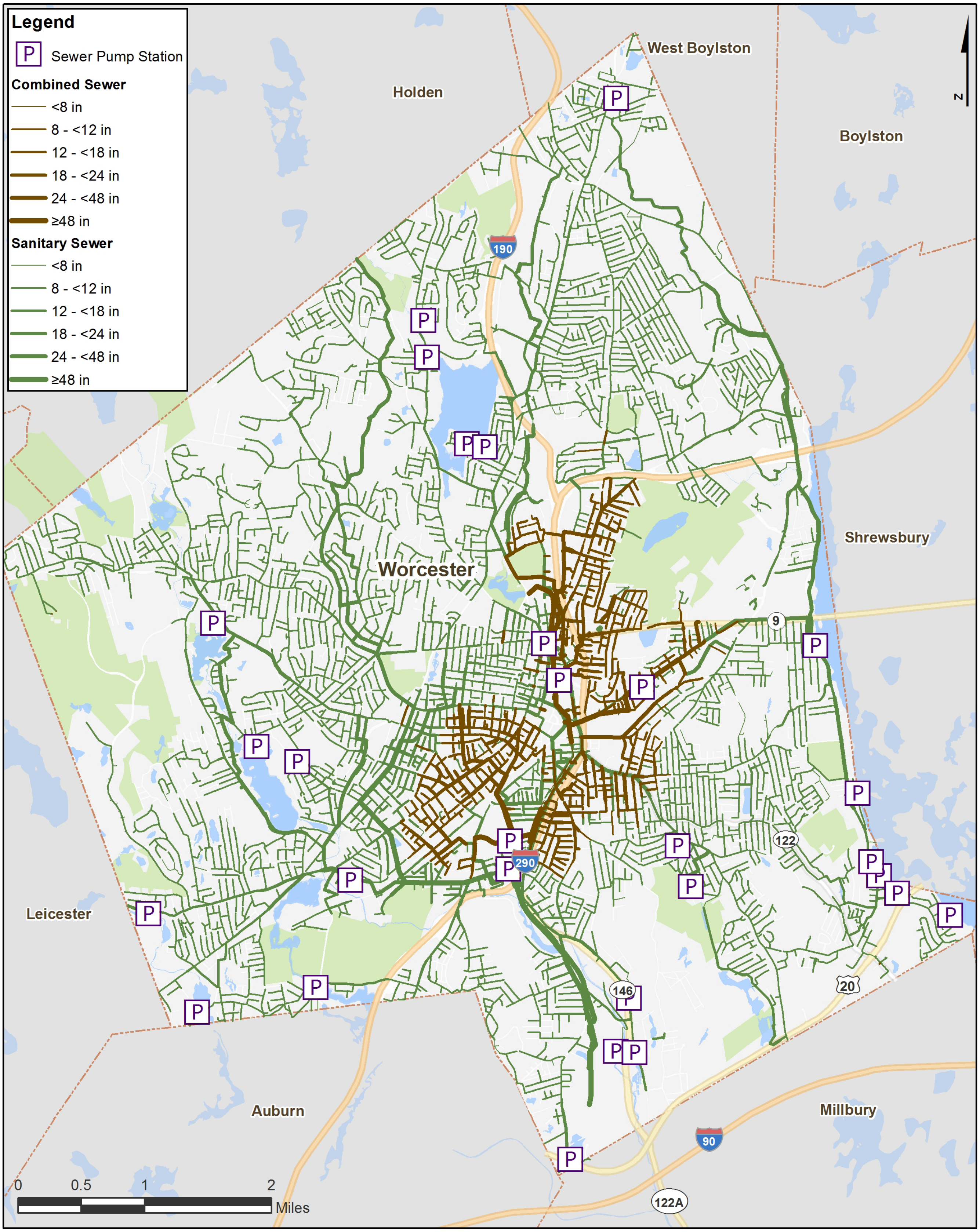
- Wastewater from the western side of Worcester flows east to the Mower Street, Chandler Street, Mill Street, and Main Street interceptors before combining with the Cambridge Street and Northwest interceptors in the south-central area of the City and eventually the Main Interceptor, which carries wastewater to the Upper Blackstone Treatment Facility.
- Wastewater from the eastern and northern sides of Worcester flows to the Lake Avenue Pump Station and is then pumped to the Shrewsbury Street Interceptor. This flow then combines with the Eastern Interceptor, which collects flow from several areas including West Boylston Street, Summer Street, and Harding Street, and is then carried to the Main Interceptor and ultimately to the Upper Blackstone Treatment Facility.

The combined sewer system makes up about 15% of the wastewater collection system and services a 4-square mile area in the central and south-central sections of the City. It functions like the wastewater collection system during dry weather, when flow enters the Quinsigamond Avenue CSO Treatment Facility and is pumped to the Upper Blackstone Treatment Facility. During wet weather, flows in the combined sewer system increase as stormwater runoff enters the system. The Quinsigamond Avenue CSO Treatment Facility continues to pump to the Upper Blackstone Treatment Facility, and when rainfall drives flow rates beyond the pumping capacity, storage and treatment is activated. At such times, the Quinsigamond Avenue CSO Treatment Facility can store up to 2.5 million gallons of combined sewage for later pumping to the Upper Blackstone Treatment Facility or treat and discharge flows to the Mill Brook tributary of the Blackstone River.

Figure 3.1 maps the wastewater collection systems (sanitary and combined) in Worcester.

The Quinsigamond Avenue CSO Treatment Facility.

FIGURE 3.1: WASTEWATER COLLECTION SYSTEMS



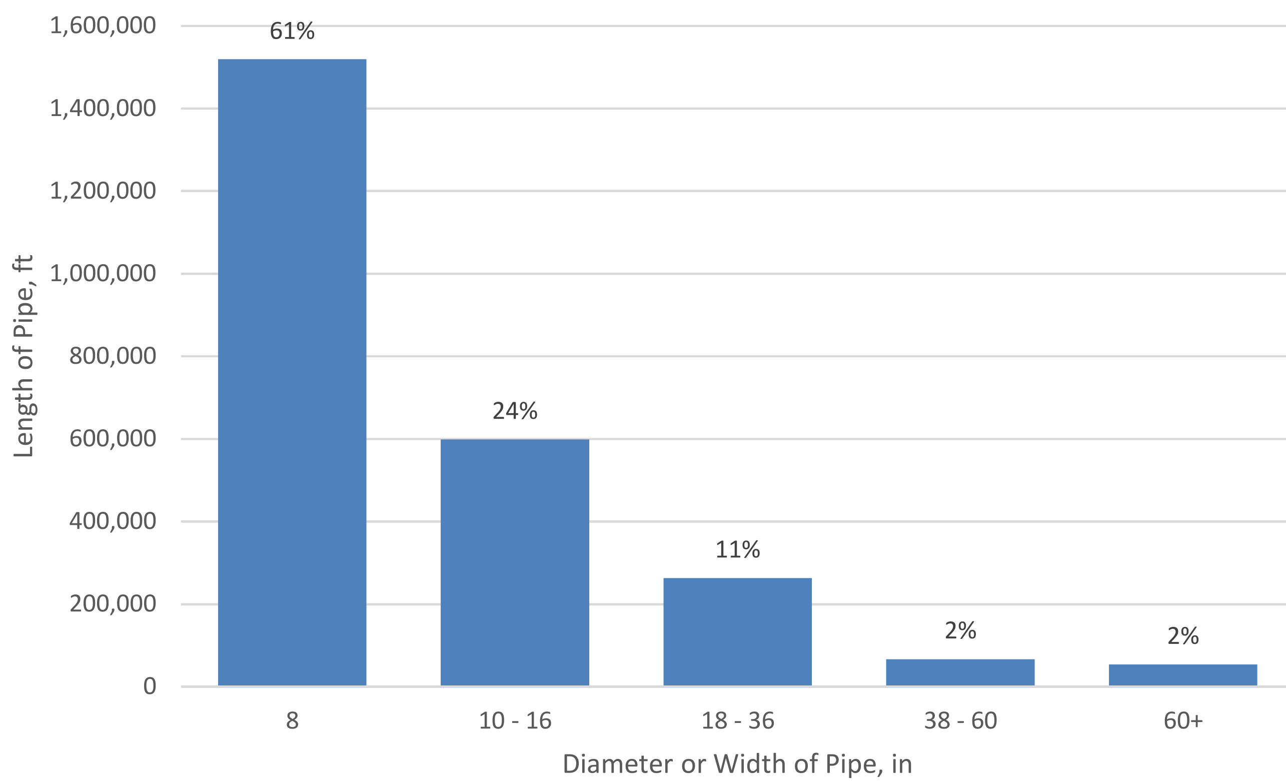
3.2.1 Pipelines

The City's wastewater collection system consists of approximately 400 miles of sewer pipeline. Homes and businesses discharge sewage through sewer service pipes (sewer laterals) that connect to local collector sewers, which flow to larger diameter interceptors and eventually to the regional Upper Blackstone Treatment Facility and Blackstone River. The collection system also conveys flow to the Upper Blackstone Treatment Facility from the surrounding towns of Rutland, Holden, West Boylston, Paxton, Shrewsbury, and the Cherry Valley Sewer District (Leicester). The towns of Auburn, Millbury, Oxford, and Sutton also contribute flow but not through the City's collection system.

Sewer pipelines in the wastewater collection system range from 8 inches to 108 inches in diameter. Nearly 72 miles of the system consist of interceptor sewers, which are pipes typically 18 inches in diameter or larger. The distribution of pipe size in the wastewater collection system is presented in **Figure 3.2**, which also notes the percent of total length at the top of each bar in the chart. Approximately 85% of sewer pipes are smaller than 18 inches in diameter.

Nearly half of the system, typically smaller collector sewers, consists of vitrified clay pipe. Clay pipe is brittle and deterioration at the joints allows for groundwater to infiltrate the system. Interceptor sewers are typically made of brick or reinforced concrete. These pipe materials have performed better than clay, but are deteriorated in certain areas, typically commensurate with the age of the pipe. The system also contains a small percentage (approximately 9%) of unreinforced cementitious pipe referred to as Draper. Draper pipe was used only for a short period of time from 1880 to 1900; however, many neighborhood sewers were constructed during this period. Due to its lack of reinforcement, much of this pipe has failed or is near failure. Approximately 10% of the sewer collection system is of undetermined material.

FIGURE 3.2: SEWER PIPE SIZE DISTRIBUTION



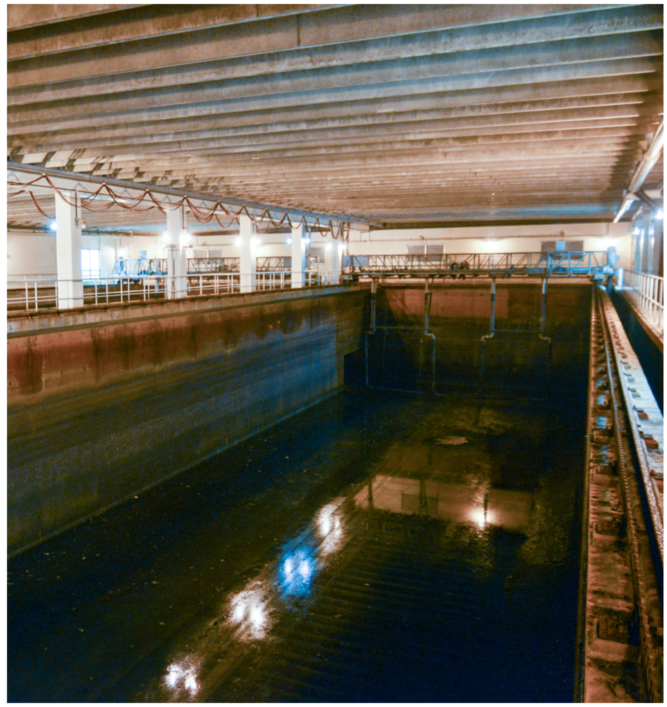
The wastewater collection system originated in the downtown area to support the industrial development noted in historical accounts, and dates to the mid-1800s. Over 150 miles of sewers currently in use were constructed prior to 1900. As the system expanded from downtown into residential areas, more modern pipe materials were used, such as reinforced concrete and, more recently, polyvinyl chloride (PVC). Approximately 50% of the total length of pipe in the wastewater collection system is or will be operating beyond its intended service life within 20 years. Therefore, the percentage of pipeline exceeding its intended service life will grow significantly over the near term without large-scale pipeline replacement or rehabilitation programs. This will pose a greater risk of system failure due to the deteriorated condition of aging pipe. Approximately 14% of the sewer pipe remaining service life is unknown due to a lack of information on the year of installation or pipe material.

3.2.2 Pump Stations

Worcester's topography varies in elevation from 350 to 1,000 feet above sea level. It is known as the City of Seven Hills, a feature that necessitates pumping to move wastewater from low elevations to the interceptors and eventually to the Upper Blackstone Treatment Facility. The Department of Public Works & Parks (DPW&P) operates and maintains 29 wastewater pump stations throughout the City. **Figure 3.1** shows the locations of these pump stations. They range in size from small "package" units that handle low volume wastewater flows from residential neighborhoods to the largest, Lake Avenue Pump Station, which pumps up to 20 million gallons per day (MGD). **Table 3.1** summarizes the year of construction and upgrades of wastewater pump stations.

3.2.2.1 Quinsigamond Avenue CSO Treatment Facility

The Quinsigamond Avenue CSO Treatment Facility was constructed in 1985 as part of Worcester's combined sewer facilities plan to address combined sewer overflows. With construction of this facility, all combined sewer overflow outfalls throughout Worcester were eliminated except for a single, permitted, treated outfall that discharges to the Blackstone River.



Inside the Quinsigamond Avenue CSO Treatment Facility.

During dry weather, the combined sewer system conveys wastewater to the Quinsigamond Avenue CSO Treatment Facility, which serves as a pump station sending flow through the Main Interceptor to the Upper Blackstone Treatment Facility. When flows increase during wet weather, the Quinsigamond Avenue CSO Treatment Facility continues to pump up to approximately 19 million gallons per day to the Upper Blackstone Treatment Facility. Pumping is halted when the overall influent flow rate from member communities approaches the capacity of the plant's biologic treatment process. The theoretical capacity of the plant's biological process is approximately 80 million gallons per day; however, cold temperatures and other conditions can limit the operational capacity. When the Upper Blackstone Treatment Facility cannot accept additional flows, excess combined flows are stored and treated at the Quinsigamond Avenue CSO Treatment Facility.

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TABLE 3.1: WASTEWATER PUMP STATION YEAR OF CONSTRUCTION AND UPGRADES

#	Station	Wastewater Type	Construction Year	Rehabilitation Year	Critical Equipment Year(s)	Generator Year	Controls Year	Supervisory Control and Data Acquisition Year
1	Arletta	Wastewater	1948	2007	1997, 2007	1997	-	-
2	Ballard Street (Millbury Street)	Wastewater	2005	-	2005, 2007	2005	-	-
3	Botany Bay	Wastewater	1983	-	1993, 2014	2014	2014	2014
4	Bridle Path	Wastewater	1961	-	1961	1988	-	-
5	Broad Meadow	Wastewater	1958	-	1958	1989	-	-
6	Brookhaven	Wastewater	1985	-	1985, 2016	2016 (Portable)	-	-
7	Crowningshield	Wastewater	1954	-	2005	-	-	-
8	Dunkirk	Wastewater	1966	1999	1999, 2008	2008	2017	2011
9	Grafton Street	Wastewater	1989	-	1989, 1990	1990	-	-
10	Greenwood Street	Wastewater	1956	-	1956	-	2016	2016
11	Hemlock	Wastewater	1974	-	1974	1986	-	-
12	Holden	Wastewater	1943	-	1988, 2012	2012	2012	2012
13	James	Wastewater	1972	1996	1972	-	-	-
14	Kettle Brook	Wastewater	1953	2007	2007	2007	2007	2012
15	Lake Ave	Wastewater	1951	2014	2014, 2015	2014	2014	2014
16	Livermore	Wastewater	1971	-	1986, 1987	1987	-	-
17	Millbury Street (Millbury II)	Wastewater	2011	-	2011	2011	-	-
18	Oak Beach Terrace	Wastewater	1968	2017	2017	2017	2017	2017
19	Pineland	Wastewater	1974	-	1974, 1976	1976	2012	2012
20	Proctor	Wastewater	1931	-	1990	1988	-	-
21	Quinsigamond	Combined Sewer	1985	-	1983, 1985	1983	-	-
22	Sears Island	Wastewater	1985	-	2012, 2014	2014	2014	2014
23	Shrewsbury	Wastewater	1998	-	1998, 1999	1999	2012	2012
24	Suntaug	Wastewater	1959	-	1959, 2003	2003	-	-
25	Upper Blackstone District Landfill	Leachate	1975	-	1975	-	-	-
26	Waller Avenue	Wastewater	2011	-	2011	-	-	-
27	Webster	Wastewater	1935	-	2016	2016	2016	2016
28	Whitla	Wastewater	1968	2019	2019	1980	2013	2013
29	Whitla II	Wastewater	1989	-	1968	1980	-	-

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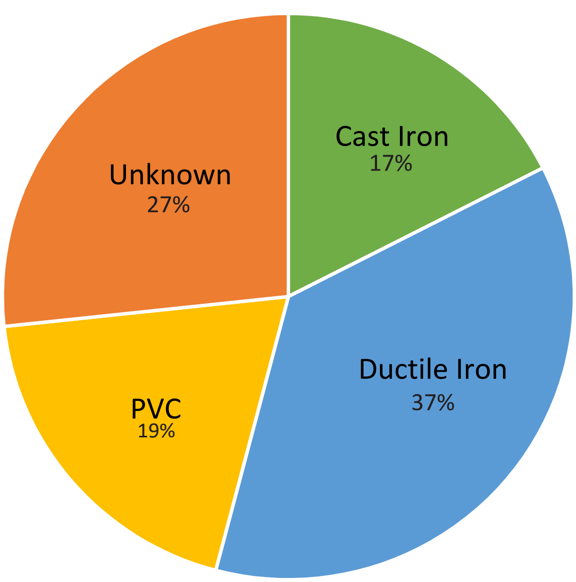
The design capacity of the Quinsigamond Avenue CSO Treatment Facility is 350 million gallons per day based roughly on the design flow of a 100-year storm in downtown Worcester. The facility includes two chlorine-contact tanks, which each hold up to 1.25 million gallons and act as storage tanks during wet weather. Flow is either released back to the Upper Blackstone Treatment Facility following high flow events or, if the storage capacity is reached, the Quinsigamond Avenue CSO Treatment Facility discharges treated combined wastewater to the Blackstone River through the Mill Brook Conduit. Treatment at this facility consists of screening, storage/settling, disinfection, and dechlorination.

To assure its continuing operation and maintain or improve its treatment effectiveness, several upgrades to the facility have been completed, including:

- In 1999, installed new drain pump and scum pump flow meters, new level sensor for incoming flow, backup wet-well level sensor, ultrasonic level sensors in each contact tank and hypochlorite bulk storage tank, new hypochlorite metering pumps, and improved supervisory control and data acquisition (SCADA) system with integration of new pumps to the supervisory control and data acquisition system.
- In 2007, replaced sodium bisulfite storage tanks.

FIGURE 3.3: SEWER FORCE MAIN MATERIALS



- In 2011, upgraded supervisory control and data acquisition monitoring system of the Quinsigamond Avenue CSO Treatment Facility including monitoring of 14 remote pump stations.
- In 2017, installed new chemical feed pumps, instrumentation, new flow meters, and supervisory control and data acquisition system upgrades.

During dry weather, the Quinsigamond Avenue CSO Treatment Facility is staffed remotely, similar to other sewer pump stations. During wet weather, the facility is typically manned.

3.2.3 Force Mains

Pump stations discharge through a pressure pipe referred to as a sewer force main. Force mains vary in length depending on the proximity of the pump station to the gravity collection system. There are 8.5 miles of force main in Worcester with cast iron, ductile iron and PVC being the predominant materials. **Figure 3.3** summarizes the sewer force main materials.

Approximately 17% of the force main pipes are cast-iron, installed in the mid-1900s. Cast-iron pipe was manufactured without an interior lining or an exterior coating. As a result, cast-iron pipe failures due to internal and external corrosion represent a substantial risk. Recently more modern pipe materials were used, such as cement-lined ductile iron and PVC, which are less susceptible to internal and external corrosion.

3.2.4 System Performance

For many decades, a less than optimal level of investment in the wastewater collection system has resulted in increased reactive maintenance and emergency repair and sub-par performance in some aspects of the system. A large percentage of the collection system, including some pump stations, has exceeded, or will soon exceed, its intended service life. Failure of these components can cause significant public health impacts and contribute to degradation of water quality.

Operations and maintenance of Worcester's wastewater collection system utilizes the services of both DPW&P staff and contractors. Regular maintenance includes flushing, heavy cleaning to remove debris and grease, chemical treatment for root control, and closed-circuit television (CCTV) inspection of critical pipelines. Significant findings pertaining to system maintenance include:

- While progress has continued on system cleaning and inspections (CCTV), these activities have been implemented at a less than optimal rate due to limited resources.
- The City employs 69 full-time employees to operate and maintain the wastewater and stormwater collection systems and pumping stations.
- It is estimated that 35% of collection system related actions are unplanned due to system failures and emergencies, which redirect resources from routine maintenance.

The performance of the wastewater collection system requires ongoing maintenance and an understanding of system conditions.

Portions of the wastewater system with a high consequence of failure, such as sewer interceptors, pump stations and sewers serving critical customers (e.g., hospitals, large apartments, major employers), require particular attention. Material, age, and condition of the system also indicate potential for failure. Key findings pertaining to system condition and potential weaknesses include:

- Approximately 49% of the wastewater collection system's pipes are approaching (within 20 years) or beyond their intended service life.
- Approximately 80% of sewer pump stations' major components are approaching or have exceeded their intended service life.
- Neighborhood collection systems consisting of unreinforced concrete pipe are increasingly requiring unplanned pipe replacement, impacting service and routine maintenance activities.

The performance of the wastewater collection system requires ongoing maintenance and an understanding of system conditions. Performance is measured by occurrences of sanitary sewer overflows, treated discharges, and system backups, and by impacts to public health and safety. Key findings pertaining to system performance include:

- Though infiltration and inflow (I/I)[1] rates in the collection system are overall better than regulatory benchmarks, capacity-related sanitary sewer overflows, basement backups, and high flows at the Upper Blackstone Treatment Facility remain problematic during wet weather.
- The collection system is subject to sanitary sewer overflows and basement backups due to non-capacity related issues such as roots, wipes, debris, and grease restricting pipelines.
- The performance of the sanitary and combined sewers, including the Quinsigamond Avenue CSO Treatment Facility, is complex and highly interdependent, and also impacts performance of the Upper Blackstone Treatment Facility.
    - During intense, short-duration storms, the combined sewer system can back-up and contribute to significant flooding in the Green Island area. When the Quinsigamond Avenue CSO Treatment Facility storage tanks approach capacity, flows from the Southbridge Street combined sewer system can be restricted and may contribute to overflows.
    - For longer-duration storms, capacity limitations in the Mill Brook Conduit contribute to system backups and street flooding. This large, culverted brook serves as a major drainage conduit for its tributary area, and the downstream portion also acts as the effluent conduit for Quinsigamond Avenue CSO Treatment Facility discharges.
- The 2004 Long-Term Combined Sewer Overflow Control Plan update recommended pump upgrades to increase pumping capacity at the Quinsigamond Avenue CSO Treatment Facility. This approach needs to be

1 Infiltration refers to groundwater that enters the collection system through cracks and defects in the pipes and structures. Inflow refers to excess flow that enters the collection system through sump pump connections or directly connected roof leaders. Both infiltration and inflow contribute extraneous flow to the collection system, which limits capacity.

reevaluated as increased wet weather flows to the Upper Blackstone Treatment Facility at times stress the capacity of its secondary treatment process. Increased pumping at the Quinsigamond Avenue CSO Treatment Facility may result in more blending at the Upper Blackstone Treatment Facility[2]. Prior to implementing this recommendation, further study is needed to characterize the flow relationship between the Quinsigamond Avenue CSO Treatment Facility and the Upper Blackstone Treatment Facility. This study would evaluate treatment effectiveness and determine the optimal operating scheme between the two facilities.

The following Key Performance Indicators for the wastewater collection system were identified:

1. **Wastewater Pipe Age:** Aging infrastructure requires more maintenance and has a greater risk of failure, requiring unplanned or emergency response by the City. This indicator is measured as the percent of sewer system pipes that exceed their intended service life.
2. **Infiltration Rate:** Infiltration limits available capacity within the wastewater system and can exacerbate system backups and overflows; it increases the total cost of wastewater transport to and treatment at the Upper Blackstone Treatment Facility. This normalized measurement is represented as a rate of infiltration in gallons per day per inch-diameter mile of the entire system.
3. **Loss-of-Service Complaints:** Loss of service to customers is indicative of a system failure. This indicator is measured as the number of complaints per year.
4. **Sanitary Sewer Overflows Rate:** Sanitary sewer overflows may impact public health and receiving-water quality. This indicator is measured as the number of events per year based on:
   - Non-capacity overflows that happen when pipelines and manholes are restricted by debris, grease, or roots, or collapses due to structural failure.
   - Capacity overflows that occur due to hydraulic limitations during wet weather and may be the result of an undersized collection system or infiltration and inflow.
5. **Unplanned Maintenance:** Unplanned maintenance diverts resources from planned system assessments and improvements. This measure reveals the extent of resources being used for reactive efforts to address failures or other problems. This indicator is measured as a maintenance rate of hours per 100 miles of pipe per year.

3.3 Stormwater Collection System

The City of Worcester encompasses nearly 40 square miles and much of that is in a very urbanized state. From its earliest days as a City, stormwater runoff from streets, parking lots, rooftops and other impervious surfaces had to be collected and conveyed away from the built environment to prevent flooding, property damage and traffic disruptions. The stormwater collection system in use today is the same system originally designed to move runoff quickly to the nearest waterway or water body. Today, however, through the Clean Water Act and National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit, water quality of urban runoff must also be considered.

Worcester's stormwater collection system includes over 16,000 city-owned catch basins. These structures collect surface runoff and convey it to the stormwater pipe network, which, in turn, carries flow to one of the 350 stormwater outfalls that discharge to receiving waters. Catch basins provide a basic level of stormwater treatment, collecting sediment in deep sumps and containing floatables through a hooded outlet trap.

Even before Worcester received the first National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit in New England in 1998, the City was implementing practices to better manage stormwater. In the 1980s many new developments were required to construct detention basins to mitigate post

2 Blending occurs when influent flows exceed the capacity of the secondary treatment process. The Upper Blackstone Treatment Facility manages the excess flow by mixing (blending) fully treated flow with primary process treated flow that is then discharged directly to the Blackstone River and must still meet NPDES permit limits.

construction runoff rates. Detention basins may also provide stormwater treatment through settling and growth of wetland plants that trap nutrients. The City also installed the first hydrodynamic particle separator at a major outfall to Lake Quinsigamond in 1997. At the time of installation this was the largest such structure in New England.

Since the dawn of the National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit era, Worcester has continued its efforts to improve stormwater quality. These include best management practices like street sweeping and catch basin cleaning, illicit discharge detection and elimination, construction control regulations to limit sediment deposition, public education, the use of green infrastructure including tree box filters and rain gardens along with an additional 31 hydrodynamic particle separators. The City has also applied Massachusetts Department of Environmental Protection Stormwater Handbook criteria to virtually every development and redevelopment project for the past 30 years. This has led to the installation of private stormwater treatment facilities, including recharge structures, throughout Worcester.

While water quality is the major driver of today's stormwater management practices, the basic need to capture and convey urban runoff away from streets and buildings remains. New infrastructure and upgrades to existing stormwater facilities are constantly being designed or evaluated to address localized flooding issues.

Figure 3.4 maps the stormwater collection system in Worcester.

3.3.1 Pipelines

The City's stormwater collection system consists of approximately 321 miles of pipe. Stormwater pipes are primarily made of vitrified clay and reinforced concrete, ranging from 6 inches to 84 inches in diameter, with some larger 13-by-18-foot box culverts comprising granite arch construction. The distribution of pipe size in the stormwater collection system is presented in **Figure 3.5**, which also notes the percent of total length at the top of each bar in the chart.

Approximately 40% of stormwater pipe of known age currently exceeds or will exceed its intended service life within 20 years. Like the wastewater collection system, the condition of the stormwater system is poor in many areas, including failing infrastructure that requires replacement or rehabilitation. The percentage of pipeline exceeding its intended service life will grow significantly in the next 20 years without pipeline replacement or rehabilitation. This will pose greater risk of system failure due to age-related deterioration.

3.3.2 Pump Stations

Stormwater pump stations have limited use in Worcester and have only been constructed at critical underpasses and a vehicular tunnel. These three stormwater pump stations include: Cambridge Street, Martin Luther King Jr. Boulevard, and Johnson Tunnel. The Cambridge Street stormwater pump station was upgraded with new pumps, supervisory control and data acquisition, and controls in 2014. The location of the pump stations is shown in **Figure 3.4**.

Table 3.2 summarizes the year of construction and key upgrades of stormwater pump stations throughout the City.

3.3.3 System Performance

The stormwater collection system is challenged by both capacity and water quality issues. The changing direction of stormwater management, from a strictly flow-driven perspective to a water quality perspective has been especially difficult given that the basic infrastructure remains the same. In some respects, this challenge has been met very successfully while in other areas performance needs to improve.

A large percentage of the stormwater collection system has exceeded, or will soon exceed, its intended service life. The stormwater pump stations are also in need of maintenance and upgrades.

Failure of stormwater system components can cause flooding and resultant public safety impacts and contribute to degradation of water quality.

FIGURE 3.4: STORMWATER COLLECTION SYSTEM

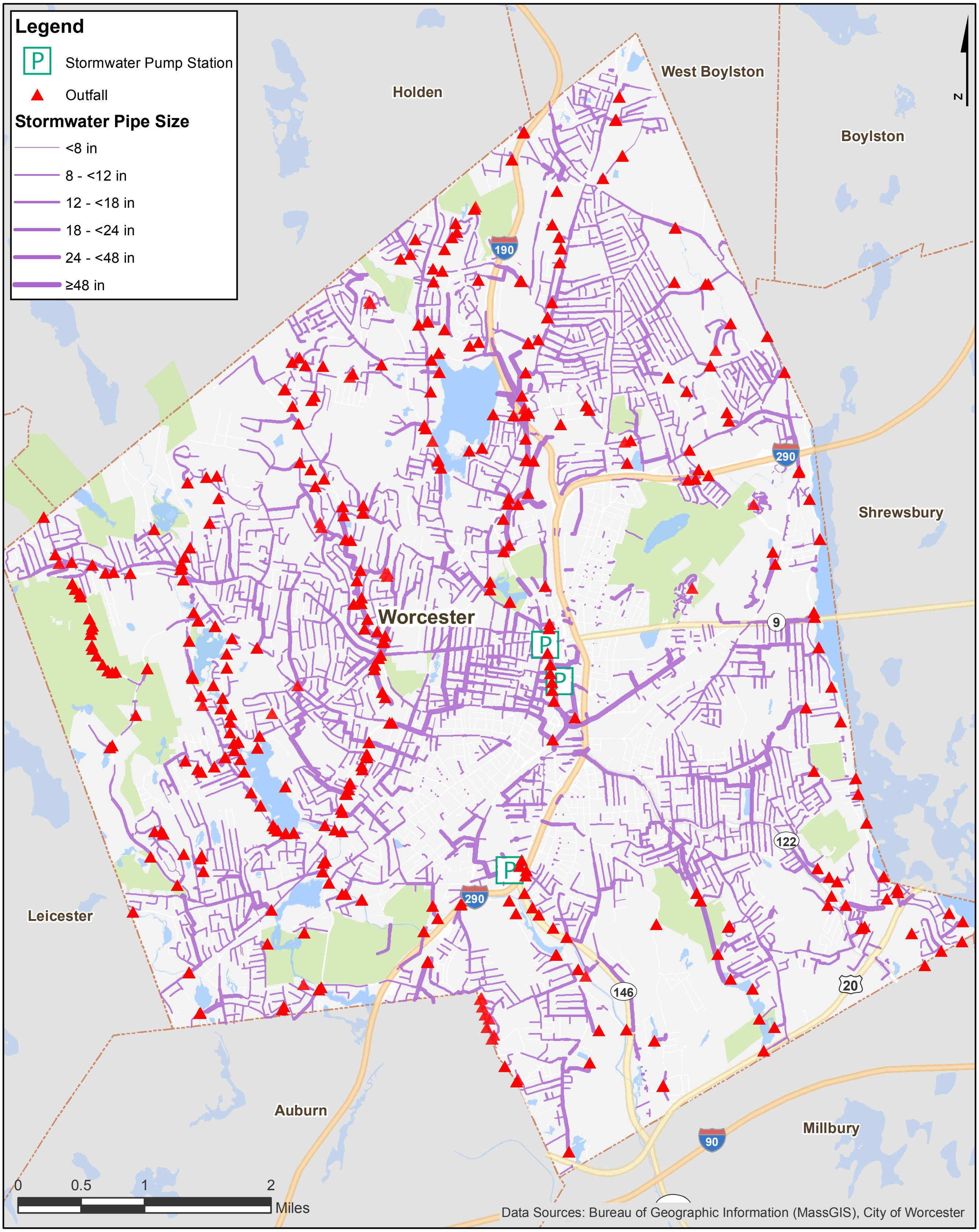


FIGURE 3.5: STORMWATER PIPE SIZE DISTRIBUTION

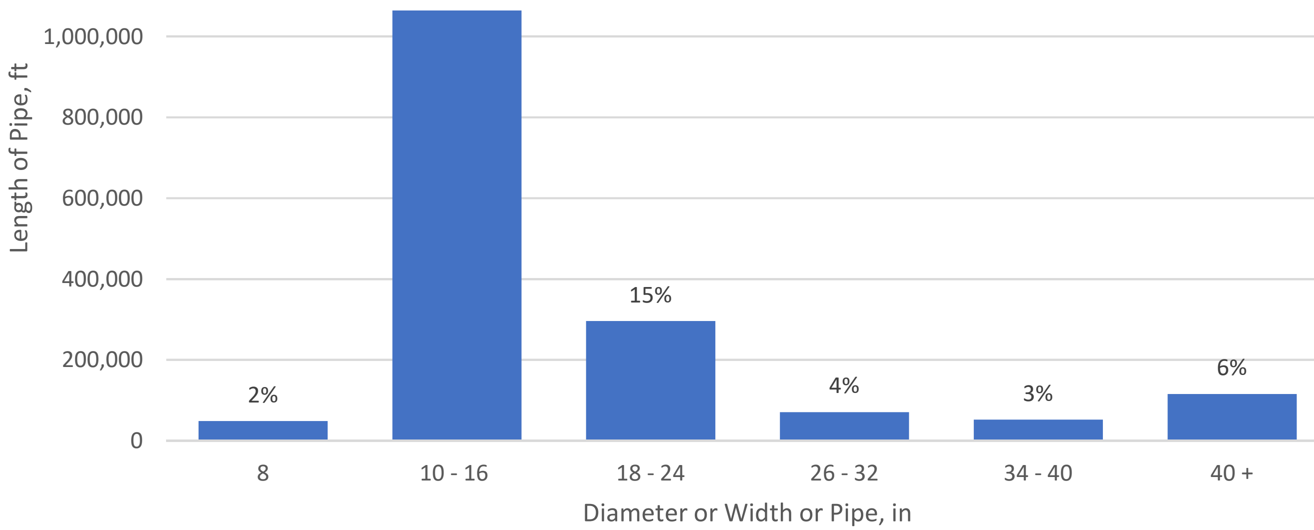


TABLE 3.2: STORMWATER PUMP STATION YEAR OF CONSTRUCTION AND UPGRADES

#	Station	Construction Year	Rehabilitation Year	Critical Equipment Year(s)	Generator Year	Controls Year	SCADA Year
1	Cambridge Street	1914	—	2014	—	2014	2014
2	Martin Luther King Jr. Boulevard	2000	—	1996, 1999	1996	—	—
3	Johnson Tunnel	1957	2000	2000	—	—	—

From a water quality perspective, the stormwater collection system is operated in accordance with a Stormwater Management Plan, which was initially developed to comply with the requirements of the 1998 National Pollutant Detection Elimination System Municipal Separate Storm Sewer System permit. Most recently updated in 2015, the Stormwater Management Plan summarizes the City's efforts to reduce stormwater pollution to the maximum extent practicable using best management practices for public education and outreach, source-controls, maintenance, system improvements, and sampling and monitoring. Key actions undertaken to reduce pollution include:

- **Catch basin cleaning:** Catch basins are cleaned at a minimum once every two years.
- **Pipeline inspection and cleaning:** Pipelines and manholes are cleaned and inspected based on performance.
- **Illicit Discharge Detection Program:** Illicit discharges are identified through outfall sampling followed up with closed-circuit television inspections, and manhole inspections. Since the start of the program in 1998, 193 illicit connections have been eliminated.
- **Street sweeping:** The City sweeps residential streets twice per year, arterial streets once per week, and downtown nightly.
- **Leaf Collection Program:** A residential leaf collection program is operated each fall. City crews collect leaves and sweep streets, with leaves then deposited at composting facilities. An average of over 12,000 tons of leaves are collected annually.
- **Stormwater Treatment Devices:** The City has used advanced technology and infrastructure to improve stormwater quality, including 32 hydrodynamic particle

separators to capture sediment buildup, oil, and floatables, 26 tree-box catch basin filters to capture and treat the first flush of a storm, and three rain gardens that treat and infiltrate captured runoff.

These best management practices focus on improving the water quality of discharges from the Municipal Separate Storm Sewer System.

Flooding at Liberty Central Industrial Park.

The capacity of the stormwater system is also a concern. Decades of growth and development have increased impervious area and the amount of runoff entering the stormwater collection system. In some areas this additional volume and rate of runoff has overwhelmed the system's capacity resulting in localized flooding, especially during large storms. During recent years, Worcester has experienced an increase in the frequency of high-intensity rain events. This phenomenon has exacerbated existing flooding problems and created new areas of concern. Observations about system performance include:

- The stormwater collection system has a history of localized and widespread flooding during both small and large storms.
- Approximately 40% of the stormwater collection system's pipes are approaching or beyond their intended service life.
- Approximately 66% of the stormwater pump stations' major components are approaching, or have exceeded, their intended service life.
- The stormwater collection system may negatively impact Worcester's water bodies, affecting public health, habitat, and recreational use.

The following Key Performance Indicators for the stormwater collection system have been identified:

1. **Stormwater Pipe Age:** Aging infrastructure requires more maintenance and has a greater risk of failure, requiring unplanned or emergency response. This indicator is measured as the percent of stormwater system pipes that exceed their intended service life.
2. **Catch Basin Cleaning:** The City implements its Stormwater Management Plan, last revised in 2015, which calls for catch basins to be cleaned once every two years. This is measured as the number of catch basins cleaned per year.
3. **Street Flooding:** Failed and undersized stormwater infrastructure can cause flooding in the public way and on private property. Flooding is measured in two distinct areas:
    - **Within Green Island Area:** As the City's most complex and problematic flood-prone area, Green Island flooding is measured as the number of days with complaints logged through the City's Customer Service Request System per year.
    - **Outside Green Island:** Flooding outside the Green Island area is measured as the number of days with complaints logged through the Customer Service Request System per year.

3.4 Upper Blackstone Treatment Facility

The Upper Blackstone Water Pollution Abatement District (Upper Blackstone District) operates the regional Upper Blackstone Treatment Facility located in Millbury. It receives wastewater flow from the member communities of Worcester,

Upper Blackstone Treatment Facility.

Auburn, Millbury, Holden, Rutland, West Boylston and Cherry Valley Sewer District. It also receives flow from portions of Sutton, Shrewsbury, Oxford, and Paxton, which are not district members.

Worcester is by far the largest member community, contributing approximately 85% of flow to the plant and paying that proportion of the operating budget.

The Upper Blackstone District was formed in 1968 and the treatment facility was completed in 1975. The Upper Blackstone Treatment Facility is designed to treat an average annual flow of 45 million gallons per day, a maximum daily flow of 80 million gallons per day, and a peak hourly flow rate of 160 million gallons per day. High-flow blending of secondary treatment is activated as necessary to avoid washout of the biologic treatment process. The treatment facility currently applies the following treatment processes:

- Screening
- Primary settling
- Anaerobic/anoxic/oxic process biological nutrient removal system
- Final settling
- Disinfection
- Dechlorination

A diagram of the Upper Blackstone Treatment Facility process is provided in **Figure 3.6**. Treated effluent is discharged to the Blackstone River.

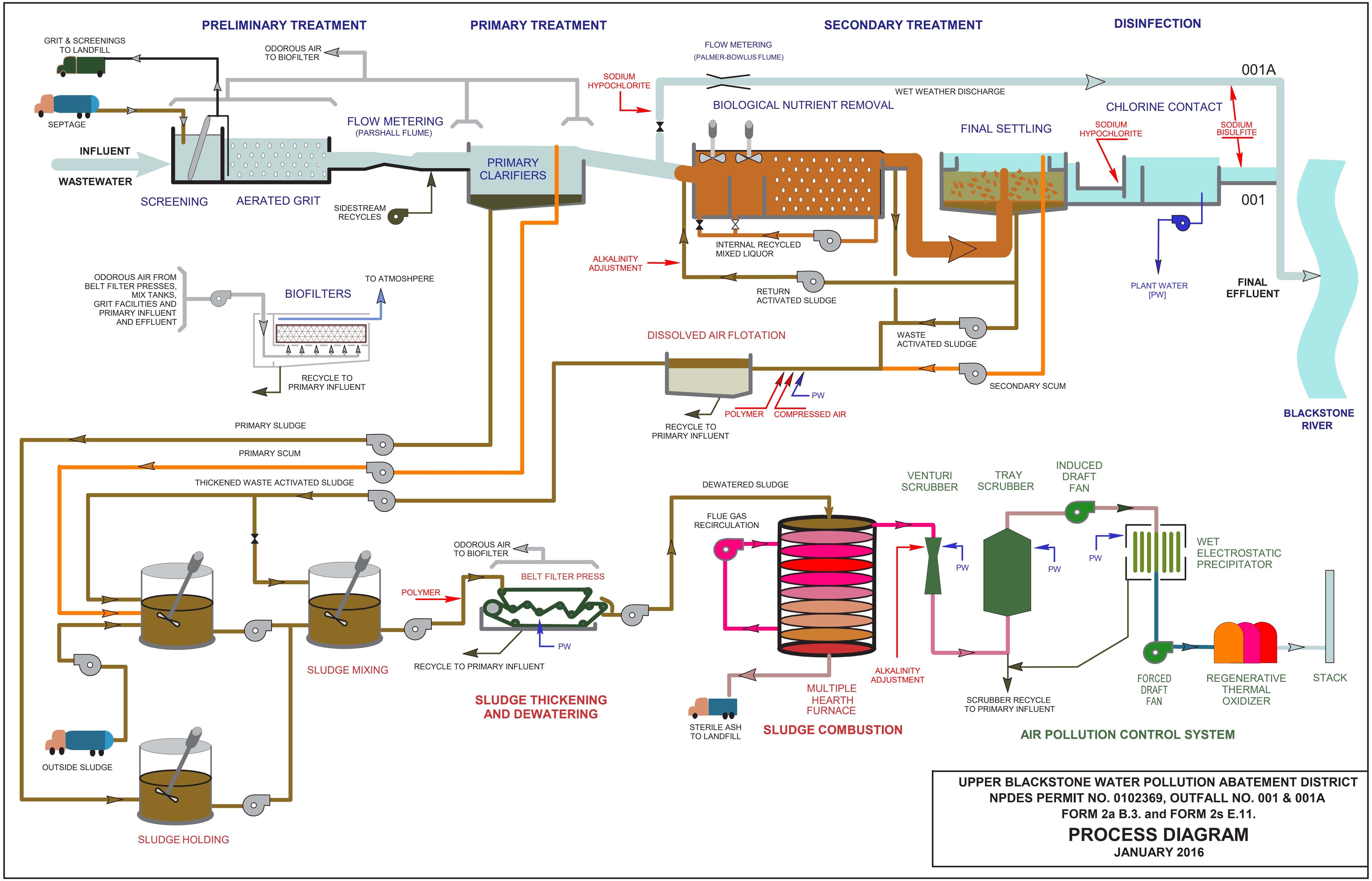
The Upper Blackstone Treatment Facility serves non-member regional communities by processing sludge generated by other wastewater treatment facilities and treating trucked-in septage and liquid wastes.

Sludge generated by the treatment facility and other plants is incinerated and the residual ash is landfilled. Due to increasingly stringent air pollution regulations, sludge incineration is practiced by fewer wastewater treatment plants in the area. The Upper Blackstone Treatment Facility will likely grow in importance as a regional sludge disposal option. However, the incinerator is approaching the end of its useful life. Over the next 5 to 10 years, the future of biosolids handling and disposal will have to be addressed. Options to replace the incinerator and continue as a regional sludge disposal facility or to abandon incineration and seek alternative disposal means will be weighed. All choices are likely to carry significant costs and will be incorporated into this Integrated Plan through the adaptive management process.

The Upper Blackstone Treatment Facility's high-flow management plan includes infrastructure to bypass its secondary treatment process during high flows from major storms by blending primary effluent with final effluent to preserve biological treatment and avoid washout.

The Upper Blackstone Treatment Facility operates with a full-time staff of operators and office employees to keep the plant functional.

FIGURE 3.6: UPPER BLACKSTONE TREATMENT FACILITY PROCESS SCHEMATIC



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The facility has received significant updates, including biological nutrient removal improvements, in three phases of construction between 2004 and 2012. These upgrades were completed, at a cost of $191 million, to comply with a modified National Pollutant Discharge Elimination System permit issued by EPA in 2001, and included installation or replacement of the following:

- **Phase 1:** Additional screening facility, additional primary settling tank and upgrades to six existing primary settling tanks, biofilter, and activated carbon systems for odor control, wet-weather bypass line, chemical storage and feed facilities, furnace replacements and upgrades, control room and supervisory control and data acquisition implementation, two diesel backup generators.
- **Phase 2:** Four aeration tanks and upgraded aeration system, modifications to six settling tanks and two new settling tanks, maintenance buildings, primary effluent channel.
- **Phase 3:** Dissolved Air Flotation sludge-thickening system, belt filter press and dewatering equipment, various pumps and mechanical systems.

In addition to the prior biological nutrient removal and facility upgrades, Upper Blackstone Treatment Facility is currently undergoing more improvements to the biological nutrient removal process to comply with the 2008 National Pollutant Discharge Elimination System permit. The design and construction schedule for the upgrades to achieve compliance were developed and issued through an Administrative Order with EPA that became effective in 2014. Upgrades are planned in three phases. Phase A construction is nearing completion and includes the following:

- Modifications to existing bioreactors to achieve better control of the anaerobic/anoxic/oxic process and improve nitrogen removal performance and efficiency.
- Installation of motorized air control valves that provide more precise control of air flow. In conjunction with the bioreactor upgrade, the Upper Blackstone Treatment Facility will be able to maintain more suitable dissolved oxygen concentrations, which will improve control for the anaerobic/anoxic/oxic process.
- Chemical feed facilities to improve denitrification and stability of the biological nutrient removal process.
- Supervisory control and data acquisition controlled hydraulic improvements to provide a more balanced distribution of flow and loading into the biological nutrient removal process units could improve overall performance.
- Regenerative Thermal Oxidizer improvements to replace equipment that have exceeded their useful service life and are necessary for solid processing to ensure air pollution control permit compliance.
- Electrical main service feed improvements to eliminate common mode of failure and improve overall reliability of the Upper Blackstone Treatment Facility and biological nutrient removal process.
- Electrical and instrumentation modifications to incorporate Phase A equipment.
- Heating, ventilation, and air conditioning controls centralization and extension to ensure process performance, control odors, and protect equipment from premature corrosion.

Phases B and C will require construction of additional tertiary treatment. These phases of construction are infrastructure investments included for evaluation in this Integrated Plan.

3.4.1 System Performance

Discharges from the Upper Blackstone Treatment Facility are regulated by the latest National Pollutant Discharge Elimination System permit, which was issued in 2008 and became effective in 2012. Since completion of biological nutrient removal improvements in 2012, the Upper Blackstone Treatment Facility has provided a high level of wastewater treatment and generally met permit limits on a monthly reporting basis. Currently, interim discharge limits are in place for the latest National Pollutant Discharge Elimination System permit. From 2016-2018, the Upper Blackstone Treatment Facility has maintained compliance with these interim limits through 99.81% of its required discharge samples.

As a testament to the Upper Blackstone Treatment Facility performance, the National Association of Clean Water Agencies recognized the District with a Gold Peak Performance Award in 2015 and Silver Peak Performance Awards in 2012, 2014, and 2016 for outstanding compliance.

Although not currently limited by the National Pollutant Discharge Elimination System permit, there are occasional high-flow blending occurrences at the Upper Blackstone Treatment Facility to avoid biological process washout during wet weather. High-flow blending occurs when influent flow exceeds the secondary treatment flow capacity. A portion of the high flows receive primary treatment and are diverted around secondary treatment then disinfected and blended with fully treated flows. The secondary treatment capacity varies depending on available storage at the Upper Blackstone Treatment Facility, temperature, and sludge blanket levels in the clarifiers. The wet-weather blending has resulted in an exceedance of the National Pollutant Discharge Elimination System discharge limits approximately 14 times from 2016 through 2018.

The following Key Performance Indicators for the Upper Blackstone Treatment Facility were identified:

1. **Compliance with National Pollutant Discharge Elimination Permit:** This is measured by percent of samples in compliance with effluent limits.
2. **Compliance during High-Flow Blending:** This is measured by the number of permit exceedances recorded during wet-weather blending events.

3.5 Drinking Water System

Worcester's drinking water system includes the following major components:

- Supply from surface water reservoirs
- Treatment at a single filtration/treatment facility
- Transmission, pumping and storage
- Distribution

The City's first public water system began operating in 1848, but the "modern" system still serving Worcester today began in 1867 with construction of Lynde Brook Reservoir. Safe drinking water and water for firefighting, industrial use, beverage production, landscape watering, recreation and myriad other uses is provided to the entire City of Worcester along with surrounding water systems serving the towns of Leicester, Holden, West Boylston, Auburn, Paxton and Millbury.

3.5.1 Supply

Worcester's drinking water is obtained from 10 surface water reservoirs in Leicester, Paxton, Rutland, Holden, and Princeton. Combined, the reservoirs hold over 7 billion gallons of water. These reservoirs are all man-made, single purpose (water supply) impoundments originally constructed by building dams across streams in the Blackstone and Nashua River Basins. There are 15 dams associated with this reservoir system, as summarized in **Table 3.3**.

Each reservoir also has a gate house or inlet structure used to control the withdrawal of water into lower reservoirs and ultimately to the intake to the filtration plant. Gate houses contain gate valves or sluice gates and their related operating mechanisms for flow control. Screens are also employed across the inlets to prevent large debris and fish from entering transfer pipes. Screens are manually cleaned with the exception of the intake to the filtration plant, which utilizes compressed air to remove debris caught on the intake screen.

3.5.2 Treatment

The Worcester Water Filtration Plant began operating in 1997. It was constructed to treat drinking water for compliance with the Safe Drinking Water Act (SDWA) amendments in 1986 that required filtration for most surface water supplies. The Water Filtration Plant, located adjacent to the Holden reservoir system, has a capacity of 50 million gallons per day and treats an average daily flow of 22 million gallons per day through the following processes:

- Pre-ozonation
- Rapid mix coagulation (alum and cationic polymer)
- Flocculation
- Direct filtration
- pH adjustment with lime
- Disinfection

Information about the Water Filtration Plant and its processes is provided on the City of Worcester website at worcesterma.gov.

Inside the City's Water Filtration Plant.

The facility uses dual media filters (sand and anthracite) to remove particulate matter, and filter performance is maintained through backwashing based on head loss. Filter backwash water is collected in a holding tank and allowed to settle. Concentrated solids are discharged to the wastewater collection system for treatment at the Upper Blackstone Treatment Facility. Supernatant backwash water is decanted from the upper levels and recycled to Holden Reservoir No. 2. Backwash water discharges to Holden Reservoir No. 2 are regulated by a National Pollutant Discharge Elimination System permit, described in **Chapter 2**.

While the Water Filtration Plant is considered relatively new, it has already undergone major upgrades of equipment since 1997 including:

- Replacement of filter air scour systems in all eight filters with a more robust stainless-steel system
- Replacement of anthracite filter media
- Installation of vacuum sludge removal system in backwash settling tank
- Upgrades to Supervisory Control and Data Acquisition system which oversees plant controls
- Replacement of Programmable Logic Controllers, which are the process-specific computers that operate the various treatment system components
- Addition of ground and roof-mounted solar arrays to supplement electric power used at the plant
- Repair to damaged filter underdrain in one filter
- Replacement of intake screen with wire-wound screen using compressed air to remove debris
- Replacement of major analytical equipment in the laboratory
- Replacement of ozone equipment with plate-style ozone generators including liquid oxygen tanks

3.5.3 Transmission, Pumping and Storage

Transmission mains are larger diameter pipes used to move drinking water between reservoirs, from pump stations to tanks, from the filtration plant to the clear wells and from the clear wells into the City. Transmission mains are critical infrastructure since they individually carry most of the drinking water that is eventually supplied to Worcester residents and businesses.

Some of the most significant transmission mains include:

- 36-inch riveted steel pipe for transferring drinking water from Quinapoxet Reservoir to Kendall Reservoir. This 1930s pipe will be rehabilitated using slip-lining, replacement and spray-on structural lining in a two-phase project beginning in fall 2019. Estimated project cost is $11 million.
- 36-inch riveted steel pipe that transfers drinking water from Olean Street Pumping Station to the Indian Hill Storage Tanks. This 1950s-era pipe has experienced a number of failures in recent years and needs significant improvements.

TABLE 3.3: WORCESTER DAM SUMMARY

Name	National ID #	Hazard Class	Size Class	Inspection Interval (years)	Date of Last Inspection	Condition
Holden Distribution Pond Dam	MA02789	Low	Non-Jurisdictional	—	—	NA
Holden #1	MA00960	High	Large	2	Dec-17	FAIR
Holden #2	MA00619	High	Large	2	Dec-17	SATISFACTORY
Kendall Reservoir	MA00622	High	Large	2	Jan-19	FAIR
Kendall Low Basin	MA02328	Significant	Intermediate	5	Oct-15	SATISFACTORY
Kettle Brook #1	MA00989	High	Intermediate	2	Apr-18	SATISFACTORY
Kettle Brook #2	MS00977	High	Intermediate	2	Apr-18	SATISFACTORY
Kettle Brook #3	MA00978	High	Intermediate	2	Apr-18	SATISFACTORY
Kettle Brook #4	MA00677	High	Intermediate	2	Apr-18	SATISFACTORY
Lynde Brook Reservoir Dam	MA00990	High	Large	2	Dec-17	SATISFACTORY
Lynde Brook Reservoir Dike	MA01290	High	Large	2	Dec-17	FAIR
Maple Spring Pond	MA01247	Significant	Intermediate	5	Jun-16	FAIR
Pine Hill Reservoir	MA00623	High	Large	2	Sep-15	FAIR
Quinapoxet	MA00929	High	Large	2	May-18	SATISFACTORY
Headworks	MA02326	Low	Intermediate	10	Apr-12	FAIR

- 42-inch ductile iron pipe that transfers drinking water from Olean Street Pumping Station to the Indian Hill Storage Tanks. This main was constructed in the 1990s. It parallels the 36-inch steel main previously noted for a distance then connects to that main. The high service distribution system is supplied by this main at a rate of 11 to 20 million gallons per day.
- 48-, 42- and 30-inch cast-iron pipes that supply the entire low service distribution system that provides 8 to 10 million gallons per day. In 2012, a break on a 30-inch transmission main resulted in a shutdown of the entire system for more than a day followed by a brief boil water order. These mains date to the late 1800s and early 1900s, and include inoperable valves that need to be replaced.
- 24-inch ductile iron pipe that transfers drinking water from Lynde Brook Reservoir to Holden Reservoir No.1. This pipe was constructed in the 1990s to allow water from the Kettle Brook and Lynde Brook Reservoirs to be transferred for treatment at the Water Filtration Plant.

Repair and rehabilitation of transmission mains is complex and costly; however, these mains carry significant flow and are critical for the supply of drinking water to the City.

Because of varying terrain and the need to maintain water system pressures, pumping is required in parts of the drinking water system. Pumping is used to transfer raw water between some reservoirs and to move finished drinking water to various parts of the distribution system. While 36% of flow into the distribution system is by gravity, 64% is pumped. Of the pumped volume, about 20% is re-pumped to reach the highest elevations.

The drinking water system incorporates 11 pumping stations; four for raw water transfer between reservoirs and seven within the distribution system. Among the raw water transfer pumping stations, two (Quinapoxet, Holden #2) are used routinely and two (Shaft 3, Kendall) are emergency stations that are rarely used. Only one (Tory Fort) of the distribution system pumping stations is currently inactive but available in an emergency.

All of the major drinking water pumping stations pump to an associated storage tank. There are 11 storage tanks in the drinking water system including the washwater tank at the Water Filtration Plant and two clearwells, which hold treated drinking water from the plant.

Storage tanks provide additional supply for firefighting, short-term redundancy should a pump station fail, stabilize system pressures and allow for pumps to occasionally shut down. In general, tank levels control pump operation with pumps being activated or shut down based on pre-set control levels in the tanks.

Storage tanks include eight ground level tanks, one elevated tank and two underground tanks. Construction materials include steel and concrete. The newest tanks were constructed as part of the Water Filtration Plant project and date back to 1995. The oldest tank was constructed in the 1920s.

Interior and exterior inspections of storage tanks are completed every three to five years. Inspection reports are the basis for any repairs or rehabilitation work that is planned. In general, steel tanks undergo major renovation, including repair and replacement of metal structural members and application of new coatings, about every 20 years. The newest tanks, all concrete construction, have moderate repair needs after their first 20 years in service.

3.5.4 Distribution

The drinking water distribution system includes:

- 565 miles of water main
- 45,000 active water services
- 6,000 hydrants
- 6,000 main valves
- 45,000 active meters

Distribution system water mains range in size from 1 inch to 48 inches in diameter. The oldest pipes in the system were installed in 1870. From that time to 1950, pipe material was generally unlined cast iron. From 1950-1970, cement-lined cast iron was used and from 1970 to present, cement-lined ductile iron was standard. A portion of the system consists of PVC pipes.

Water services, which connect water mains to buildings, were generally made of iron in the early years, followed by copper and then plastic (polyethylene). Iron services, dating back to the late 1800s, are still in use today. The portion of a service located in the street is the responsibility of the City, while that portion between the property line and the meter is the property owner's to repair or replace.

A key function of any drinking water system is to provide water for fire suppression. That is most commonly implemented through the use of fire hydrants. Hydrants are situated at key locations throughout the City to assure ready access for the Worcester Fire Department. Hydrants are also key components for water distribution system operations, providing a point for water main flushing, pressure monitoring, access to water for other municipal uses, temporary water service connections and feeding bypass piping during water system construction projects.

There are 6,000 active hydrants in the City. In recent decades, the hydrant type has been standardized on one particular model. Prior to that, there were a variety of models and configurations used. As fire-fighting practices have evolved, desired hydrant characteristics have changed. Older style hydrants still in use and still functional may not match the needs of today's fire-fighting equipment and thus need to be replaced. Older hydrants lacking break-away flanges can be damaged by vehicles and snowplows and also need replacement. As urban redevelopment advances and streets are reconstructed and re-aligned, hydrants often have to be relocated and, in most instances, a new hydrant will be installed in the new location. Along with all these needs to replace hydrants, there is also a significant maintenance component to assure hydrants function. When the fire department responds to a fire, the expectation is that hydrants will be found close by and that the hydrants will all work. The responsibility falls upon the DPW&P's Water Division to make sure that expectation is met.

The drinking water system includes some 6,000 valves to control flow and shut down segments of the system for emergencies and planned improvements. Valves range from 1 inch to 48 inches and include gate valves and butterfly valves. The oldest valves still in use date back to the late 1800s. Some of the oldest valves are incredibly well constructed with top-grade materials and workmanship. The fact that they still function after 130 years is testament to the craftsmanship of the past. Some of the newer valves from the 1980s are problematic in that they are inoperable or that the bolts holding the bonnet to the body have corroded away causing the valve to essentially split. Year of installation is therefore not a telltale indicator of valve condition or useful life.

As with hydrants, valves require a high level of maintenance to ensure operation and identify failed units before they are needed in an emergency. Valve exercising programs are the industry standard for valve maintenance.

To ensure that customers are billed fairly for water and sewer service provided by the City, water meters are installed on each active service. Meters measure the volume of water used at a premises. Water and sewer rates are then applied to the metered use and bills issued accordingly. Worcester bills most customers quarterly and a small number of the largest water users are billed monthly. Sewer use for most residential properties is based on 80% of water use. Meters range in size from 5/8 inch to 10 inches. Generally, small meters range up to 2 inches and large meters are considered 2 inches and above.

A small meter change-out program was completed in 1992 with the replacement of all small meters over a seven-year period. Those meters are mostly still in place today and at the end of their expected useful lives. A small meter change-out program is planned to begin in 2019 and continue for five years. That program will replace the remaining 1990 vintage meters, which were state-of-the-art at that time, with modern meters that provide a variety of features unavailable 20 years ago. Approximately 37,000 small meters will be replaced.

Large meters are much fewer in number but track consumption by larger customers that use far more water than residential customers. Large meters can often be repaired rather than replaced. Large meter testing is a critical maintenance function to assure the largest water users are being billed fairly and that overall system water use is property tracked. The decision to replace or repair a large meter is based on testing results. There are also more options available for large meter technology and the choice of meter type can be based on specific customer requirements.

3.5.5 System Performance

Performance of the drinking water system can be measured in a variety of ways. The ultimate goal is to provide safe drinking water to meet the needs of the community. Water quality is therefore a primary consideration in drinking water system metrics. Because there are so many variations on the term "water quality," multiple metrics may be needed to fully address performance in this area. The most basic is compliance with established drinking water standards, specifically Maximum Contaminant Levels, established under the federal Safe Drinking Water Act and Massachusetts Drinking Water Regulations. There are also performance standards for surface water treatment facilities that must be met to assure safe drinking water. These are reported to MassDEP monthly. The drinking water system has maintained compliance with all water quality and treatment standards since shortly after the Water Filtration Plant went online in 1997. Because of the critical public health importance of drinking water, that performance level must continue into the future.

Performance must also be tracked relative to the filter backwash water National Pollution Discharge Elimination System permit at the Water Filtration Plant. This is a regulatory requirement but, since the discharge is to a water supply reservoir, it is also in the City's best interest to minimize adverse water quality impacts. The City has maintained permit compliance for the backwash discharge since implementation of the Clari-Trac system in 2007. Changing permit limits, especially for aluminum, could make future compliance more challenging.

Source water management cannot be overlooked in terms of drinking water system performance. All of Worcester's drinking water is derived from man-made impoundments created for the single purpose of public water supply. The impoundments all depend on functioning dams to ensure adequate capacity to meet the needs of the City and surrounding towns. The dams are all regulated by the Massachusetts Office of Dam safety, which mandates regular inspections, reports and corrective actions. Dam inspections follow a rating system with the overall condition of each dam being assigned a score from 1-5 ranging from unsafe to good. The City strives to assure that each of the 15 dams in the reservoir system meet at least a rating of fair (3). Based on the most recent inspections, all of the reservoir related dams currently achieve a rating of "fair" or better, but each have issues to be corrected in order for ratings to be maintained or improved.

The following Key Performance Indicators for the drinking water system were identified:

1. **Compliance with Drinking Water Quality Standards:** This is measured by percent of compliance samples meeting Maximum Contaminant Levels.
2. **Compliance with Surface Water Treatment Standards:** This is measured by percent of measures meeting performance standards for surface water treatment facilities.
3. **Dam Safety:** This is measured by the number of dams meeting an overall condition of fair or better following inspection in accordance with Office of Dam Safety.
4. **Compliance with National Pollutant Discharge Elimination Permit at Water Filtration Plant:** This is measured by percent of samples in compliance with effluent limits.

3.6 Natural Aquatic Systems

This Integrated Plan focuses on water infrastructure systems and how those systems need to be analyzed, managed and improved in order to continue to provide vital services to Worcester's residents and businesses. In addition to these man-made systems, designed to use and manipulate water for many purposes, are natural aquatic systems that also play a role in Worcester's vitality. Natural aquatic systems include lakes, ponds, rivers, streams and wetlands. These are often influenced by water infrastructure, but they are not part of the infrastructure and are therefore not directly addressed by this plan.

Natural aquatic systems provide recreation, wildlife habitat, aesthetic values, flood control, water quality mitigation and other functions of value to society. These systems are also impacted by the built environment and infrastructure that can degrade water quality, reduce capacity through sediment deposition, damage recreational opportunities through aquatic plant and algae growth, and diminish flood storage through filling. While water resources infrastructure improvements, as envisioned in this Integrated Plan, may help reduce further impacts, correcting existing problems that may have resulted from man-made or natural influences is not part of this integrated planning process.

The management of natural aquatic systems in the City of Worcester is approached in a variety of ways. Funding is typically through the City tax levy and use of available grants. Implementation falls on various departments. The Parks Division, for example, will use budgeted funds and state/federal grants to make improvements at beaches and at ponds located in City parks. These improvements may address access, safety or water quality problems at these specific water bodies. More recently, a Lakes and Ponds, or "Blue Spaces," program was established by the DPW&P. This initiative directs City staff and resources to address issues like invasive weed control, algae monitoring and control, water quality analysis and public education as related to major recreational waters in Worcester. Future endeavors such as lake dredging, in-lake treatment for phosphorus reduction and enhanced weed and algae control will be directed and implemented through the Lakes and Ponds Program and/or Parks Division following this general approach. Projects like these are therefore not included in this Integrated Plan.

3.7 Benchmarking System Performance

The goal of benchmarking the performance of Worcester's water resources management systems is to identify gaps between current system performance and performance targets. Performance gaps indicate areas where enhancements are needed.

The gaps between baseline performance and performance targets reveal areas of the water resources systems that require attention to improve performance. Conversely, instances where baseline conditions meet or exceed the performance standards reveal areas where current performance levels should be sustained. Larger gaps may suggest priority areas on which to focus.

For the Integrated Plan, Key Performance Indicators were identified for each of the City's water resources systems. Key Performance Indicators are quantifiable metrics for measuring the performance of the water resources systems and are used to inform the gap analysis. These metrics can be continuously tracked as recommended system improvements are completed. Not all system performance needs or strengths will be identified through a benchmarking analysis, but the Integrated Plan includes the areas of performance that are critical.

3.7.1 Setting Benchmarks

Key Performance Indicators were based on system performance aspects while also considering regulatory drivers. The benchmarking process used industry standards published by the American Water Works Association and the Canadian National Water and Wastewater Benchmarking Initiative, summarized as follows:

American Water Works Association[3]

The American Water Works Association Utility Benchmarking Program was created to provide performance statistics and measures for decision makers responsible for public utilities including potable water, wastewater, and/or stormwater services across the United States.

The American Water Works Association's Utility Benchmarking Program collects data from a wide variety of small and large public utilities through a yearly survey, which is then compiled in a report. In fiscal year 2015, 163 organizations participated in the American Water Works Association's Utility Benchmarking Survey, 91 (55%) of which provided both water and wastewater services similar to the City of Worcester.

3 American Water Works Association, Benchmarking Performance Indicators for Water and Wastewater: 2016 Edition

The American Water Works Association's report presents aggregate data for five general performance indicators:

1. Organizational Development
2. Business Operations
3. Customer Service
4. Water Operations
5. Wastewater Operations

Data are broken out by national region (Canada and United States combined), population, and historical trends. Each data set is separated into quartiles: 25th percentile, 50th percentile (median), and 75th percentile, referred to as performance indicator levels.

The data presented in the American Water Works Association's report are limited by the variability of each unique utility provider. Of the 163 participating organizations, 65 (40%) fall within the same population range (100,001 to 500,000 people) as the City of Worcester. Fourteen of the organizations are in Worcester's region (EPA Region I), however, none are in Massachusetts.

Canadian National Water and Wastewater Benchmarking Initiative[4]

The Canadian National Water and Wastewater Benchmarking Initiative was created to serve as the national standard for water and wastewater utility benchmarking in Canada.

The Canadian National Water and Wastewater Benchmarking Initiative program currently represents data from 43 of Canada's municipalities and regional districts with a service population greater than 50,000. Combined representative population is over 60% of Canada's total population. To ensure consistency, trained Canadian National Water and Wastewater Benchmarking Initiative staff collect data yearly through on-site visits to each participating municipality.

The Canadian National Water and Wastewater Benchmarking Initiative measures performance for three water resources systems: wastewater, water and stormwater. Each system type is then separated into categories with data represented as minimum, maximum, and median response values.

The Canadian National Water and Wastewater's Benchmarking Initiative report provides limited data classifying the size and region of municipalities. Differing regional and national regulations for water quality and municipal government were considered when analyzing the available data.

3.7.2 Baseline Performance

Key Performance Indicators were selected to measure water resources system performance. These consist of system performance areas deemed vital. Systems data from various reports and records were used to establish the baseline performance for each Key Performance Indicator. The ability to quantify system performance improves as new data, tools and techniques become available. The adaptive management process (**Chapter 10**) will be used to modify infrastructure investment priorities as these improvements unfold and guide decision-making.

3.7.3 Gap Analysis

A gap analysis was completed using the selected Key Performance Indicators. **Table 3.4** summarizes the gap analysis.

The end of the chapter includes summary forms that detail the analysis of each Key Performance Indicator and include:

- A metric summary
- Baseline performance
- Performance targets
- A gap analysis with proposed concepts to meet the identified needs of each water resources management system

3.7.4 Use of Gap Analysis

The relative size and importance of these performance gaps guide the City in prioritizing improvements. Key findings include:

- Baseline performance of the City's systems exceed or meet the Integrated Plan targets for the following Key Performance Indicators:
    - Frequency of annual catch basin cleaning is well above the performance target, based on the catch basin cleaning frequency

4 Canadian National Water and Wastewater Benchmarking Initiative, National Research Council and AECOM, 2013

established in the Stormwater Management Plan. This level of effort should continue through Stormwater Management Plan implementation to capture sediment before it reaches receiving waters.

- Infiltration rate for the entire sewer system is better than the target for excessive infiltration for the entire collection system established by EPA. However, it is recognized that some catchment areas exhibit higher infiltration rates. This Integrated Plan includes infrastructure investments to further investigate these areas.
- All of the drinking water system performance targets are currently being achieved, including water quality standard compliance, water treatment standard compliance, dam safety ratings and filter backwash National Pollution Discharge Elimination System Permit compliance. Ongoing investment and maintenance in the water supply system is needed to assure future performance.

- Baseline performance of the City's systems failed to meet the Integrated Plan performance targets for the following Key Performance Indicators:
    - Collection System Pipe Age: Minimizing system failures and reducing overall risk through system upgrades is critical. This supports reducing loss-of-service complaints and addresses the performance gap in the unplanned maintenance Key Performance Indicator along with others shown in **Table 3.4**.
    - Number of loss-of-service complaints is of concern. Maintaining quality, uninterrupted service to customers is a priority.
- Frequency of non-capacity related sanitary sewer overflows in the wastewater collection system caused by restrictions and blockages in pipes from roots, grease, or pipe collapses.

By analyzing performance gaps, this Integrated Plan identifies infrastructure improvements to improve the performance of each water resources system.

TABLE 3.4: PERFORMANCE GAP ANALYSIS SUMMARY

System	Key Performance Indicator	Baseline Performance	Performance Target	Gap Between Baseline and Performance Target
Wastewater Collection	Wastewater Pipe Age *(% of system exceeding service life)*	34.7	0	34.7
	Infiltration Rate *(gallons per day per inch of diameter per mile of entire collection system)*	1,463	< 1,500	No gap
	Loss-of-Service Complaints *(per year)*	234	176	58
	Non-Capacity Sewer Overflow Rate *(events per 100 miles of pipe per year)*	3.92	1.31	2.61
	Capacity (Wet Weather) Sewer Overflow Rate *(events per 100 miles of pipe per year)*	0	0.7	No gap
	Unplanned Maintenance *(hours per 100 miles of pipe per year)*	3,303	1,257	2,046

TABLE 3.4: PERFORMANCE GAP ANALYSIS SUMMARY *(Continued)*

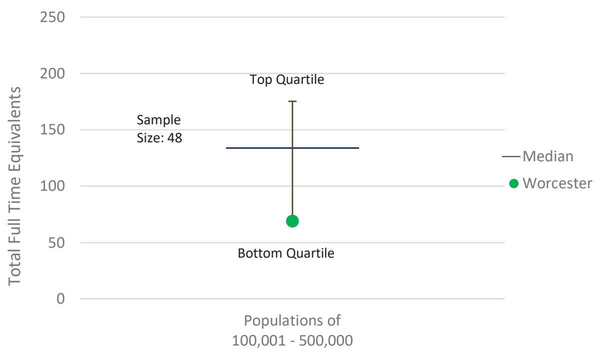
System	Key Performance Indicator	Baseline Performance	Performance Target	Gap Between Baseline and Performance Target
Stormwater Collection	Stormwater Pipe Age *(% of system exceeding service life)*	18.4	0	18.4
	Catch Basin Cleaning *(number cleaned per year)*	8,811	> 8,358	No gap
	Street Flooding Rate Within Green Island Area *(days with Customer Service Request System complaints per year)*	9.5	6	3.5
	Street Flooding Rate Outside Green Island Area *(days with Customer Service Request System complaints per year)*	51	39	12
Upper Blackstone Treatment Facility	Compliance with National Pollutant Discharge Elimination System Permit *(percent of samples in compliance)*	99.81%*	100	0.19
	Compliance during High-Flow Blending *(percent of samples in compliance)*	99.84*	100	0.16
Drinking Water	Compliance with Drinking Water Quality Standards: *(percent of compliance samples meeting Maximum Contaminant Limits)*	100%	100%	No gap
	Compliance with Surface Water Treatment Standards *(percent of measures meeting performance standards for surface water treatment facilities)*	100%	100%	No gap
	Dam Safety *(number of dams meeting an overall condition of fair or better following inspection in accordance with Office of Dam Safety)*	15	15	No gap
	Compliance with National Pollutant Discharge Elimination Permit at Water Filtration Plant *(percent of samples in compliance with effluent limits)*	100%	100%	No gap

* Based on discharge data from 2016 through 2018.

3.7.5 Operations and Maintenance

The performance of the City's water resources systems is directly related to the age of the systems and their overall condition, as well as operations staffing to populations served. As shown in **Figure 3.7**, American Water Works Association data reveals that Worcester's wastewater staffing level is at the bottom quartile level, compared to other communities within the same population range (100,001 to 500,000 people).

FIGURE 3.7: WASTEWATER STAFFING BENCHMARK



As previously noted, several aspects of the systems are not meeting performance targets. Closing these performance gaps requires a combination of both capital and non-capital expenditures, both of which form the basis for this Integrated Plan.

Operations and maintenance efforts form the backbone of water resources system management. Presently, operations and maintenance costs comprise nearly a third of the sewer operations' budget, which covers both wastewater and stormwater systems. The most significant cost center for operations and maintenance is staffing. Current staffing levels were compared with benchmark data compiled by the American Water Works Association, to determine performance levels.

3.7.5.1 Wastewater/Stormwater

Examining wastewater system operations staffing levels provides some insight into the City's non-capital expenditures.

Worcester has 69 full-time equivalent sewer staff. The American Water Works Association data relates wastewater between fiscal years 2010-2012, Worcester sent an average of 26.77 MGD of wastewater to the Upper Blackstone Treatment Facility, or 0.388 MGD per employee. As shown in **Figure 3.8**, Worcester has a higher volume of wastewater treated per employee than the top quartile for similar sized communities. When this metric is factored in with the additional 50 staff at the Upper Blackstone Treatment Facility (effectively lowering the MGD/employee ratio), the City's staffing levels are more in line with the median levels.

FIGURE 3.8: WASTEWATER STAFFING BENCHMARK (WASTEWATER TREATED IN MGD PER EMPLOYEE

Overall, wastewater system operations appear to be understaffed. Additional staffing and operational spending can help to improve overall performance in both the wastewater and stormwater systems. Considering the age of the systems, as well as Worcester's topography, which requires pump stations to move wastewater, more staff than the average similarly sized utility would appear to be needed.

3.7.5.2 Drinking Water

Consideration of staffing for wastewater system operations also requires evaluation of drinking water operations. These two enterprise-funded systems are managed in similar ways, and rates are paid by the same user base. Therefore, over- or under-spending on one system impacts the other system's performance. Examining drinking water operations staffing levels provides additional insight into the City's non-capital expenditures.

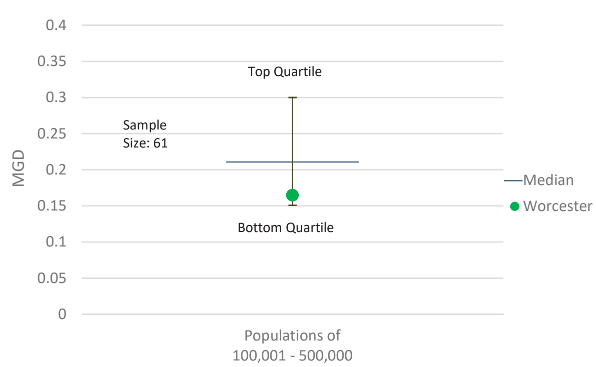
Worcester has 137 full-time equivalent drinking water staff. The American Water Works Association publishes data that relates drinking water operations staffing to population served. As shown in **Figure 3.9**, compared to other communities, American Water Works Association data indicates that Worcester's drinking water staffing level is near the median level of staffing.

FIGURE 3.9: WATER STAFFING BENCHMARK

From an overall staffing perspective, the City appears to be at an appropriate staffing level based on general operations. However, this comparison may be misleading considering the City's drinking water supply system includes an extensive reservoir component not typical of the comparative communities. Security and maintenance of the reservoirs contributes to a higher need for operations support than many other drinking water systems, especially those with groundwater-only supplies. Therefore, it is more likely that the City's drinking water operations is understaffed compared to these industry benchmarks.

During fiscal year 2017, the Water Filtration Plant produced 22.58 MGD, or 0.165 MGD per employee. When compared by volume of water produced per employee, Worcester's water staffing levels are between the median and the bottom quartile for similar sized communities as shown in **Figure 3.10**.

FIGURE 3.10: WATER STAFFING BENCHMARK (WATER PRODUCED IN MGD PER EMPLOYEE)



With respect to drinking water production rates per employee, the industry benchmarks suggest that Worcester is less efficient at producing water than other utilities (less water produced per employee). However, as previously noted, this metric does not consider the extensive reservoir system that the City maintains, nor does it account for the complexities of the drinking water system itself. In a city with varying terrain, operating the drinking water system requires maintenance of multiple pressure zones and various pumping stations. In addition, considering the overall age of the system, the maintenance required to keep the system operational is not accounted for in these metrics.

Overall, water operations appear to be adequately staffed. However, additional staffing and operational spending can help maintain or improve the system's overall performance.

3.8 Key Performance Indicator Summary

The gap analysis of the City's water resources system identifies 15 Key Performance Indicators across three City systems, consisting of the wastewater collection, stormwater collection and drinking water systems. An additional two Key Performance Indicators were identified for the Upper Blackstone Treatment Facility.

Table 3.5 details the analysis of each Key Performance Indicator and includes:

- A metric summary
- Baseline performance
- Performance targets
- A gap analysis with proposed actions to close the gap between baseline performance and performance targets

The following acronyms are used in the Key Performance Indicator summary:

AWWA	American Water Works Association
BOD5	5-Day Biological Oxygen Demand
CSO	Combined Sewer Overflow
CSRS	Customer Service Request System
EPA	Environmental Protection Agency
GIS	Geographic Information System
gpd/idm	gallons per day of infiltration per inch diameter mile of sewer
MassDEP	Massachusetts Department of Environmental Protection
NPDES	National Pollutant Discharge Elimination System
SSO	Sanitary Sewer Overflow
TSS	Total Suspended Solids

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS

METRIC SUMMARY	
System	Wastewater Collection
Performance Indicator	Wastewater Pipe Age
Description	This metric measures the percent of separate and combined sewer pipe in the wastewater collection system that exceeds its intended service life.
BASELINE PERFORMANCE	
Data Source	Worcester's wastewater pipe GIS inventory • 2,560,050 linear feet wastewater pipe Risk Model Technical Memorandum, **Appendix 5.2** • Collection Systems Risk Model Assumptions
PERFORMANCE TARGET	
Regulatory Guidance	N/A
Standard Used	Pipe with age greater than its intended service life should be rehabilitated or replaced to reduce risk of failure. Rehabilitate or replace pipe to achieve improvement over baseline performance.
GAP ANALYSIS	
Baseline Performance	34.7% of total length with age beyond intended service life (2016).
Performance Target	0% of total length with age beyond intended service life.
Performance Gap	34.7% of total length with age beyond intended service life.
Proposed Action	Increase pipeline rehabilitation and replacement in order to achieve improvement over baseline.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS *(Continued)*

METRIC SUMMARY	
System	Wastewater Collection
Performance Indicator	Infiltration Rate
Description	This metric measures the citywide infiltration rate by total gallons per day of infiltration per inch diameter mile (gpd/idm) of separate and combined wastewater collection pipe.
BASELINE PERFORMANCE	
Data Source	Worcester's wastewater pipe GIS inventory • 475 miles wastewater pipe • 6,172 idm wastewater pipe *Flows by Community and Responses to Rain Events Memorandum, 2015, CDM Smith* • Average Infiltration Flow = 9,028,039 gallons per day *Quick Guide for Estimating Infiltration and Inflow for Region 1 NPDES Annual Reporting, 2014, EPA* referencing Metcalf and Eddy's text *"Wastewater Engineering: Collection and Pumping of Wastewater, 1981."* • 1,500 gpd/idm benchmark for excessive infiltration of entire collection system
PERFORMANCE TARGET	
Regulatory Guidance	"Infiltration rates for whole collection systems that are lower than 1,500 gpd/idm are not usually excessive." MassDEP recommends sewer subsystems of about 20,000 linear feet that exhibit infiltration rates above 4,000 gpd/idm be investigated for contributing potentially excessive infiltration.
Standard Used	EPA and MassDEP guidance for wastewater collection system infiltration rates
GAP ANALYSIS	
Baseline Performance	1,463 gpd/idm system-wide average infiltration rate (2010-2014)
Performance Target	<1,500 gpd/idm for entire wastewater collection system.
Performance Gap	No gap
Proposed Action	• Current infiltration rate meets EPA guidance for citywide wastewater collection system. • Study flows in wastewater subsystem catchment areas for identification of potentially excessive infiltration based on MassDEP guidance.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued*)

METRIC SUMMARY	
System	Wastewater Collection
Performance Indicator	Loss of Service Complaints
Description	This metric measures the number of complaints related to loss of service in the wastewater collection system per year.
BASELINE PERFORMANCE	
Data Source	CSRS database service complaints related to: • Wastewater backing up into homes
PERFORMANCE TARGET	
Regulatory Guidance	N/A
Standard Used	Lowest number of loss of service complaints per year in the last 10 years.
GAP ANALYSIS	
Baseline Performance	234 complaints (2016)
Performance Target	176 complaints
Performance Gap	58 complaints
Proposed Action	• Wastewater collection system inspection and rehabilitation. • Private sewer service inspection and rehabilitation. • Fats, oils, and grease cleaning based on targeted sewer inspections and known problem areas. • Increase Inspectional Services inspections of grease traps.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Wastewater Collection
Performance Indicator	Non-capacity Sewer Overflow Rate
Description	This metric measures the number of non-capacity related sanitary sewer overflows documented per 100 miles of pipe (events/100 miles of pipe) per year. Overflows caused by problems within customer-controlled facilities are excluded. Non-capacity overflow is a discharge related to maintenance issues, such as debris, fats, oils, and grease, roots, or structural failures, rather than a result of a rain event.
BASELINE PERFORMANCE	
Data Source	City of Worcester Sanitary Sewer Overflow List • Sanitary sewer overflow occurrences *Integrated Planning Report for Wet Weather Management in the Upper Blackstone Water Pollution Abatement District and the City of Worcester, Feb. 1, 2016, MWH Global* • 459 miles sanitary and combined wastewater pipelines
PERFORMANCE TARGET	
Regulatory Guidance	MassDEP Operation and Maintenance Regulations, 314 CMR 12.00 “No person owning or maintaining a sewer system shall operate such system in a manner that causes, or allows additional sewer extensions or sewer connections to the system that would result in: (a) Any surcharging, overflow or bypassing of the system that is not authorized by a discharge permit issued by the Department pursuant to M.G.L. c. 21, § 43;”
Standard Used	AWWA Median Benchmark for Combined Operations – Wastewater
GAP ANALYSIS	
Baseline Performance	3.92 events/100 miles of pipe (18 events citywide, 2017)
Performance Target	1.31 events/100 miles of pipe (6 events citywide)
Performance Gap	2.61 events/100 miles of pipe (12 events citywide)
Proposed Action	• Pump station improvements and maintenance. • Wastewater system inspection and rehabilitation. • Fats, oils, and grease and root cleaning based on targeted sewer inspections and known problem areas.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Wastewater Collection
Performance Indicator	Capacity (Wet Weather) Sewer Overflow Rate
Description	This metric measures the number of capacity related sanitary sewer overflows documented per 100 miles of pipe (events/100 miles of pipe) per year. Overflows caused by problems within customer-controlled facilities are excluded. Capacity related overflow is a discharge related to hydraulic limitations during a storm event as a result of undersized pipes or excessive infiltration and inflow.
BASELINE PERFORMANCE	
Data Source	City of Worcester Sanitary Sewer Overflow List • Sanitary sewer overflow occurrences *Integrated Planning Report for Wet Weather Management in the Upper Blackstone Water Pollution Abatement District and the City of Worcester, Feb. 1, 2016, MWH Global* • 459 miles sanitary and combined wastewater pipelines
PERFORMANCE TARGET	
Regulatory Guidance	MassDEP Operation and Maintenance Regulations, 314 CMR 12.00 “No person owning or maintaining a sewer system shall operate such system in a manner that causes, or allows additional sewer extensions or sewer connections to the system that would result in: (a) Any surcharging, overflow or bypassing of the system that is not authorized by a discharge permit issued by the Department pursuant to M.G.L. c. 21, § 43;”
Standard Used	AWWA Median Benchmark for Combined Operations – Wastewater.
GAP ANALYSIS	
Baseline Performance	0 (0 events citywide, 2017)
Performance Target	0.7 (3 events citywide)
Performance Gap	No gap
Proposed Action	• Pump station improvements and maintenance. • Wastewater system inspection and rehabilitation. • Fats, oils, and grease and root cleaning based on targeted sewer inspections and known problem areas.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Wastewater Collection
Performance Indicator	Unplanned Maintenance
Description	This metric measures the total hours spent on unplanned wastewater maintenance to the collection system per 100 miles of pipe per year (hours per 100 miles of pipe in collection system).
BASELINE PERFORMANCE	
Data Source	Emergency Sewer Repairs List from City of Worcester • Contractor hours spent on unplanned maintenance City of Worcester Fiscal Year Operating Budgets • DPW&P estimated hours spent on unplanned maintenance (Assumed 20 staff utilized 35% of time on unplanned maintenance) *Integrated Planning Report for Wet Weather Management in the Upper Blackstone Water Pollution Abatement District and the City of Worcester, Feb. 1, 2016, MWH Global* • 459 miles sanitary and combined wastewater pipelines
PERFORMANCE TARGET	
Regulatory Guidance	N/A
Standard Used	Meet AWWA Median Benchmark for Combined Operations – Wastewater.
GAP ANALYSIS	
Baseline Performance	3,303 hours / 100 miles of pipe (average 2006-2016)
Performance Target	1,257 hours / 100 miles of pipe
Performance Gap	2,046 hours / 100 miles of pipe
Proposed Action	• Wastewater system inspection and rehabilitation program.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Stormwater Collection
Performance Indicator	Stormwater Pipe Age
Description	This metric measures the percent of pipe in the stormwater collection system with age that exceeds its intended service life.
BASELINE PERFORMANCE	
Data Source	Worcester's stormwater pipe GIS inventory • 1,954,425 linear feet stormwater pipe Risk Model Technical Memorandum, **Appendix 5.2** • Collection Systems Risk Model Assumptions
PERFORMANCE TARGET	
Regulatory Guidance	N/A
Standard Used	Pipe with age greater than its intended service life should be rehabilitated or replaced to reduce risk of failure. Rehabilitate or replace pipe to achieve improvement over baseline performance.
GAP ANALYSIS	
Baseline Performance	18.4% of total length beyond intended service life.
Performance Target	0% of total length beyond intended service life.
Performance Gap	18.4% of total length beyond intended service life.
Proposed Action	Increase pipeline rehabilitation and replacement in order to achieve improvement over baseline age beyond intended service life.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Stormwater Collection
Performance Indicator	Catch Basin Cleaning
Description	This metric measures the number of catch basins cleaned per year.
BASELINE PERFORMANCE	
Data Source	Stormwater Annual Reports from 2005 to 2017 *Draft: Stormwater Management Plan, December 2015, City of Worcester DPW* • 16,715 catch basins citywide *1998 NPDES Worcester Permit No. MAS010002* • Catch basin cleaning requirements
PERFORMANCE TARGET	
Regulatory Guidance	Each catch basin shall be cleaned at least every other year.
Standard Used	Current National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Permit requirements.
GAP ANALYSIS	
Baseline Performance	8,811 catch basins cleaned (average 2005-2017)
Performance Target	Minimum 8,358 catch basins cleaned (or 50% of current inventory)
Performance Gap	No gap
Proposed Action	Current program is in compliance with the National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System Permit requirements. Continue current Catch Basin Cleaning program outlined in the Stormwater Management Plan.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued*)

METRIC SUMMARY	
System	Stormwater Collection
Performance Indicator	Street Flooding Rate Within Green Island Area
Description	This metric measures the number of days per year with a recorded complaint related to street flooding in the public way within the Green Island area based on the CSRS database.
BASELINE PERFORMANCE	
Data Source	CSRS database service complaints related to flooding in: • Streets within Green Island
PERFORMANCE TARGET	
Regulatory Guidance	N/A
Standard Used	Lowest number of complaints per year in the last 10 years
GAP ANALYSIS	
Baseline Performance	9.5 days with street flooding complaints per year within Green Island area on average from 2006-2016.
Performance Target	6 days with street flooding complaints per year within Green Island area.
Performance Gap	3.5 days
Proposed Action	Implement Green Island flood reduction recommendations

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Stormwater Collection
Performance Indicator	Street Flooding Rate Outside Green Island Area
Description	This metric measures the number of days per year with a recorded complaint related to street flooding in the public way outside the Green Island area in the CSRS database.
BASELINE PERFORMANCE	
Data Source	CSRS database service complaints related to flooding in: • Streets outside Green Island
PERFORMANCE TARGET	
Regulatory Guidance	N/A
Standard Used	Lowest number of complaints per year in the last 10 years
GAP ANALYSIS	
Baseline Performance	51 days with street flooding complaints on average per year outside Green Island area on average from 2006–2016.
Performance Target	39 days with street flooding complaints on average per year outside Green Island area.
Performance Gap	12 days
Proposed Action	Targeted studies and projects at known flooding locations.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued*)

METRIC SUMMARY	
System	Upper Blackstone Treatment Facility
Performance Indicator	Compliance with National Pollutant Discharge Elimination System Permit (NPDES Permit MA 0102369)
Description	This metric measures the percentage of samples that meets its permit requirements to the Blackstone River from the Upper Blackstone Treatment Facility.
BASELINE PERFORMANCE	
Data Source	Upper Blackstone Treatment Facility Records
PERFORMANCE TARGET	
Regulatory Guidance	The Upper Blackstone District must report the following in a timely manner: daily effluent total suspended solids; daily minimum and maximum pH; daily maximum fecal coliform; daily average and daily maximum total chlorine residual; daily dissolved oxygen; and daily average and maximum 5-day carbonaceous biochemical oxygen demand (CBOD5); weekly ammonia-nitrogen; weekly total nitrogen; weekly total phosphorus; weekly dissolved ortho phosphorus; weekly total copper; weekly total zinc; weekly total cadmium; weekly total aluminum; and monitoring requirements for these parameters.
Standard Used	National Pollutant Discharge Elimination System Permit.
GAP ANALYSIS	
Baseline Performance	99.81% of samples in compliance. (2016-2018)
Performance Target	100% of samples in compliance.
Performance Gap	0.19%
Proposed Action	• Update Long Term Control Plan. • Targeted separation of combined sewer. • Reduce infiltration and inflow.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Upper Blackstone Treatment Facility
Performance Indicator	Compliance for High-Flow Blending (NPDES Permit MA 0102369)
Description	This metric measures the percentage of samples associated with high-flow blending that meets its permit requirements to the Blackstone River from the Upper Blackstone Treatment Facility.
BASELINE PERFORMANCE	
Data Source	Upper Blackstone Treatment Facility Records
PERFORMANCE TARGET	
Regulatory Guidance	The Upper Blackstone District must report the following in a timely manner: daily effluent total suspended solids; daily minimum and maximum pH; daily maximum fecal coliform; daily average and daily maximum total chlorine residual; daily dissolved oxygen; and daily average and maximum 5-day carbonaceous biochemical oxygen demand (CBOD5); weekly ammonia-nitrogen; weekly total nitrogen; weekly total phosphorus; weekly dissolved ortho phosphorus; weekly total copper; weekly total zinc; weekly total cadmium; weekly total aluminum; and monitoring requirements for these parameters.
Standard Used	National Pollutant Discharge Elimination System Permit.
GAP ANALYSIS	
Baseline Performance	99.84% (14 samples) in compliance associated with high-flow blending. (2016-2018)
Performance Target	100% of samples in compliance during high-flow blending.
Performance Gap	0.16%
Proposed Action	• Update Long Term Control Plan. • Targeted separation of combined sewer. • Reduce infiltration and inflow.

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Drinking Water
Performance Indicator	Compliance with Drinking Water Quality Standards
Description	This metric is measured by percent of compliance samples meeting Maximum Contaminant Levels.
BASELINE PERFORMANCE	
Data Source	DPW&P Water Division records
PERFORMANCE TARGET	
Regulatory Guidance	Massachusetts Drinking Water Quality Standards
Standard Used	100% compliance with Maximum Contaminant Levels
GAP ANALYSIS	
Baseline Performance	100% compliance with Maximum Contaminant Levels
Performance Target	100% compliance with Maximum Contaminant Levels
Performance Gap	No gap
Proposed Action	• Continue investment in drinking water system

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Drinking Water
Performance Indicator	Compliance with Surface Water Treatment Standards
Description	This metric is measured by percent of measures meeting performance standards for surface water treatment facilities.
BASELINE PERFORMANCE	
Data Source	DPW&P Water Division records
PERFORMANCE TARGET	
Regulatory Guidance	Massachusetts Surface Water Treatment Standards
Standard Used	100% compliance with Surface Water Treatment Standards
GAP ANALYSIS	
Baseline Performance	100% compliance with Surface Water Treatment Standards
Performance Target	100% compliance with Surface Water Treatment Standards
Performance Gap	No gap
Proposed Action	• Continue investment in drinking water system

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued)*

METRIC SUMMARY	
System	Drinking Water
Performance Indicator	Dam Safety
Description	This is measured by the number of dams meeting an overall condition of fair or better following inspection in accordance with Office of Dam Safety.
BASELINE PERFORMANCE	
Data Source	DPW&P Water Division records
PERFORMANCE TARGET	
Regulatory Guidance	Massachusetts Office of Dam Safety
Standard Used	Overall condition of fair or better following inspection
GAP ANALYSIS	
Baseline Performance	15 dams meeting overall condition of fair or better
Performance Target	15 dams meeting overall condition of fair or better
Performance Gap	No gap
Proposed Action	• Continue investment in drinking water system

TABLE 3.5: KEY PERFORMANCE INDICATOR SUMMARY FORMS (*Continued*)

METRIC SUMMARY	
System	Drinking Water
Performance Indicator	Compliance with National Pollutant Discharge Elimination Permit at Water Filtration Plant
Description	This is measured by percent of samples in compliance with effluent limits.
BASELINE PERFORMANCE	
Data Source	DPW&P Water Division records
PERFORMANCE TARGET	
Regulatory Guidance	National Pollutant Discharge Elimination System Permit at Water Filtration Plant
Standard Used	100% compliance with discharge limits.
GAP ANALYSIS	
Baseline Performance	100% compliance with National Pollutant Discharge Elimination Permit
Performance Target	100% compliance with National Pollutant Discharge Elimination Permit
Performance Gap	No gap
Proposed Action	• Continue investment in drinking water system

3.9 Closing the Gaps

Subsequent sections of this Integrated Plan rely on the findings of this gap analysis. **Chapter 5** identifies capital expenditures, or infrastructure investments, that address the needs of the City's water resources systems. Evaluation of the impact of these investments is accomplished using a benefits model to analyze and score potential system investments, as described in **Chapter 6**. The budgetary impact of increased operations and maintenance spending is detailed in **Chapter 7**, and both capital and non-capital expenditures make up the implementation plan presented in **Chapter 8**.

CHAPTER 4.
Public Participation Process

4.1 Overview

The City's effort to engage the public in its integrated planning process had three main objectives:

1. To open channels of communication between the Department of Public Works & Parks (DPW&P) and the public to help raise awareness about the importance and extent of services it provides customers.
2. To maximize the Integrated Plan outreach and level of public engagement to ensure the process was inclusive of all interests and reflective of shared community priorities from planning through implementation.
3. To ensure the City accurately identified plan goals and benefit priorities.

Offering the public a variety of opportunities to learn more about DPW&P services and this Integrated Plan and the chance for residents to provide input was essential to the success of the public participation process. The DPW&P sought to hear from a broad set of community interests. These relationships that were built through the public participation process will help the City maintain engagement and foster public feedback during implementation.

4.2 Communications Plan

The City developed a phased approach for communications to maximize flexibility and incorporate new information throughout the planning process. Each phase detailed the objectives, tools, and schedule for the outreach program. Phase 1 focused on developing outreach materials, online web portals, and conducting pilot group briefings. Phase 2 focused on stakeholder assessment, additional pilot group briefings, and outreach implementation to take place in Phase 3. The communications approach identified key stakeholders, media outlets for press releases, and potential partners to better understand and reach the City's constituencies. The public participation process was designed to create awareness, gather input, and develop public understanding of the need for this Integrated Plan.

4.3 Public Participation Strategies and Tools

The City's phased approach to engage the public included the following:

4.3.1 Phase 1: Foundation

Phase 1 laid the foundation for the program using the following:

1. An eye-catching and easily recognizable brand and tagline to convey a consistent look and message on all Integrated Plan materials.

The Integrated Plan logo.

2. A project-specific website: *http://www.worcesterma.gov/worcester-waters*. The site includes links to documents and videos and a feature to sign up for email updates and meeting notices.
3. An Integrated Plan-specific email address to receive questions and comments: *cleanwaters@worcesterma.gov* and a coordinated system for updates to the City and DPW&P social media platforms. The City updates the project website and posts information to social media and City platforms.

4.3.2 Phase 2: Engagement

Phase 2 set the stage for a broader outreach program with existing organizations that could help the City understand and engage hard-to-reach audiences.

4.3.2.1 Pilot Group Briefings

Pilot group briefings were conducted with:

1. Worcester Regional Chamber of Commerce
2. Worcester Regional Research Bureau
3. Worcester Community Action Council
4. Mass Audubon's Broad Meadow Brook Conservation Center & Wildlife Sanctuary
5. YWCA

Refer to **Appendix 4.1** for a copy of the presentation slides for these pilot group meetings. Input from these groups assisted in developing the City's communication plan.

4.3.2.2 Partnerships

The City utilized the following to help expand communications:

- Worcester Telegram & Gazette
- Worcester Magazine
- Worcester Government Channel
- Charter TV Channel 3
- Worcester Public Library
- Worcester Regional Transit Authority
- EcoTarium
- Clark University's Community Development and Planning Department

4.3.3 Phase 3: Outreach

Phase 3 of the engagement program was a comprehensive effort to solicit input and information to all stakeholders. The City's outreach program was a blend of in-person contact, online print, and media outreach providing multiple ways to get information and provide input.

4.3.3.1 Community Events

The City developed a traveling exhibit and staffed pop-ups at the following community events:

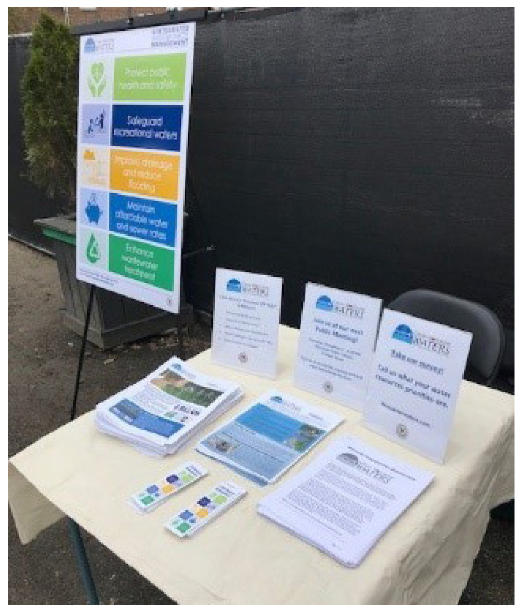
1. sTART on the Street, September 16, 2018; 30,000-50,000 in attendance
2. Movies on the Common, September 13, 2018; roughly 50 in attendance
3. Doherty High School football game, October 12, 2018; hundreds in attendance
4. Canal District Farmers Market, October 20, 2018; roughly 100 in attendance

These community events catered to different demographics that allowed for the Integrated Plan message to reach a broader audience. The pop-up table at various events facilitated the introduction of the Integrated Plan to people who might otherwise not be aware of the plan or fill out the feedback form. The City also presented the Integrated Plan to Neighborhood Watch Group meetings.

The exhibit table at stART on the Street.

Movie-goers view the stationary exhibit table during Movies on the Common.

Hundreds attended the Doherty High School football game.



Nearly 100 people attended the Canal District Farmers Market.

4.3.3.2 City-Sponsored Events

1. Stationary exhibits were placed at the following key community gathering spots starting October 26, 2018 and running until January 15, 2019:
   a. Worcester Public Library (Main Branch)
   b. City Hall (lobby and Planning Department)
   c. DPW&P Customer Service
2. The City held public meetings on May 16 and November 8, 2018. The format for each meeting was similar and included a brief presentation followed by an "open house." This consisted of stations staffed by the City where participants could view information and ask questions about the Integrated Plan. The City Manager opened the May 16, 2018, meeting and discussed the importance of balancing needs and the Integrated Plan. The meeting was filmed by and aired on the Worcester Government Channel, and can be viewed here: *http://view.earthchannel.com/PlayerController.aspx?PGD=worcema&eId=1413*.

Stationary table at the Worcester Public Library (Main Branch).

Worcester City Manager opens the May 16, 2018, public meeting.

The open house stations at the first public meeting on May 16 were organized around the 10 priorities of the Integrated Plan. The open house included interactive voting where participants could vote on their perceived importance of the 10 priorities. The results supported the Integrated Plan priorities.

The November 8 meeting updated the community on the results of the City's evaluations of water resources investment goals. The open house stations were based on the City's and communities' priorities, infrastructure needs, limited financial resources, and the focus of the Integrated Plan. The slides from the presentations can be viewed as **Appendix 4.2**. The display boards featured in both public meetings can be seen as **Appendix 4.3.**

Attendees explore the stations and ask questions during the November 8, 2018, open house.

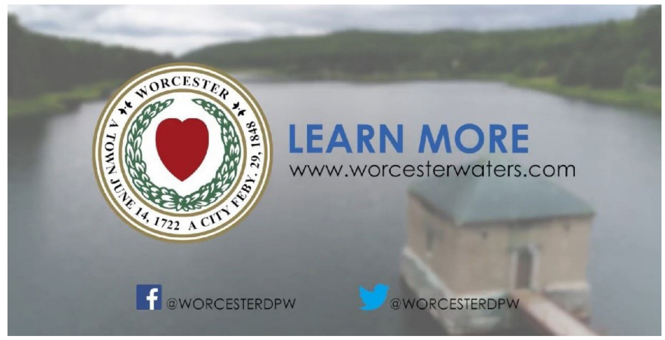
4.3.3.3 Online and Broadcast Platforms

1. **Feedback form:** The City developed an online feedback form to gather information about demographics, types and frequency of use of local waterbodies, residential and business information, problems encountered such as flooding and backups, and the public's water resource priorities. Qualtrics was the online program used for the feedback form and was available in English, Spanish and Vietnamese. The feedback form was opened on June 14, 2018, and closed on November 29, 2018. The form was distributed on the project website and in print at various City events. The City received 172 responses.

2. **Websites:** The City's Technical Services staff developed an Integrated Plan website: *http://www.worcesterma.gov/worcester-waters*. The site includes photos, links to meeting documents (presentations and open house boards), fact sheets, a link to the online feedback form, and videos. It was updated with meeting notices and other pertinent information. Calendar and news items were also posted on the City's main website. There were significant spikes in views and higher levels of activity on the Integrated Plan website from the March launch through June and from late October through November. There were a total of 2,967 unique page views. The highest level of activity seemed to be correlated to email blasts announcing meetings and materials availability from the project email address.

3. **Email blasts:** The City established a project bulk email account with MailChimp. It was used to distribute meeting notices and announcements of materials availability, the launch of the online feedback form, video, and Public Service Announcements (PSAs). The account had 146 subscribers consisting of residents, business owners, employees, students, and other stakeholders.
4. **Social media (Facebook and Twitter):** Calendar items, news, and videos were posted on the City's and DPW&P's Facebook, Twitter and YouTube channels.
5. **5-minute educational video:** The City developed a video to present an overview of the services provided by the DPW&P and the goals, purpose, and benefits of an Integrated Plan. City Manager, Ed Augustus, led a tour including aerial drone footage of the Upper Blackstone Treatment Facility and other City facilities for the video. The video was linked from the project website and the City's and DPW&P's Facebook pages: *https://youtu.be/G_Fjfs_Ipm0*. It also began airing on the DPW&P YouTube channel and on the Worcester Government Channel on October 12, 2018. The video was announced on the City and project website, to local media, and email subscribers. It is captioned in English and Spanish.
6. **30-second video Public Service Announcement:** The City developed a Public Service Announcement using footage from the 5-minute educational video. The purpose of the Public Service Announcement was a call to action for people to complete the online feedback form. Air time for the Public Service Announcement was donated by Charter TV Channel 3 and the Worcester Government Channel. Charter TV 3 aired the 30-second piece 102 times between October 30 and November 26, 2018. The Government Channel aired it 291 times between October 26 and December 8, 2018. It also aired on the DPW&P's YouTube channel through November 26, 2018. It was captioned in English and Spanish.

A still from the 5-minute video shows City Manager Ed Augustus giving a tour.



A still from the 30-second PSA.

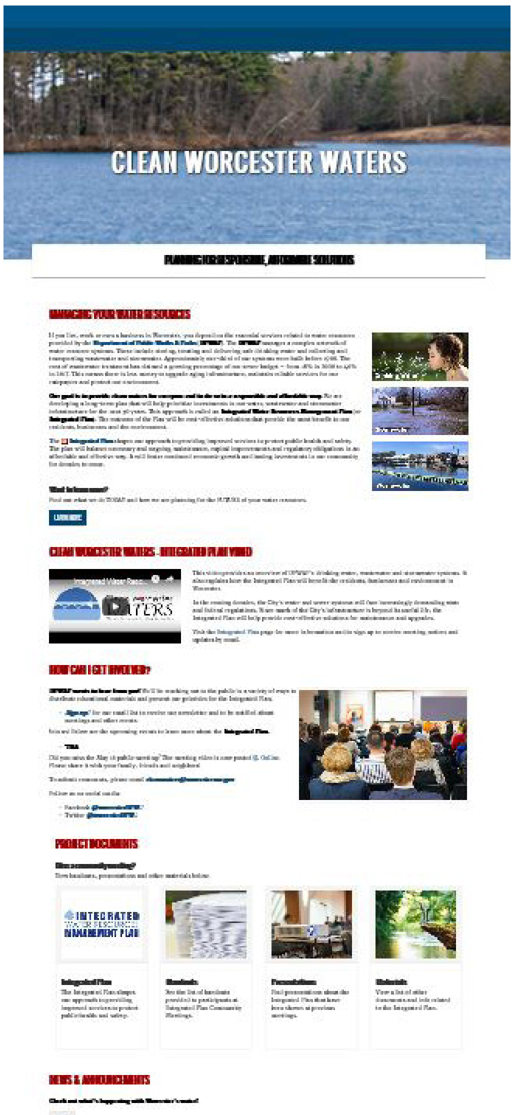
7. **Radio show:** City Manager Ed Augustus and DPW&P Commissioner Paul Moosey appeared on WTAG's Jordan Levy Show on October 15, 2018, to discuss the importance of the Integrated Plan.

4.3.3.4 Print Materials

1. **Fact sheets:** The City developed two fact sheets to post on the website and use as handouts at meetings and exhibits (stationary and pop-up). Refer to **Appendix 4.4** for the fact sheets. The first fact sheet was an overview of an Integrated Plan and its benefits. The second was an educational piece that described the scope and importance of the services the City's DPW&P provides as well as a brief description of the Integrated Plan. The fact sheets were translated into Spanish and Vietnamese.

The cover page of the fact sheet.

The rotating banner on the City's main website and the DPW&P's website provided another avenue for visitors to learn about the Integrated Plan.



2. 

Front of bookmark, left; back of bookmark, right.

Bookmark: The City developed a bookmark to use as a giveaway at event pop-ups, at stationary exhibits, at meetings, and at the DPW&P's Customer Service Center and the City's Planning Department office. On the front of the bookmark, a graphic design shows the five goals of the Integrated Plan, the logo, and tagline. The website address and a link to the online feedback form can be found on the back of the bookmark.

3. **Worcester Regional Transit Authority bus ads:** The City designed a bus ad for placement in the interior of all 52 buses in the fleet to reach transit users in all areas of the City. The ad placement costs were waived by the Worcester Regional Transit Authority. The ad used the same graphic design as the Integrated Plan poster and bookmark showing the five goals, the logo, tagline, and website address. A total of 104 ads were placed – 52 in English and 52 in Spanish. They were posted in the buses from approximately October 5 to November 30, 2018.

The bus ads placed inside the Worcester buses.

4. **Feedback form:** The form was available in print at pop-up events and meetings. Completed print forms were manually entered into the online program.

4.3.3.5 Press Outreach

The City Manager's office coordinated and conducted a press roundtable to help local and regional outlets understand the need for the Integrated Plan and the benefits. Worcester Magazine, Telegram & Gazette, and Charter TV3 attended. The objective was to ensure the press understood the benefits and challenges as well as who to contact if they had questions as the Integrated Plan was finalized and implemented. An additional objective was to create more outlets for information and develop relationships that would result in balanced reporting. Refer to **Appendix 4.5** for the articles covering the Integrated Plan.

4.4 Public Input and Conclusions

The City launched a comprehensive engagement campaign to raise awareness about the existence and importance of the Integrated Plan.

The feedback from the public was positive and affirmed the goals and priorities of the Integrated Plan.

CHAPTER 5.

Selecting Options for Improving Water Resources Infrastructure

5.1 Overview

This Integrated Plan analyzes potential infrastructure investments in the City's water resources systems, including the:

- Drinking water system
- Wastewater collection system
- Stormwater collection system
- Upper Blackstone Treatment Facility

Investment in the City's drinking water infrastructure is considered essential to protecting public health. Therefore, drinking water system investments are the top priority, as reflected in the Drinking Water System Capital Improvement Plan detailed in **Chapter 8**. The current and projected investment requirements for drinking water infrastructure are relatively well understood and can be presented with some confidence.

In contrast, the selection and analysis of potential wastewater, stormwater, and Upper Blackstone Treatment Facility infrastructure investments are much more complex. A detailed approach to identifying and assessing such investments is included in the latter sections of this chapter.

This Integrated Plan prioritizes investments that effectively address one or more performance needs identified in **Chapter 3**. The following sections outline the process to address the City's priorities through infrastructure investments that achieve multiple benefits to the environment, public health, and public safety.

5.2 Drinking Water Investments

Drinking water system infrastructure investments include annual system maintenance and new capital to ensure continued safe drinking water to Worcester residents and businesses. Investments cover five categories representing major components of the system. This management approach includes operations and maintenance best practices and industry standards. The five categories consist of the following:

- Supply
- Treatment
- Pumping and Storage
- Distribution
- Building/Facilities Rehabilitation

5.2.1 Supply

The supply category consists of reservoir and dam improvements, and watershed land acquisition. Needed investments are dependent on the size and the criticality of the system component.

5.2.2 Treatment

The treatment category consists of maintenance and rehabilitation of the Water Filtration Plant. Investments primarily focus on cyclical expenses, such as modifications to the major treatment components, building upgrades, and maintaining the telemetry/supervisory control and data acquisition system at the plant.

5.2.3 Pumping and Storage

The pumping and storage category consists of periodic upgrades of pump stations and storage tanks.

5.2.4 Distribution

The drinking water distribution category consists of infrastructure maintenance and rehabilitation for the citywide drinking water system components, such as hydrants, transmission and water main rehabilitation programs.

5.2.5 Building/Facilities Rehabilitation

The building/facilities rehabilitation category consists of miscellaneous costs to maintain the drinking water system buildings and facilities. Projects include water system security and facility maintenance.

5.3 Resources to Identify Infrastructure Investments

For the wastewater and stormwater systems, the City identified infrastructure investments to address performance gaps using the following resources:

1. Existing reports and studies
2. Infrastructure risk models and geographic information system (GIS) analyses
3. Operational data

5.3.1 Existing Reports and Studies

The City compiled a Compendium of past infrastructure reports and studies conducted since 2000. These reports and studies were undertaken to address significant needs in the City's water resources systems. Some of the report recommendations have been implemented and some are still outstanding. These reports and studies were considered to determine whether outstanding recommendations remain viable.

Currently, the Compendium consists of studies and reports on the wastewater, stormwater, and drinking water systems along with major facilities, such as Quinsigamond Avenue CSO Treatment Facility, Upper Blackstone Treatment Facility, and the Water Filtration Plant.

These studies were reviewed with respect to the following:

- Addressing deferred infrastructure investment
- Assessing infrastructure capacity
- Renewing existing infrastructure through rehabilitation and/or replacement
- Improving quality of surface waters
- Protecting public health and safety
- Supporting economic growth
- Meeting regulatory requirements

A list of the reports and studies included in the Compendium is provided in **Appendix 5.1**.

5.3.2 Infrastructure Risk Models and GIS Analyses

This Integrated Plan utilizes infrastructure risk models that measure factors of the wastewater and stormwater systems and aid in identifying short- and long-term needs. The risk models were created using the City's wastewater and stormwater GIS data, which defines pipe and structure asset attributes including size, material, and year of construction.

Risk is defined as the product of the probability of failure and the consequence of failure:

Risk = probability of failure x consequence of failure

The probability of failure is a function of the condition of the infrastructure assets. Pipes and structures that are in poor condition are more likely to fail. Condition data was not readily available for all assets. In those cases, age and material were used as proxies for condition based on industry guidance. Older pipes are generally in worse condition and certain pipe materials last longer than others.

While the condition of the asset is an important indicator to understand, it is also important to understand the consequence of failure, or the criticality of the asset. For example, a large diameter sewer interceptor that serves a significant portion of the City, including critical users like large businesses and hospitals, is a more critical asset, and therefore has a greater consequence of failure, than a small diameter local collector sewer.

Consideration of both the probability of failure and the consequence of failure is necessary. A technical memorandum describing the risk model development and results is provided in **Appendix 5.2.**

This Integrated Plan uses the risk models to identify areas of high-risk within the wastewater and stormwater systems, including the City's pump stations. High-risk assets are considered the highest priority for renewal since these assets have the greatest probability and consequence of failure. Failing assets should be addressed after high-risk assets since these assets have the same probability of failure, but lower consequence of failure compared to high-risk assets. Critical assets (high consequence of failure) are identified for further investigation and study when condition (probability of failure) is uncertain.

The results of the pipeline and manhole risk models indicate:

- One in 9 (approximately 11%) wastewater system assets (manholes and pipelines) are rated as high-risk where both probability of failure and consequence of failure are considered unacceptable. Nearly 1 in 7 (approximately 13%) stormwater system assets (manholes and pipelines) are rated as high-risk. These assets should be considered the highest priority for inspection and/or replacement.
- One in 4 (approximately 25%) wastewater system assets (manholes and pipelines) are considered to be failing where the probability of failure is considered unacceptable, but the criticality is lower. Nearly 1 in 4 (approximately 23%) stormwater system assets (manholes and pipelines) are rated as failing.
- Combined, 3 in 7 (approximately 43%) of both the wastewater system and stormwater system pipelines are rated high-risk or failing assets.
- Of the wastewater system pipelines, 3 of 7 (approximately 44%) are rated high-risk or failing. This is roughly 1,100,000 linear feet of sewer pipeline. To repair or replace these pipelines, the total estimated renewal cost would be approximately $390 million[1].

The results of the pump station risk models indicate:

- More than half of the 29 wastewater pump stations evaluated are rated as high-risk or failing.
- Four pump stations are rated high-risk due to the high volume of flow, close proximity to a Tier 1 water body, and age of critical components. To address these assets, the total renewal cost would be approximately $2.2 million[2].
- Eleven pump stations are rated failing due to the age of critical components, which would cost an estimated $1.9 million[3] to renew.

1 This replacement value was calculated using an average unit price of $250 per linear foot for pipes less than 18 inches in diameter and $1,000 per linear foot for interceptors (18 inches in diameter or greater). These unit prices were used consistently for conceptual level cost estimating throughout this Integrated Plan.

2 Based on estimates used to develop conceptual costs in the Integrated Plan.

3 Based on estimates used to develop conceptual costs in the Integrated Plan

These results inform infrastructure investment options in the following ways:

- Prioritize high-risk pipes for focused operation and maintenance activities, such as pipeline cleaning and inspection.
- Prioritize an annual pipeline inspection program to obtain condition data.
- Provide the basis for an annual pipeline renewal program to address high-risk pipes that will reduce reactive maintenance.
- Provide the basis for a pump station inspection program to obtain condition assessments of pump station components.
- Provide the basis for a pump station renewal program to address high-risk pump stations and components to extend service life and reduce reactive maintenance.
- Provide the basis for an asset management program to prioritize and track capital investments and operation and maintenance activities.

As new information becomes available through regular inspections, the risk models will be updated to reevaluate infrastructure needs. By implementing programs that renew assets beyond their service life, the City can reduce unplanned, reactive maintenance and focus limited resources on proactive maintenance.

5.3.3 Operational Data

The City evaluated operational data to identify other system needs not captured through the Compendium or the risk models. This data analysis focused on areas prone to flooding, system backups and overflows, regulatory issues, and water quality, which resulted in a better understanding of existing conditions.

Two resources were used to quantify operational needs:

- Customer Service Request System, which tracks reported issues and service requests made by residents and businesses.
- History of routine and emergency maintenance activities.

System performance needs identified through operational data often coincide with areas of limited information. The evaluations confirmed areas in need of additional study and assessment to focus on:

- Obtaining additional system data
- Defining current baseline performance
- Understanding of operational characteristics of existing systems
- Evaluating future capital reinvestments or new capital investments
- Exploring green infrastructure implementation
- Improving operation and maintenance activities

5.4 Wastewater and Stormwater Investments

Wastewater and stormwater infrastructure investments are grouped into four categories:

- Capital Reinvestment
- New Capital Investment
- Study and Assessment
- Upper Blackstone Treatment Facility Asset Investment

5.4.1 Capital Reinvestment

The capital reinvestment category includes existing system infrastructure improvements and addresses deferred pipe renewal. Reinvesting in the existing infrastructure is one of the most cost-effective methods to close performance gaps. Restoring system performance is achieved by rehabilitating structural deficiencies and failing infrastructure.

This approach addresses the following gaps in system performance developed in **Chapter 3**. Performance targets were established through the gap analysis.

- **Pipe Age:** Aging infrastructure requires more maintenance and has a greater risk of failure. The City's performance target is for all infrastructure to be operating within its intended service life.
- **Unplanned Maintenance:** Unplanned or emergency maintenance often occurs due to deferred capital improvements. Unplanned

maintenance usurps scheduled maintenance activities, redirecting limited resources. The performance target is to substantially reduce unplanned maintenance.

- **Infiltration:** System-wide infiltration rates, as a whole, currently meet the desired benchmark. However, localized catchment areas have high infiltration rates that contribute to negative impacts, such as sanitary sewer overflows. Infiltration results in increased costs for transport to and treatment of wastewater at the Upper Blackstone Treatment Facility. In addition, as pipes age and deteriorate, cracks and defects result in new sources of infiltration. This Integrated Plan focuses on identifying and reducing infiltration where cost effective, following regulatory protocols, in subsystem areas with high infiltration rates.
- **Loss of Service:** Loss-of-service complaints contribute to the high rate of unplanned maintenance. While it is impossible to eliminate loss-of-service events entirely, the performance target is to reduce loss-of-service complaints.
- **Non-Capacity Sanitary Sewer Overflows:** Non-capacity sanitary sewer overflows occur when pipelines and manholes are restricted by debris, such as wipes, fats, oils, grease, roots, or structural failure. The performance target is to substantially reduce non-capacity sanitary sewer overflows through system renewal.

5.4.2 New Capital Investment

The new capital investment category includes construction of new infrastructure to improve or expand existing systems. This category incorporates increasing capacity to relieve existing hydraulic deficiencies, constructing new infrastructure in underserved areas, supporting development, and modifying existing systems to meet regulatory mandates. New capital investment supports economic growth and improves water quality.

This approach addresses the following gaps in system performance identified in **Chapter 3**:

- **Capacity (Wet Weather) Sanitary Sewer Overflows:** Capacity sanitary sewer overflows occur when flows exceed hydraulic capacity. The City's performance target is to substantially reduce these sanitary sewer overflows through targeted upgrades.
- **Street Flooding:** Flooding is characterized both geographically and by severity. Although it is impossible to eliminate flooding for all wet weather events, the performance target is to reduce the number of days with flooding complaints through stormwater system improvements.
- **Compliance with the Upper Blackstone Treatment Facility's National Pollutant Discharge Elimination System Permit:** The Upper Blackstone Treatment Facility is required to maintain compliance under its current National Pollutant Discharge Elimination System Permit. The performance target is for the Upper Blackstone Treatment Facility to remain in compliance with the discharge permit.

5.4.3 Study and Assessment

The study and assessment category includes field investigations to document infrastructure status, such as pipe material, size, and condition. This category also includes hydraulic modeling to better understand how the system operates. These study and assessment investments are critical to:

- Identify and evaluate needed capital reinvestment and new capital investment
- Provide information to improve operation and maintenance activities
- Update the Integrated Plan as part of an adaptive management process

This approach addresses the following gaps in system performance identified in **Chapter 3**:

- **Pipe Age:** Regular infrastructure inspections inform rehabilitation decision-making.
- **Infiltration:** Inspections reveal where infiltration is entering the collection system through cracks and defects.
- **Loss of Service/Sanitary Sewer Overflows:** Regular inspections identify areas where hydraulic conditions may cause loss of service, system backups, or overflows due to

inadequate capacity, fats, oils, and grease, debris, or damaged pipes.

- **Compliance during High-Flow Blending:** Modeling system hydraulics and studying wet weather conditions to identify opportunities to reduce flows to the Quinsigamond Avenue CSO Treatment Facility and the Upper Blackstone Treatment Facility.
- **Street Flooding:** Field investigations and hydraulic modeling to identify areas where hydraulic limitations contribute to street flooding.

5.4.4 Upper Blackstone Treatment Facility Asset Investment

The Upper Blackstone Treatment Facility Asset Investment category includes ongoing investment in capital assets to maintain the current high-level treatment and performance at the Upper Blackstone Treatment Facility.

This approach addresses the following gaps in system performance identified in **Chapter 3**:

- **Compliance with the Upper Blackstone Treatment Facility's National Pollutant Discharge Elimination System Permit:** Maintaining the current capacity and water quality level of service keeps the Upper Blackstone Treatment Facility in compliance with the discharge permit.
- **Compliance during High-Flow Blending:** The Upper Blackstone Treatment Facility is required to maintain compliance with its current National Pollutant Discharge Elimination System Permit during high-flow blending.

These essential investments are required and are therefore not subjected to the evaluation and screening process discussed in **Chapter 6**.

5.5 Master List of Infrastructure Investments

A master list of infrastructure investments needed to address performance gaps within the water resources systems was identified. These investments are also referred to as projects or improvements throughout this plan. This process included:

- Review of existing studies and reports
- Review the risk models results
- Reference operational data

Each infrastructure investment was grouped into one of the four categories based on the objective of the project:

- Capital Reinvestment
- New Capital Investment
- Study and Assessment
- Upper Blackstone Treatment Facility Asset Investment

This process identified 62 conceptual infrastructure investments, or projects, which are listed in **Tables 5.1-5.4**. These tables provide the following information:

- **Project Name:** The project name is the name of the project.
- **Key Performance Indicators:** The Key Performance Indicators are as noted in **Chapter 3** and show the range of Key Performance Indicator gaps that each project helps to address.
- **Project Objective:** The project objective identifies the system performance needs to be addressed, and the goals of the project.

5.5.1 Capital Reinvestment

Table 5.1 summarizes the infrastructure investments encompassed in the Capital Reinvestment category.

5.5.2 New Capital Investment

Table 5.2 summarizes the infrastructure investments encompassed in the New Capital Investment category.

5.5.3 Study and Assessment

Table 5.3 summarizes the studies and assessments.

5.5.4 Upper Blackstone Treatment Facility Asset Investment

Investment in Upper Blackstone Facility Assets assures continuation of the high level of treatment performance and effluent water quality. **Table 5.4** summarizes the facility asset investments.

TABLE 5.1: CAPITAL REINVESTMENTS

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Draper Pipe Replacement Program	•	•	•	•	•					Draper pipes have poor structural strength and are susceptible to higher risks of failure, thus their replacement is a high priority. Replacement of Draper pipes will reduce the risk of structural failure and sewer collapses, blockages, basement backups, and sanitary sewer overflows, and will reduce groundwater infiltration into the wastewater system.
Annual Pipeline Renewal Program & Twin Invert Removal	•	•	•	•	•	•				An estimated program budget of $3.5M to $6.5M per year is necessary to replace pipelines that have exceeded their intended service life. This program will reduce the risk of failure in the system, reduce I/I, contamination, and sanitary sewer overflows. Conceptual sequencing and budget needs may be adjusted once the City's Asset Management Program is implemented and the Annual Sanitary Sewer and Storm Drain Inspection Program is underway. This project also includes the replacement of twin invert manholes within the Draper pipe replacement project areas. Twin invert manholes include both sewer and drain pipe connections and contribute to combined sewer overflows during wet weather or due to pipeline failures.
Annual Interceptor Inspection and Cleaning Program	•	•	•	•	•	•				Use the sewer and drain system risk model to develop sewer and drain cleaning and assessment sequencing to inspect both systems annually over a 10-year cycle, as recommended by MassDEP. Interceptors are pipes greater than 18 inches in diameter. The assessment sequencing may be adjusted once the City's Asset Management Program is implemented.
Lower Cambridge Street Sewer Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. The Sanitary Sewer Interceptor Inspection and Evaluation Program identified defects on Cambridge Street between Southbridge Street and Dorrance Street. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Everett Gaylord Boulevard, Laurel Street, Summer Street — Short Term Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. This project addresses defects identified as short-term rehabilitation, which require attention within approximately five years. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Western Interceptor — Critical Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. This project addresses defects identified during the Western Interceptor Sewer Evaluation, which were designated as critical. Critical rehabilitation is designated for sewer segments with structural defects that require immediate rehabilitation. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Western Interceptor — Short Term Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. This project addresses defects identified during the Western Interceptor Sewer Evaluation, which were designated as short term. Short term rehabilitation is designated for sewer segments with structural defects that require rehabilitation within five years. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Vernon Street — Short Term Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. This project addresses defects identified as short term rehabilitation, which require attention within approximately five years. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.

TABLE 5.1: CAPITAL REINVESTMENTS ***(Continued)***

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Eastern Interceptor (Old Lincoln Street/Goldsberry Street) — Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system on Old Lincoln Street and Goldsberry Street. Roots and infiltration were found in a section of the interceptor that has a history of capacity issues and surcharging. This project is part of a larger effort to undertake sewer repairs found to be cost-effective or value-effective during the Sanitary Sewer Interceptor Evaluation and Inspection Program — Phase 2 for the Mill Street Interceptor Area. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Northwest Interceptor (Park Avenue) — Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system on Park Avenue between Maywood Street and Winfield Street. This project is part of a larger effort to make sewer repairs found to be cost-effective or value-effective during the Sanitary Sewer Interceptor Evaluation and Inspection Program — Phase 2 for the Mill Street Interceptor Area. Repairs to defects will reduce the likelihood of infiltration, further sewer degradation, sewer collapses, and blockages.
Cherry Valley Area I/I Removal — Phase 1	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. A sanitary sewer evaluation survey in the Cherry Valley area identified sewer segments and manholes with infiltration and inflow considered to be cost effective to remove. Approximately 238,290 gallons per day of peak infiltration will be removed as a result of this project. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Cherry Valley Area I/I Removal — Phase 2	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. Defects were identified during the Cherry Valley Area Sewer System Evaluation Survey and were found to be cost effective to remove. Approximately 304,654 gallons per day of peak infiltration will be removed. Repairs to defects will reduce the likelihood of sewer collapses, blockages, basement backups, and sanitary sewer overflows.
Mower Street Interceptor, Chandler Street Interceptor, and Mill Street Interceptor — Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of critical structural failure and reduce groundwater infiltration into the wastewater collection system. This project addresses defects identified during the Interceptor Inspection and Evaluation Program to be cost-effective to repair. Repairs to critical defects will reduce the likelihood of sewer collapses, blockages, and sanitary sewer overflows near the Coes Reservoir. Additionally, this project will reduce wastewater flow treated at the Upper Blackstone Treatment Facility.
Pleasant Street and Park Avenue Sewer Rehabilitation and I/I Removal	•	•	•	•	•					Reduce the risk of structural failure and reduce groundwater infiltration into the wastewater system. Defects were identified during the Pleasant Street and Park Avenue Hydraulic Capacity Analysis that are contributing to flooding issues on Pleasant Street and Park Avenue. Repairs to defects will reduce the likelihood of I/I, sewer collapses, and blockages.
Canton Street Overflow Collector Rehabilitation and I/I Removal	•	•	•	•	•					Reduce groundwater infiltration into the 120-by-144-inch Canton Street Overflow Collector. The two defects at construction joints were identified during cleaning and inspection of the existing overflow collector in Canton Street. The defects were observed and estimated to be contributing approximately 1,300 gallons per day of infiltration. Repairs to the conduit will reduce the likelihood of flooding, basement backups and sanitary sewer overflows.

TABLE 5.1: CAPITAL REINVESTMENTS *(Continued)*

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Annual Interceptor Renewal Program	•	•	•	•	•	•				Utilize the sewer and drain system risk model to create conceptual project sequencing for the first 10 years to improve stormwater and sewer interceptor condition, remove twin inverts, and reduce inflow and infiltration. Interceptors are pipes greater than 18 inches in diameter. An estimated program budget of $3.5M per year is necessary to replace interceptors that have exceeded their intended service life and reduce risk of failure in the system. Conceptual sequencing and budget needs may be adjusted once the City's Asset Management Program is implemented and the Annual Sanitary Sewer and Storm Drain Inspection Program is underway.
Mill Street and Main Street Pipe Replacement	•	•	•	•	•					Increase capacity and divert flow to the Mill Street Interceptor to relieve surcharging and overflow of the Chandler Street Interceptor. Reduced flow in the Chandler Street Interceptor will result in fewer sanitary sewer overflows and basement backups near Mann Street and Beaver Brook Parkway. Reduce upstream surcharging in the Mill Street Interceptor by replacing undersized and collapsed pipes in Mill Street and by cleaning both siphons.
Cambridge Street and Eastern Interceptor Cleaning			•	•	•					Restore capacity to the wastewater collection system through cleaning and removal of debris, sediment, and grease from sewer interceptors. Restoring capacity will reduce occurrences of sanitary sewer overflows and basement backups.
Brosnihan Square Siphon Cleaning			•	•	•					Restore capacity to the wastewater collection system through cleaning and removal of debris, sediment, and grease from sewer interceptors. Restoring capacity will reduce occurrences of sanitary sewer overflows and basement backups.
Green Street Siphon Cleaning			•	•	•					Identify locations of excessive infiltration and inflow as well as pipe deficiencies in the wastewater collection system for subsequent rehabilitation.
Lafayette Street Sewer Rehabilitation and I/I Removal	•	•	•	•	•					Restore capacity to the wastewater collection system through cleaning and removal of debris, sediment, and grease from sewer interceptors. Restoring capacity will reduce occurrences of sanitary sewer overflows and basement backups.
Cherry Valley Area I/I Rehabilitation and I/I Removal — Root Treatment	•	•	•	•	•					Restore capacity to the wastewater collection system through cleaning and removal of debris, sediment, and grease from sewer interceptors. Restoring capacity will reduce occurrences of sanitary sewer overflows and basement backups.
Mower Street Interceptor, Chandler Street Interceptor, and Mill Street Interceptor Cleaning			•	•	•					Restore capacity to the wastewater collection system through cleaning and removal of debris, sediment, and grease from sewer interceptors. Restoring capacity will reduce occurrences of sanitary sewer overflows and basement backups.

TABLE 5.1: CAPITAL REINVESTMENTS *(Continued)*

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Pump Station Renewal Program			•	•	•					Proactive pump station rehabilitation and replacement lowers the risk of pump station failures and sanitary sewer overflows and reduces reactive maintenance.
Pump Station Generators Replacement Program			•	•	•					Improve the reliability and capability of power generators at sewage pump stations. This project will reduce sewer system backups and sanitary sewer overflows during loss of power, improve public safety, reduce emergency responses and replacement, and allow for proactive maintenance.
Proctor Pump Station Rehabilitation			•	•	•					Reduce the risk of sanitary sewer overflows and system backups due to pump station failure from outdated equipment at the Proctor Pump Station.
Hemlock Pump Station Rehabilitation			•	•	•					Reduce the risk of sanitary sewer overflows and system backups due to pump station failure from outdated equipment at the Hemlock Pump Station.
Bridle Path Pump Station Rehabilitation			•	•	•					Reduce the risk of sanitary sewer overflows and system backups due to pump station failure from outdated equipment at the Bridle Path Pump Station.

TABLE 5.2: NEW CAPITAL INVESTMENTS

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Green Island Flooding Relief Conduit					•	•				Relieve flooding in the Green Island area by construction of a relief conduit that discharges directly to the Blackstone River for high flows that exceed the capacity of the Quinsigamond Avenue CSO Treatment Facility and effluent conduit. The Quinsigamond Avenue CSO Treatment Facility currently discharges to the Mill Brook Conduit. The relief conduit will protect public health and safety, reduce property damage, improve water quality, and protect economic activity.
Quinsigamond Avenue CSO Treatment Facility Pump Upgrades										Reduce the volume of treated discharges to the Mill Brook and the Blackstone River from the Quinsigamond Avenue CSO Treatment Facility during wet weather.
Upper Blackstone Nutrient Removal Upgrade — Phase B									•	Address water quality issues in the Blackstone River and Narragansett Bay by reducing effluent nutrient loads from the Upper Blackstone Treatment Facility. This project is the second phase of a three-phase program to meet the 2008 National Pollutant Discharge Elimination System permit limits on total phosphorus and total nitrogen.
Upper Blackstone Nutrient Removal Upgrade — Phase C									•	Address water quality issues in the Blackstone River and Narragansett Bay by reducing effluent nutrient loads from the Upper Blackstone Treatment Facility. This project is the third phase of a three-phase program to meet the 2008 National Pollutant Discharge Elimination System permit limits on total phosphorus and total nitrogen.
High Flow Reduction and Management									•	Reduce and manage high flow requiring bypass at the Upper Blackstone Treatment Facility. Achieve compliance with the 2008 National Pollutant Discharge Elimination System permit for all flow events.
Water Filtration Plant Backwash Handling Alternative — Wastewater System Discharge										Discharge Water Filtration Plant filter backwash water to the wastewater collection system with treatment at the Upper Blackstone Treatment Facility.
Water Filtration Plant Backwash Handling Alternative — Coagulant Change										Eliminate aluminum backwash discharge to Holden Reservoir #2 by replacing aluminum-based coagulant with iron-based coagulant.
Water Filtration Plant Backwash Handling Alternative — On-Site Treatment: Clarifiers & Recycling Backwash										Treat Water Filtration Plant backwash on-site.
Water Filtration Plant Backwash Handling Alternative — On-Site Treatment: Settling Lagoon										Treat Water Filtration Plant backwash on-site.
Additional Illicit Discharge Detection Elimination Protocol										Implement a comprehensive illicit discharge detection and elimination protocol to remove direct illicit connections and cross contamination between sanitary sewers and storm drains. The goal of the illicit discharge detection and elimination protocol is to improve water quality of stormwater discharged to surface waters.

TABLE 5.2: NEW CAPITAL INVESTMENTS *(Continued)*

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Additional Best Management Practices							•			Implementation of Best Management Practices to improve quality of stormwater discharged to surface waters.
Additional Stormwater Sampling/Monitoring										Expand the stormwater monitoring and sampling program.
Indian Lake Phosphorus Reduction										Improve the water quality and recreational value of Indian Lake by reducing total phosphorus concentration.
Additional Total Maximum Daily Load Compliance Measures										Treat stormwater to meet total maximum daily limits set by MassDEP, improving water quality of the City's surface waters.
Private Street Conversion Program						•				Improve surface water quality and public health and safety by eliminating unpaved roads through an annual program.
Bancroft School Stormwater Bioretention Phosphorus Removal										Construct low impact development phosphorous removal project within a small area of the Indian Lake watershed.
Hamill Route Relief Interceptor Construction				•	•	•				Provide a new route to divert flow from the upper portion of the Chandler Street Interceptor into the lower portion of the Cambridge Street Interceptor downstream of a hydraulic bottleneck, which will significantly reduce surcharging and overflows, improving water quality in the Beaver Brook during wet weather.
Green Island Area Flooding Reduction Improvements — Quinsigamond Avenue CSO Treatment Facility Bypass Gate Modifications						•				Reduce the volume of combined sewer overflows bypassing treatment at the Quinsigamond Avenue CSO Treatment Facility during wet weather to improve water quality in the Mill Brook and Blackstone River.
Granite Street Area Infrastructure Improvements		•								This project is part of a larger effort to address current infrastructure needs in the Granite Street area, existing drainage problems, drainage requirements for future growth, and water distribution requirements to serve future commercial/light industrial facilities and multi-story, densely developed residential facilities currently zoned in the project area. This project will specifically address sewer and drainage needs.
Pleasant Street and Park Avenue Sewer Replacement	•	•	•	•	•					Reduce the risk of surcharging, flooding, and sanitary sewer overflows in the wastewater collection system.
Twin Invert Elimination				•	•					Reduce potential of sanitary sewer overflows and permanently separate sewer and drain system manholes containing twin inverts.

TABLE 5.3: STUDY AND ASSESSMENT

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Green Island Flooding & Long Term Control Plan Update						•		•	•	Improve water quality, public health, safety, and reduce flooding, treated discharges, and wet weather bypass of the Quinsigamond Avenue CSO Treatment Facility. Evaluate the City's regulatory compliance and identify improved combined sewer overflow control alternatives to meet permit requirements.
Drainage System Master Plan	•					•	•	•	•	Reduce the risk of flooding and impacts to public health and safety.
Citywide Water Quality Baseline Sampling										Perform in-stream water quality characterization to develop baseline conditions for future comparison in Tier 1 and 2 water bodies.
Evaluate Stormwater Treatment Devices						•				Improve water quality and reduce quantity of stormwater runoff prior to entering surface waters.
Annual Pipeline Inspection Program	•	•	•	•	•	•				Use the sewer and drain system risk model to develop sewer and drain cleaning and assessment sequencing to inspect both systems annually over a 10-year cycle, as recommended by MassDEP. The assessment sequencing may be adjusted once the City's Asset Management Program is implemented. This program will inspect sewer pipes of less than or equal to 18 inches in diameter and their parallel drain system pipes.
Northern Tributary of Lake Avenue Pump Station I/I Study			•	•	•					Identify locations of excessive I/I as well as pipe deficiencies in the wastewater collection system for subsequent rehabilitation.
Asset Management Program Implementation	•	•	•	•	•	•				Implement a work-order based asset management program to manage, track, and optimize operations and maintenance activities and capital improvements.
Northwest (Holden & Rutland) Interceptor Inspection	•	•	•	•	•	•				Identify locations of excessive I/I as well as pipe deficiencies in the wastewater collection system for subsequent rehabilitation.
Pump Stations Inspections & Evaluations		•		•	•	•				Reduce sanitary sewer overflows, flooding, system backups, and operations and maintenance activities, and protect water quality by replacing outdated equipment.

TABLE 5.4: UPPER BLACKSTONE TREATMENT FACILITY ASSET INVESTMENTS

Name	Pipe Age (Wastewater or Stormwater)	Infiltration Rate	Loss of Service Complaints	Sanitary Sewer Overflow Rate (Non-Capacity or Capacity)	Unplanned Maintenance	Street Flooding	Catch Basin Cleaning	Compliance during High-Flow Blending at Upper Blackstone Treatment Facility	Compliance with NPDES Permit at Upper Blackstone Treatment Facility	Objective
Upper Blackstone Treatment Facility Asset Management Program					•			•	•	Annual maintenance and upkeep of facility assets in order to maintain the existing treatment capacity and quality of the Upper Blackstone Treatment Facility.
Upper Blackstone Treatment Facility Auxiliary Power								•	•	To provide backup power through a main power source, sized to handle all liquid processes at the Upper Blackstone Treatment Facility.
Upper Blackstone Treatment Facility Solids Handling Facilities Plan										Study alternatives for replacement of the Upper Blackstone Treatment Facility incinerators.
Upper Blackstone Treatment Facility Laboratory									•	Construct a new laboratory building, visitors center, and administrative facilities to replace current outdated space. Allow for continued support of NPDES compliance.

5.5.5 Conceptual Cost Estimate

A conceptual level cost estimate was developed for each infrastructure investment. These opinions of probable cost generally fell into four cost categories:

1. Cost developed in a past Compendium report.
2. Cost developed from a similar recommendation in a past report, or from industry construction bid data.
3. Annual cost set by DPW&P budget.
4. Conceptual cost developed in this Integrated Plan.

The American Society for Testing and Materials (ASTM) Standard Classification for Cost Estimate Classification System (E2516-11) provides a system for classifying cost estimates. The class of the cost estimate is determined by the design stage in terms of percent complete and is referred to as the "degree of projection definition." **Table 5.5** shows the five different classes of cost estimates per ASTM Standard E2516-11.

Based on ASTM guidelines, all of the infrastructure investments cost estimates can be classified as ASTM Class 5, which has the greatest cost estimating variability and lowest expected accuracy, regardless of the source of cost data. These cost estimates are conceptual based on the three resources used to identify the infrastructure investments, and their use should be limited to screening and feasibility purposes.

Cost Category 1: Cost Developed in a Past Compendium Report

Cost data previously developed from past reports or studies contained in the Compendium and where the scope is unchanged were used where available. Costs were utilized and adjusted for inflation to present-day values using Engineering News Record Construction Cost Indices (ENR CCI, August 2017, 10842).

TABLE 5.5: CLASSES OF COST ESTIMATES PER ASTM STANDARD E2516-11

ASTM Cost Estimate Class	Degree of Projection Definition	End Usage	Typical Estimating Method	Expected Accuracy Range for: General Construction
Class 5	0 - 2%	Screening or feasibility	Factors/models or judgment	L: -20% to -30% H: +30% to +50%
Class 4	1 - 15%	Concept study or feasibility	Primarily factors/models	L: -10% to -20% H: +20% to +30%
Class 3	10 - 40%	Budget authorization or control	Mixed, but primarily factors/models	L: -5% to -15% H: +10% to +20%
Class 2	30 - 70%	Control or bid	Primarily deterministic	L: -5% to -10% H: +5% to +15%
Class 1	70 - 100%	Check estimate or bid	Deterministic	L: -3% to -5% H: +3% to +10%

For example, Mill Street and Main Street Pipe Replacement came from the Cambridge Street Area Improvements — Alternative Evaluation completed in January 2014. The cost was adjusted to present-day value at $5.03 million ($4.48 million in 2014).

Cost Category 2: Cost developed from a Similar Recommendation in a Past Report, or from Industry Construction Bid Data

Cost data for the project does not exist, but the conceptual scope of work can be quantified. Conceptual cost estimates were developed utilizing similar recommended projects in the Compendium, or using recent construction bid data for projects of similar size and scope. Local bid data and cost from other Massachusetts municipalities was used. Costs were adjusted to present-day values using ENR CCIs and typically included additional cost considerations as described below.

For example, the Upper Blackstone Treatment Facility Auxiliary Power consists of providing backup power sized to handle all liquid processes at the Upper Blackstone Treatment Facility. Based on a similar recommendation from a past report, the Upper Blackstone District estimates that the investment would be approximately $6.625 million.

Cost Category 3: Annual Cost Set by DPW&P Budget

Cost is set by other factors and targets. For example, the City has target spending goals for the Pump Station Renewal Program set at $1 million per year.

Cost Category 4: Conceptual Cost Developed in the Integrated Plan

Cost data for the project does not exist. Conceptual cost estimates were developed from a conceptual scope of work and engineering experience.

For example, the Draper Pipe Replacement Program utilized similar engineering experience to develop the scope of work and cost estimate. This project focused on replacement of Draper pipe, which includes reconstruction of existing manholes and construction of new manholes. With limited information on Draper pipe, the scope for the project was based on Worcester's GIS database and operational data to determine the extent of replacement.

Table 5.6 summarizes the conceptual cost for each project and includes the following information:

- Project Name
- Cost Value — The cost value is the conceptual project cost developed for planning purposes.
- Cost Category — The method in which the cost was determined.

The Infrastructure Investment Data Sheets included in **Appendix 8.2** provide additional details, such as which contingencies were included in the conceptual cost estimates.

5.6 Operations and Maintenance

This Integrated Plan recognizes that an increased focus on operations and maintenance is critical to proper management of the water resources systems as a whole and represents a necessary complement to all capital infrastructure investments. Operating and maintaining the City's systems become more expensive as they continue to degrade, causing more frequent emergency responses to restore proper operation. In conjunction with the Capital Reinvestment strategy, the City must continue to invest in operations and maintenance efforts to keep up with its aging infrastructure.

5.7 Next Steps

The projects outlined herein were evaluated through a multi-criterion benefit model to provide an objective approach to considering the benefits of each infrastructure investment. The evaluation and screening of all investments using the benefits model is described in **Chapter 6**.

TABLE 5.6: INFRASTRUCTURE INVESTMENT COST SUMMARY

Name	Type	Cost Value	Cost Category
Draper Pipe Replacement Program	Capital Reinvestment	$55,500,000	4
Annual Pipeline Renewal Program & Twin Invert Removal	Capital Reinvestment	$3,5000,000-$6,500,000/year	4
Annual Interceptor Inspection and Cleaning Program	Capital Reinvestment	$1,000,000/year	4
Lower Cambridge Street Sewer Rehabilitation and I/I Removal	Capital Reinvestment	$1,530,000	1
Everett Gaylord Boulevard, Laurel Street, Summer Street — Short Term Rehabilitation and I/I Removal	Capital Reinvestment	$800,000	1
Western Interceptor — Critical Rehabilitation and I/I Removal	Capital Reinvestment	$870,000	1
Western Interceptor — Short Term Rehabilitation and I/I Removal	Capital Reinvestment	$4,400,000	1
Vernon Street — Short Term Rehabilitation and I/I Removal	Capital Reinvestment	$1,400,000	1
Eastern Interceptor (Old Lincoln Street/ Goldsberry Street) — Rehabilitation and I/I Removal	Capital Reinvestment	$1,800,000-$2,400,000	1
Northwest Interceptor (Park Avenue) — Rehabilitation and I/I Removal	Capital Reinvestment	$3,700,000-$4,500,000	1
Cherry Valley Area I/I Removal — Phase 1	Capital Reinvestment	$4,500,000	1
Cherry Valley Area I/I Removal — Phase 2	Capital Reinvestment	$4,300,000	1
Mower Street Interceptor, Chandler Street Interceptor, and Mill Street Interceptor — Rehabilitation and I/I Removal	Capital Reinvestment	$900,000	1
Pleasant Street and Park Avenue Sewer Rehabilitation and I/I Removal	Capital Reinvestment	$275,000	1
Canton Street Overflow Collector Rehabilitation and I/I Removal	Capital Reinvestment	$50,000	1
Annual Interceptor Renewal Program	Capital Reinvestment	$3,500,000/year	4

TABLE 5.6: INFRASTRUCTURE INVESTMENT COST SUMMARY *(Continued)*

Name	Type	Cost Value	Cost Category
Mill Street and Main Street Pipe Replacement	Capital Reinvestment	$5,100,000	1
Cambridge Street and Eastern Interceptor Cleaning	Capital Reinvestment	$440,000-$650,000	1
Brosnihan Square Siphon Cleaning	Capital Reinvestment	$440,000-$650,000	1
Green Street Siphon Cleaning	Capital Reinvestment	$440,000-$650,000	1
Lafayette Street Sewer Rehabilitation and I/I Removal	Capital Reinvestment	$830,000	0
Cherry Valley Area I/I Rehabilitation and I/I Removal — Root Treatment	Capital Reinvestment	$117,000	1
Mower Street Interceptor, Chandler Street Interceptor, and Mill Street Interceptor Cleaning	Capital Reinvestment	$440,000-$650,000	1
Pump Station Renewal Program	Capital Reinvestment	$1,000,000/year	3
Pump Station Generators Replacement Program	Capital Reinvestment	$300,000/year	1
Proctor Pump Station Rehabilitation	Capital Reinvestment	$630,000	2
Hemlock Pump Station Rehabilitation	Capital Reinvestment	$700,000	2
Bridle Path Pump Station Rehabilitation	Capital Reinvestment	$700,000	2
Green Island Flooding Relief Conduit	New Capital Investment	$40,000,000	1
Quinsigamond Avenue CSO Treatment Facility Pump Upgrades	New Capital Investment	$4,000,000	1
Upper Blackstone Nutrient Removal Upgrade — Phase B	New Capital Investment	$102,300,000	1
Upper Blackstone Nutrient Removal Upgrade — Phase C	New Capital Investment	$156,000,000	1

TABLE 5.6: INFRASTRUCTURE INVESTMENT COST SUMMARY *(Continued)*

Name	Type	Cost Value	Cost Category
High Flow Reduction and Management	New Capital Investment	$56,250,000	3
Water Filtration Plant Backwash Handling Alternative — Wastewater System Discharge	New Capital Investment	$45,000,000	2
Water Filtration Plant Backwash Handling Alternative — Coagulant Change	New Capital Investment	Assessment: $60,000; Plant Modifications: $0-10,000,000+	3
Water Filtration Plant Backwash Handling Alternative — On-Site Treatment: Clarifiers & Recycling Backwash	New Capital Investment	$19,000,000	3
Water Filtration Plant Backwash Handling Alternative — On-Site Treatment: Settling Lagoon	New Capital Investment	$21,000,000	3
Additional Illicit Discharge Detection Elimination Protocol	New Capital Investment	$4,100,000	1
Additional Best Management Practices	New Capital Investment	$1,300,000	1
Additional Stormwater Sampling/Monitoring	New Capital Investment	$1,590,000	1
Indian Lake Phosphorus Reduction	New Capital Investment	$10,700,000	1
Additional Total Maximum Daily Load Compliance Measures	New Capital Investment	$990,000,000	1
Private Street Conversion Program	New Capital Investment	$1,500,000/year	4
Bancroft School Stormwater Bioretention Phosphorus Removal	New Capital Investment	$150,000	1
Hamill Route Relief Interceptor Construction	New Capital Investment	$9,000,000	1
Green Island Area Flooding Reduction Improvements — Quinsigamond Avenue CSO Treatment Facility Bypass Gate Modifications	New Capital Investment	$320,000	1
Granite Street Area Infrastructure Improvements	New Capital Investment	$18,600,000	1
Pleasant Street and Park Avenue Sewer Replacement	New Capital Investment	$3,500,000	1

TABLE 5.6: INFRASTRUCTURE INVESTMENT COST SUMMARY *(Continued)*

Name	Type	Cost Value	Cost Category
Twin Invert Elimination	New Capital Investment	$460,000,000	2
Green Island Flooding & CSO Long Term Control Plan Update	Study	$2,750,000-$3,500,000	3
Drainage System Master Plan	Study	$750,000-$1,500,000	3
Citywide Water Quality Baseline Sampling	Study	$360,000 for two years of sampling	3
Evaluate Stormwater Treatment Devices	Study	$125,000/acre	2
Annual Pipeline Inspection Program	Study	$1,000,000/year	4
Northern Tributary of Lake Avenue Pump Station I/I Study	Study	$250,000	2/3
Asset Management Program Implementation	Study	$1,250,000-$2,500,000	3
Northwest (Holden & Rutland) Interceptor Inspection	Study	$1,500,000	2
Pump Stations Inspections & Evaluations	Study	$100,000	3
Upper Blackstone Treatment Facility Asset Management Program	Upper Blackstone Facility Asset Investment	$3,500,000/year	3
Upper Blackstone Treatment Facility Auxiliary Power	Upper Blackstone Facility Asset Investment	$6,625,000	2
Upper Blackstone Treatment Facility Solids Handling Facilities Plan	Upper Blackstone Facility Asset Investment	$800,000	2
Upper Blackstone Treatment Facility Laboratory	Upper Blackstone Facility Asset Investment	$9,250,000	2

CHAPTER 6.

Evaluation & Screening of Infrastructure Investments

6.1 Overview

The City has identified infrastructure investments to close existing performance gaps (**Chapter 5**) and grouped them into three categories: Capital Reinvestment, New Capital Investment, and Study and Assessment. This Integrated Plan uses a multi-criteria benefits model to select infrastructure investments that offer the greatest potential environmental and public health benefit.

Ten criteria were selected for the benefits model and a numerical scoring system was applied. The benefits model is used as a guide in developing the management plan for implementation.

6.2 Benefits Model Framework

A multi-criteria benefits model framework is a widely used tool in integrated water resources planning.

The use of a multi-criteria benefits model is intended to evaluate and compare a variety of infrastructure investments. The framework establishes criteria to evaluate and score each infrastructure investment.

Certain projects are not included in the benefits model because they must be implemented to maintain operation of critical facilities and instead will be implemented based on the framework discussed in **Chapter 5**.

6.2.1 Benefits Criteria

Criteria used in the model estimate the benefits of individual investments.

The 10 benefits criteria are detailed in **Section 6.4**. Public outreach feedback further supported the benefits criteria selected.

6.2.2 Benefits Scoring

Worcester's benefits model uses a numeric scale from 0 to 5 to score proposed investments for each benefits model criterion. This numeric scale measures the degree to which an infrastructure investment could result in:

- None of the attributes of the criterion
- Some attributes of the criterion
- All the attributes of the criterion

The six potential scores (0 through 5) represent relative qualitative increases in estimated benefits provided by an infrastructure investment. Investments that meet the full intent of the benefit criterion receive a score of 5, while investments that do not achieve any benefit receive a score of 0. Intermediate scores are assigned depending on the level of benefit and how it aligns with the scoring definitions. However, scores are not always defined for all six levels. For example, if the relative increases in benefits are too small to justify using intermediate scores (e.g., a benefit criterion may include scores of 0, 1, 3, 5; skipping intermediate scores of 2 and 4). The scoring definitions for each criterion are presented in **Table 6.2** and further described in **Section 6.4**.

Each potential investment was scored using criteria based on data from a variety of sources, including:

- GIS analysis
- City's Customer Service Request System entries
- Risk Model results
- Regulatory requirements and guidelines
- DPW&P records
- Industry standards

6.3 Identification of Benefits Criteria

To identify the benefits criteria, the City considered the goals of this Integrated Plan, the triple bottom line framework, and the results of the Key Performance Indicators gap analysis described in **Chapter 3**.

6.3.1 Integrated Plan Goals

The following goals were established for the development of this Integrated Plan:

- Protect public health and safety:
  - Maintain high-quality drinking water.
  - Reduce frequency and occurrence of sanitary sewer overflows.
  - Minimize basement backups of sewage caused by sewer system deficiencies.
- Protect and improve full-contact recreational waters:
  - Lake Quinsigamond, Indian Lake, Coes Reservoir, Bell Pond, and Cook's Pond.
- Manage stormwater:
  - Reduce the frequency, duration, and extent of flooding, particularly the Green Island neighborhood.
  - Manage wet weather flows to Upper Blackstone Treatment Facility.
  - Improve quality of stormwater discharges.
- Maintain affordable water and sewer user rates.
- Improve treatment effectiveness and operations at the Quinsigamond Avenue CSO Treatment Facility.

6.3.2 Triple Bottom Line

Triple bottom line analysis includes cost of infrastructure, social factors, and environmental considerations in decision making.

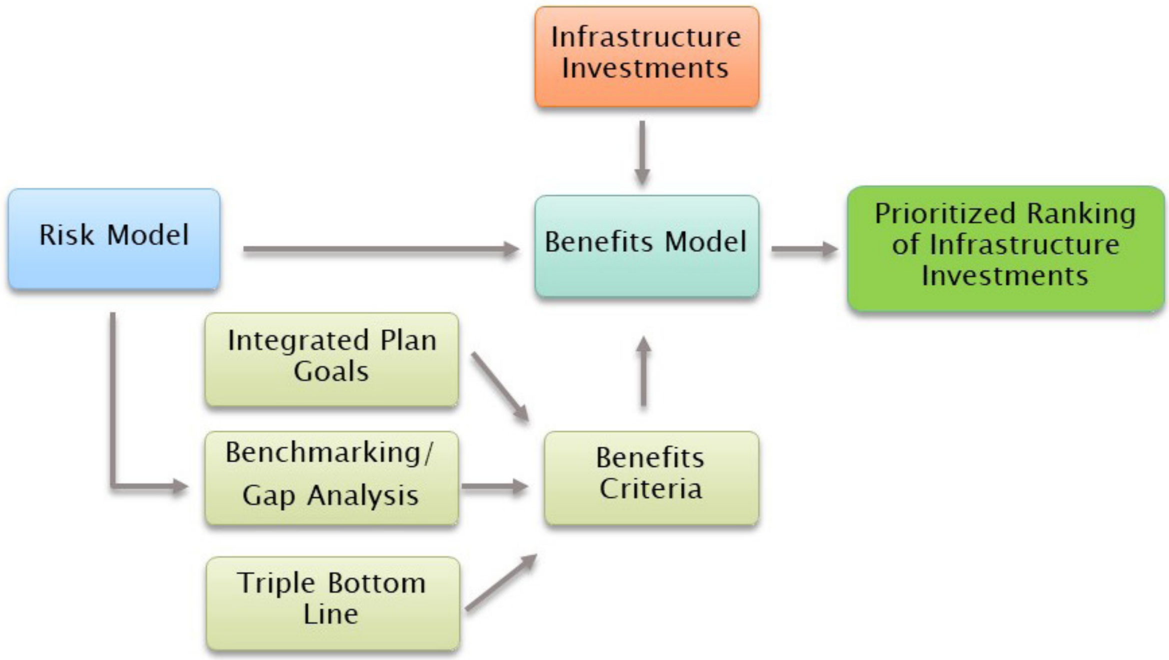
The benefits model criteria considered how infrastructure investments would impact the environmental and social needs of the City, in addition to the overall cost of the investment.

6.3.3 Key Performance Indicators Gap Analysis

The Key Performance Indicators and performance gaps measured in **Chapter 3** identified the City's needs. Key Performance Indicators represent specific performance aspects of the water resources systems and provide a direct measure of the City's targets for infrastructure management, and therefore reflect specific priorities within the benefits model.

The overall evaluation process described within this chapter is represented graphically in **Figure 6.1**.

FIGURE 6.1: DEVELOPMENT OF THE BENEFITS MODEL



6.4 Validation of the Benefits Criteria

This section details each of the 10 selected criteria, including the reason why the criterion was selected, a brief description, and the measurement and scoring process. The selected criteria are presented in **Table 6.1**, while **Table 6.2** provides a full list of the benefits criteria with summaries of the key details. Scoring for each criterion is defined on a scale from 0 to 5.

6.4.1 Reduce Basement Backups

Background: Basement backups can cause property damage and threaten public health and safety. This benefit criterion captures infrastructure investments that would reduce basement backups. The criterion also addresses a significant performance gap identified in **Chapter 3** — reducing loss of sewer service occurrences. Furthermore, this criterion captures all three elements of the triple bottom line.

Description: The Reduce Basement Backup criterion reflects the likelihood that an infrastructure investment will reduce the frequency of or eliminate sewer backups into basements.

Measurement: This criterion scoring considers areas of historical basement backups and the proximity of infrastructure investments to reported backup locations.

Scoring: Scoring is assigned based on density of reported basement backups within a geographic area, as defined in **Figure 2.6** in **Chapter 2.** Because the data source does not support a more refined scale, this criterion includes scoring definitions for scores of 0, 1, 3 and 5.

- Infrastructure investments that would improve the wastewater system in geographic areas where 10 or more reported backups have occurred from 2006 to 2016 are considered significant and receive the highest benefit score (5) under this category. Applicable sewer system improvements include sewer pipe rehabilitation or replacement, or pump station upgrades.
- Low to moderate wastewater system improvements are defined as those located where fewer than 10 reported historical backups have occurred. These investments receive a score of 3.
- Investments that would improve the wastewater system outside of areas with a history of basement backups receive a score of 1, and those with no impact on basement backup reduction receive a score of 0.

TABLE 6.1: BENEFITS CRITERIA

Benefits Criteria Name	Description
Reduce Basement Backups	Likelihood of an infrastructure investment to reduce the frequency of or eliminate basement backups.
Reduce Flooding	Likelihood of an infrastructure investment to reduce the frequency and severity of street and property flooding during short- and long-duration storm events.
Reduce Infrastructure Risk	Ability of an infrastructure investment to reduce the risk to critical infrastructure. High-risk assets are more likely to require costly repairs, cause extensive service disruptions, and have environmental impacts.
Protect Environmental Justice Population	Analysis of whether the infrastructure investment's implementation will benefit an Environmental Justice neighborhood.
Protect Public Health and Safety	Extent to which an infrastructure investment protects public health and safety.
Protect Sensitive Resource Areas	The influence an infrastructure investment has on protecting sensitive environmental resources including, but not limited to, wetlands and wildlife habitat.
Improve Recreational Water Quality	Ability of an infrastructure investment to improve recreational water quality and aesthetics by reducing pollutants, such as bacteria, nutrients, sediment load. This criterion also captures improvements that benefit downstream tributaries such as the Blackstone River.
Reduce Reactive Operations and Maintenance Efforts	Ability of an infrastructure investment to reduce the City's reactive maintenance efforts, including addressing failing infrastructure and unplanned maintenance needs through pipe replacement or renewal.
Regulatory Compliance	Ability of an infrastructure investment to address current regulatory obligations in the form of permits, active administrative orders, policies and guidelines, and the Clean Water Act.
Support Local Economy	Ability of an infrastructure investment to maintain business continuity and support economic development.

6.4.2 Reduce Flooding

Background: Surface flooding has widespread public health, public safety, environmental, and economic impacts. The City has documented that the type and frequency of flooding episodes is changing. Low-lying locations like the Green Island area have perennial occurrences of street and private property flooding that impact public health, degrade water quality, cause safety hazards, and disrupt businesses. One of the goals of this Integrated Plan is to improve stormwater management. Several Key Performance Indicators measure performance gaps related to flooding occurrences. This criterion captures these gaps and all the elements of the triple bottom line consistent with this Integrated Plan.

Description: The Reduce Flooding criterion reflects the likelihood that an infrastructure investment will reduce the frequency and extent of street and property flooding during short- and long-duration storm events, particularly within flood-prone areas.

Measurement: The benefits model evaluates locations of documented flood events and spatially compares these with the geographic infrastructure investment area. Data sources used to measure this criterion include the Customer Service Request System-reported flooding locations as described in **Chapter 2**, flooding studies, and institutional knowledge.

Scoring: For this criterion, infrastructure investments are scored qualitatively based on the estimated significance of flood reduction in proximity to known flood-prone areas. The level of detail provided by the data sources did not justify a scoring delineation for scores 2 and 4. This criterion includes scoring definitions for 0, 1, 3 and 5.

- Investments that would replace or upgrade stormwater infrastructure to provide increased system capacity near the most flood-prone areas receive a score of 5.
- Investments that would replace or upgrade stormwater infrastructure to provide increased system capacity near low- to moderate-intensity flood-prone areas receive a score of 3.
- Investments that would provide a lesser flood-reduction benefit receive a score of 1.

6.4.3 Reduce Infrastructure Risk

Background: A third of the City's wastewater infrastructure is beyond its useful (design) life because of years of underfunded capital renewal budgets. **Chapter 3** and **Chapter 5** of this Integrated Plan document the significant risks posed by failing or poorly performing components of water resources systems. This criterion recognizes investments that reduce infrastructure risk. As noted previously, infrastructure risk is defined as the product of the probability and consequence of failure. **Chapter 5** identifies potential investments to address system performance needs for the City's water resources management systems. This benefit captures all three elements of the triple bottom line including protection of the environment, minimizing risks to public safety, and sustainable management of the City's infrastructure.

Description: This criterion captures the ability of an infrastructure investment to reduce the risk to the City and the public posed by failing or underperforming critical infrastructure assets. The risk model technical memorandum in **Appendix 5.2** provides the basis for assessing the likely risk reduction for each potential investment.

Measurement: The risk model is designed to calculate risk scores for the City's water resources infrastructure. This criterion considers physical integrity and pipeline size as the primary metrics. Secondary metrics may only individually make a minor contribution to the total benefits score, but when combined, they better differentiate infrastructure investment benefits across the scoring range. In addition to the data provided by the risk model, the scope of a potential infrastructure investment provides an approximation of its benefit or risk reduction.

Scoring: The scoring for this criterion is based on the relative scale of the improvement and the infrastructure risk within the infrastructure investment area. The risk model described in **Section 5.3.2** and in the Risk Model technical memorandum in **Appendix 5.2** provides guidance on how probability of failure ratings and consequence of failure ratings were determined.

- Citywide improvements to infrastructure with current risk scores classified as "Poor" probability of failure and "Very High" consequence of failure receive a score of 5.
- Local improvements to infrastructure (such as within a small neighborhood) that have a mix of "Acceptable" probability of failure and "Moderate" consequence of failure ratings, receive a score of 3.
- Minimal improvements to infrastructure with "Excellent" probability of failure and "Insignificant" consequence of failure ratings receive a score of 1.

6.4.4 Protect Environmental Justice Population

Background: One of the defining goals of this Integrated Plan is to ensure water and sewer user rates remain affordable to the City's residents. Environmental Justice communities often include populations with low income levels. Other characteristics are immigration status and English language proficiency. As defined by the state of Massachusetts, Environmental Justice communities are "those most at risk of being unaware of or unable to participate in environmental decision-making or those most unable to gain access to state environmental resources." This benefit criterion supports both the economic and social elements of the triple bottom line by capturing infrastructure investments that protect Environmental Justice communities.

Description: This criterion reflects the likelihood that an infrastructure investment has a direct benefit on Environmental Justice communities.

Measurement: This criterion is scored using a binary system based on whether the infrastructure investment directly protects nearby Environmental Justice communities. Because infrastructure investment can either protect the Environmental Justice community or not provide any benefit, there are no intermediate benefit scores. The benefits model assesses whether the investment protects Environmental Justice communities within the City using geographical Environmental Justice mapping available from the State.

Scoring: Infrastructure investments receive a score of 0 if they would not benefit the Environmental Justice communities within the City, and a score of 5 if they would benefit the Environmental Justice communities.

6.4.5 Protect Public Health and Safety

Background: Another goal of this Integrated Plan is to protect public health and safety, which is represented by the social component of the triple bottom line. The primary purpose is to ensure this protection through proper operation and management of the City's water resources systems.

Description: This criterion captures infrastructure investments that improve public health and safety.

Measurement: The benefits model qualitatively scores infrastructure investments based on the estimated significance of improvement to public health and safety. It considers the size of the population expected to benefit from the improvements using the infrastructure investment area and available population density data.

Scoring: To facilitate the scoring process, this criterion uses MassGIS population density data to create three categories in the City: low, medium, and high density. As such, the scoring system only includes scoring definitions for 0, 1, 3 and 5.

- Infrastructure investments that would provide public health and safety improvements in an area with multi-family and commercial land use receive the highest score of 5.
- Investments that would provide public health and safety improvements in areas with public open spaces and medium-density land use receive a score of 3.
- Investments that would provide public health and safety improvements in areas with single family residential and other low-density land uses receive a score of 1.

6.4.6 Protect Sensitive Resource Areas

Background: This criterion recognizes water resources infrastructure investments that protect sensitive environmental resource areas within the City. These include, but are not limited to, wetlands and wildlife habitat. This benefit focuses on the environmental element of the triple bottom line.

Description: This criterion reflects the influence an infrastructure investment has on protection of sensitive environmental resource areas. Sensitive resource areas are defined using MassGIS mapping, such as BioMap2, priority habitats of rare species, and vernal pools.

Measurement: The benefits model scores infrastructure investments based on how they protect sensitive environmental resources through their proximity to these areas.

Scoring: The MassGIS mapping was used to identify the location of sensitive resource areas relative to infrastructure investments. The level of detail provided by MassGIS data did not justify a scoring delineation for scores 2 and 4. This criterion includes scoring definitions for 0, 1, 3 and 5, only.

- Infrastructure investments that would provide protection to rare species habitats receive the highest score of 5.
- Infrastructure investments that would provide protection to verified vernal pools and wetlands receive a score of 3.

- Infrastructure investments that would provide protection to potential vernal pools receive a score of 1.

6.4.7 Improve Recreational Water Quality

Background: As described in **Chapter 2**, the City's recreational water bodies represent an important quality-of-life asset to residents. Degradation of water quality can have a significant impact on the value of these recreational waters.

Description: This benefit criterion captures water quality improvements to recreational water bodies provided by each proposed infrastructure investment. This criterion also captures improvements that benefit downstream tributaries such as the Blackstone River.

Measurement: This criterion reflects the likelihood of an infrastructure investment to improve water quality and aesthetics of recreational water bodies by reducing pollutants, such as bacteria, nutrients, and sediment loading. Using the three-tiered classifications for surface water bodies within the City presented in **Figure 2.8** in **Chapter 2**, this benefit criterion qualitatively assesses improvements.

Scoring: To facilitate the scoring process, this criterion is aligned with the tiered classification such that the scoring system includes scoring definitions for 0, 1, 3 and 5, only.

- Major water quality improvements to Tier 1 or Tier 2 (recreational) water bodies receive the highest score of 5.
- Minor improvements to these water bodies receive a score of 3, while those that benefit Tier 3 water bodies receive a score of 1.
- Infrastructure investments that do not directly impact water quality receive a score of 0 under this criterion.

6.4.8 Reduce Reactive Operations and Maintenance Efforts

Background: Through the Key Performance Indicator analysis, a significant performance gap was documented in reactive operations and maintenance efforts. The City's aging water resources systems require frequent emergency response and reactive maintenance. This criterion captures the benefits of infrastructure investments that include proactive management of the systems, while supporting all three elements of the triple bottom line.

Description: This benefit criterion reflects the ability of an infrastructure investment to reduce reactive maintenance efforts, including addressing failing infrastructure and unplanned maintenance needs through pipe replacement or renewal.

Measurement: This criterion references specific data from the risk model — maintenance probability of failure scores, which are one component of the total probability of failure scores. The maintenance probability of failure scores identify assets that are more likely to fail due to lack of maintenance.

Scoring: An infrastructure project that would replace assets with high (unacceptable or poor) maintenance probability of failure scores generally receives the highest score. Where risk model scores are unavailable, this criterion is measured based on GIS maps that correlate infrastructure investment areas with historical unplanned maintenance events. Study and assessment infrastructure investments that support future replacement infrastructure investments are also scored highly under this criterion.

- Infrastructure investments that would replace or upgrade assets with high-maintenance probability of failure ratings (areas that typically experience unplanned maintenance) across multiple neighborhoods receive the highest score of 5.
- Investments that would replace or upgrade assets with high-maintenance probability of failure ratings in localized areas (such as a single street) receive a score of 4.
- Infrastructure investments that include inspection of assets with high-maintenance probability of failure ratings across multiple neighborhoods receive a score of 4.

- Infrastructure investments that would replace or upgrade assets with low-maintenance probability of failure ratings across multiple neighborhoods receive a score of 3.
- Infrastructure investments that include inspection of assets with high-maintenance probability of failure ratings in localized areas receive a score of 3.
- Infrastructure investments that replace or upgrade assets with low-maintenance probability of failure ratings in localized areas receive a score of 2.
- Infrastructure investments that include inspection of assets with low-maintenance probability of failure ratings across multiple neighborhoods receive a score of 2.
- Projects that include inspection of assets with low-maintenance probability of failure ratings in localized areas receive a score of 1.

6.4.9 Regulatory Compliance

Background: The City is subject to local, state, and federal environmental laws and several Clean Water Act discharge permits. The challenges associated with compliance to all the regulatory requirements are presented in **Chapter 2**.

Description: This criterion measures how each infrastructure investment helps the City achieve ongoing regulatory compliance.

Measurement: This benefit criterion captures efforts to maintain compliance with the City's regulatory obligations under state and federal environmental laws.

Scoring: This criterion places the scoring standards into four groups:

- Components that directly address NPDES permits or administrative orders receive a score of 5.
- Components that comply with other local, state, or federal regulatory requirements receive a score of 3.
- Components that address policies and guidelines receive a score of 1.
- Components with no impact on regulatory compliance receive a score of 0.

6.4.10 Support Local Economy

Background: The City's water resources systems support the entirety of its economy. As a benefit that focuses on the economic element of the triple bottom line, this criterion measures how each infrastructure investment sustains business continuity and economic development and improves property values.

Description: This criterion reflects the ability of an infrastructure investment to support business continuity and overall growth in the City.

Measurement: Infrastructure investments can provide benefits to the local economy with two major objectives: (1) Provide reliable service to existing customers; (2) Expand service to support new business and development. The benefit model acknowledges that both are critical to support economic growth, with reliability being a focus.

Scoring: Based on the aforementioned measurement, infrastructure investments that qualify for this criterion receive a score of 0, 4, or 5.

- Based on MassGIS land use data, infrastructure investments that would improve the level of service and reliability of the existing water resources systems within residential, commercial and industrial areas receive the highest score of 5.
- Based on the City's redevelopment plans, infrastructure investments that would expand services to areas with planned development goals receive a score of 4.
- Investments that offer no direct measurable benefit to business continuity or economic development receive a score of 0.

6.4.11 Benefits Criteria Summary

Table 6.2 summarizes all benefits criteria, including description, source, measurement, and the scoring system for each of the criterion.

TABLE 6.2: BENEFITS CRITERIA SUMMARY

Benefits Criteria	Description	Source	Measurement	Quantification	Scoring System
Reduce Basement Backups	Likelihood of an infrastructure investment to reduce the frequency of or eliminate basement backups.	• Customer Service Request System data and resultant basement backup heat map • Institutional knowledge • GIS analysis	• Location of infrastructure investment in proximity to reported backup locations	• Review Customer Service Request System database within infrastructure investment area to determine qualitative score. • Location of infrastructure investment in proximity to historical backup locations	5. Sewer system improvements in known basement backup areas (>= 10 reported backups) 3. Sewer system improvements in known basement backup areas (< 10 reported backups) 1. Any improvement in sewer system without reported backups 0. No impact to basement backup reduction
Reduce Flooding	Likelihood of an infrastructure investment to reduce the frequency and severity of street and property flooding during short- and long-duration storm events.	• Customer Service Request System reported flooding events • Flooding Studies • DPW&P institutional knowledge • GIS analysis	• Location of infrastructure investment in proximity to documented flood locations	• Location of infrastructure investment in proximity to historical flooding areas	5. Increase stormwater/combined system capacity in high intensity flood prone areas 3. Increase stormwater system capacity in low/moderate intensity flood prone areas 1. Any stormwater quantity management infrastructure investment in known flood prone areas 0. No direct benefit to flood reduction
Reduce Infrastructure Risk	Ability of an infrastructure investment to reduce the risk to critical infrastructure. High risk assets are more likely to require costly repairs, cause extensive service disruptions, and have environmental impacts.	• Risk model • GIS analysis	• Reduction in risk through execution of the scope.	• Measure risk of: ◦ Physical integrity ◦ Infrastructure size ◦ Proximity to water bodies ◦ Historical records ◦ Population density ◦ Proximity to critical customers	5. Significant risk reduction with a larger impact area 4. Significant risk reduction with a smaller impact area 3. Moderate risk reduction with a larger impact area 2. Moderate risk reduction with a smaller impact area 1. Low risk reduction 0. No direct impact to risk reduction
Protect Environmental Justice Population	Analysis of whether the infrastructure investment's implementation will benefit an Environmental Justice neighborhood.	• GIS analysis • Environmental Justice community mapping	• Proximity to Environmental Justice neighborhoods	• Infrastructure investment located within or benefiting designated Environmental Justice community	5. Majority within or benefiting Environmental Justice neighborhood 0. Outside or not benefiting Environmental Justice neighborhood
Protect Public Health and Safety	Extent to which an infrastructure investment protects public health and safety.	• MassGIS • Population data • DPW&P institutional knowledge	• Population density	• Qualitative estimate of protection of public health/safety • Location of infrastructure investment in proximity to land use density	5. Reduces either impact on public health or impact on public safety in high density land uses 3. Reduces either impact on public health or impact on public safety in medium density land uses 1. Reduces either impact on public health or impact on public safety in low density land uses 0. No impact to public health or safety

TABLE 6.2: BENEFITS CRITERIA SUMMARY *(Continued)*

Benefits Criteria	Description	Source	Measurement	Quantification	Scoring System
Protect Sensitive Resource Areas	The influence an infrastructure investment has on protecting sensitive environmental resources including, but not limited to, wetlands and wildlife habitat.	• Analysis using MassGIS environmental resource data (e.g., Priority Habitats of Rare Species, Vernal Pools, etc.)	• Proximity to sensitive environmental resource areas	• Location of infrastructure investment in proximity to sensitive environmental areas • Qualitative estimate of benefits to protect sensitive environmental areas	5. Greatest protection of sensitive resource areas 3. Moderate protection of sensitive resource areas 1. Minor protection of sensitive resource areas 0. No measured protection of sensitive resource areas
Improve Recreational Water Quality	Ability of an infrastructure investment to improve recreational water quality and aesthetics by reducing pollutants, such as bacteria, nutrients, sediment load.	• DPW&P institutional knowledge • GIS analysis • Estimated load reductions	• Proximity to tiered water bodies • Water quality improvement	• Location of infrastructure investment in tiered water body watershed • Estimated improvement in water quality (bacteria, nutrients, phosphorus) • Major water quality improvement: reduction of known sanitary sewer overflows • Minor water quality improvement: sediment reduction	5. Water quality Benefit to Tier 1 or Tier 2 with major water quality improvements 3. Water quality Benefit to Tier 1 or Tier 2 with minor water quality improvements 1. Any water quality benefits to Tier 3 0. No direct impact to water quality improvements
Reduce Reactive Operations & Maintenance Efforts	Ability of an infrastructure investment to reduce the City's reactive maintenance efforts, including addressing failing infrastructure and unplanned maintenance needs through pipe replacement or renewal.	• DPW&P institutional knowledge • Risk Model • Existing maintenance lists and mapping	• Proximity to areas identified with current high maintenance needs	• Location of infrastructure investment • Estimate of current maintenance needs based on maintenance heat map, using probability of failure from risk model if available	5. Replacement infrastructure investments with high probability of failure in a large area 4a. Replacement infrastructure investments with high probability of failure in a small area, or 4b. Inspection infrastructure investments with high probability of failure in a large area 3a. Replacement infrastructure investments with low probability of failure in a large area, or 3b. Inspection infrastructure investments with high probability of failure in a small area 2a. Replacement infrastructure investments with low probability of failure in a small area, or 3b. Inspection infrastructure investments with low probability of failure in a large area 1. Inspection infrastructure investments with low probability of failure in a small area 0. No direct impact on reducing reactive operation & maintenance efforts

TABLE 6.2: BENEFITS CRITERIA SUMMARY *(Continued)*

Benefits Criteria	Description	Source	Measurement	Quantification	Scoring System
Regulatory Compliance	Ability of an infrastructure investment to address current regulatory obligations in the form of permits, active administrative orders, policies and guidelines, and the Clean Water Act.	• Permit and regulatory policy review • DPW&P institutional knowledge	• Compliance with permit • Compliance with administrative orders • Compliance with policies/guidelines/ Clean Water Act	• Infrastructure investments that support compliance with local, state or federal regulatory requirements • Obligations directly referenced in permits or administrative orders • Infrastructure investments consistent with the Clean Water Act • Illicit discharge and detection elimination; reduction in number of failed on-site sewage disposal systems; capacity, management, operations and maintenance	5. Infrastructure investment that directly address administrative orders or NPDES permits 3. Infrastructure investment that comply with local, state or federal regulatory requirements 1. Infrastructure investment that are consistent with policies and guidelines 0. No impact on regulatory compliance
Support Local Economy	Ability of an infrastructure investment to maintain business continuity and support economic development.	• MassGIS land use data • Data from Office of Economic Development • DPW&P institutional knowledge	• Proximity to commercial land use • Relation of infrastructure investment to projected economic development	• Qualitative estimate of infrastructure investment impact on reliability and continuity of existing services or economic development infrastructure investments • Impact on areas of proposed development and redevelopment	5. Infrastructure investment that improves reliability of service for residential, commercial or industrial users 4. Infrastructure investment that expands service for planned residential, commercial or industrial users 0. No direct impact on economic development, business continuity, or property values

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6.5 Evaluation Results

The benefits model calculates the total benefits score for each infrastructure investment by adding the scores for each criterion. **Chapter 5** presented three categories of investments to address key needs in performance: Capital Reinvestment, New Capital Investment, and Study and Assessment. A fourth category focuses on Upper Blackstone Facility Asset Investment, which is excluded from the benefits model. Each investment category is scored separately. **Figures 6.2** through **6.4** show the results of the benefits model for each approach, with investments presented in order of the highest total benefits score. The total benefits score is represented as a composite bar-chart indicating an aggregate of each criterion.

Prioritizing multi-benefit infrastructure investments maximizes the efficiency of the City's capital spending.

Figure 6.2 summarizes the rankings of Capital Reinvestment projects. All capital reinvestments received a score in at least eight of the ten benefits criteria, indicating that these investments have a well-rounded scope and provide multiple benefits to the City.

The highest-rated infrastructure investments in this category are programs for annual rehabilitation or replacement, reduction of infiltration and inflow, interceptor inspection and cleaning. These programs directly address many priorities identified by the City. Some of the key benefits include increasing reliability of the collection systems, protecting recreational water quality and the environment, and reducing reactive maintenance, while benefiting Environmental Justice communities.

Middle ranking capital reinvestments focus on sewer rehabilitation and infiltration and inflow removal. These programs rank lower because they do not have any reduced flooding benefits and because their geographic areas tend to be smaller than areas of high-ranking infrastructure investments.

Lower ranking infrastructure investments, such as the Hemlock Pump Station Rehabilitation, Brosnihan Square Siphon Cleaning, or Canton Street Overflow Collector Rehabilitation and Inflow and Infiltration Removal, address most of the 10 of the criteria. However, the overall benefits are lower due to the limited geographical areas and resulting benefits. Consequently, these infrastructure investments received lower scores for certain benefits criteria such as basement backup reduction, recreational water quality, and flood reduction.

Figure 6.3 summarizes the rankings of New Capital Investments. The benefits model results indicate some infrastructure investments from this category provide multiple benefits in achieving the goals of the plan, while others provide limited to no benefits.

The top new capital infrastructure investment, Green Island Flooding Relief Conduit, has the highest overall score out of all the infrastructure investments of this plan. This investment would provide a new pipeline route to convey flow from the Quinsigamond Avenue CSO Treatment Facility that will significantly reduce capacity-related flooding and combined sewer overflows in the Green Island area. The Hamill Route Relief Interceptor Construction has similar flooding and sanitary sewer overflows reduction benefits.

Middle-ranking infrastructure investments in this category include additional stormwater improvements and offer benefits in just a few of the criteria.

Lower ranking infrastructure investments, such as the Indian Lake Phosphorus Reduction, High Flow Reduction and Management or Additional Stormwater Sampling/Monitoring projects, have both limited and localized benefits.

Figure 6.4 summarizes the investments recommended for Study and Assessment that are important to address data gaps related to system performance. These investments are different from those in the other two approaches.

The top two Studies and Assessments — the Drainage System Master Plan and Annual Pipeline Inspection Program — are both program-type investments that allow a better understanding of the conditions and performance of existing systems. These programs identify deficiencies and provide additional data to develop investments. The future impacts of these programs may change the priorities of this Integrated Plan and may be incorporated into future versions of the plan through the adaptive management approach described in **Chapter 10**.

Appendix 6.1 includes a sensitivity analysis, which demonstrates the impacts of changing the influence of criteria. This sensitivity analysis reveals that the top 20 ranked projects consistently achieve the highest total benefits scores. This confirms that using an equal influence approach is appropriate for the benefits model and for this Integrated Plan.

6.6 Conclusion

The results of the multi-criteria benefits model identify the infrastructure investments to be considered in this Integrated Plan. These results provide an initial priority based on greatest potential benefits and are combined with the Financial Capability Assessment, outlined in **Chapter 7**.

FIGURE 6.2: RANKED CAPITAL REINVESTMENTS

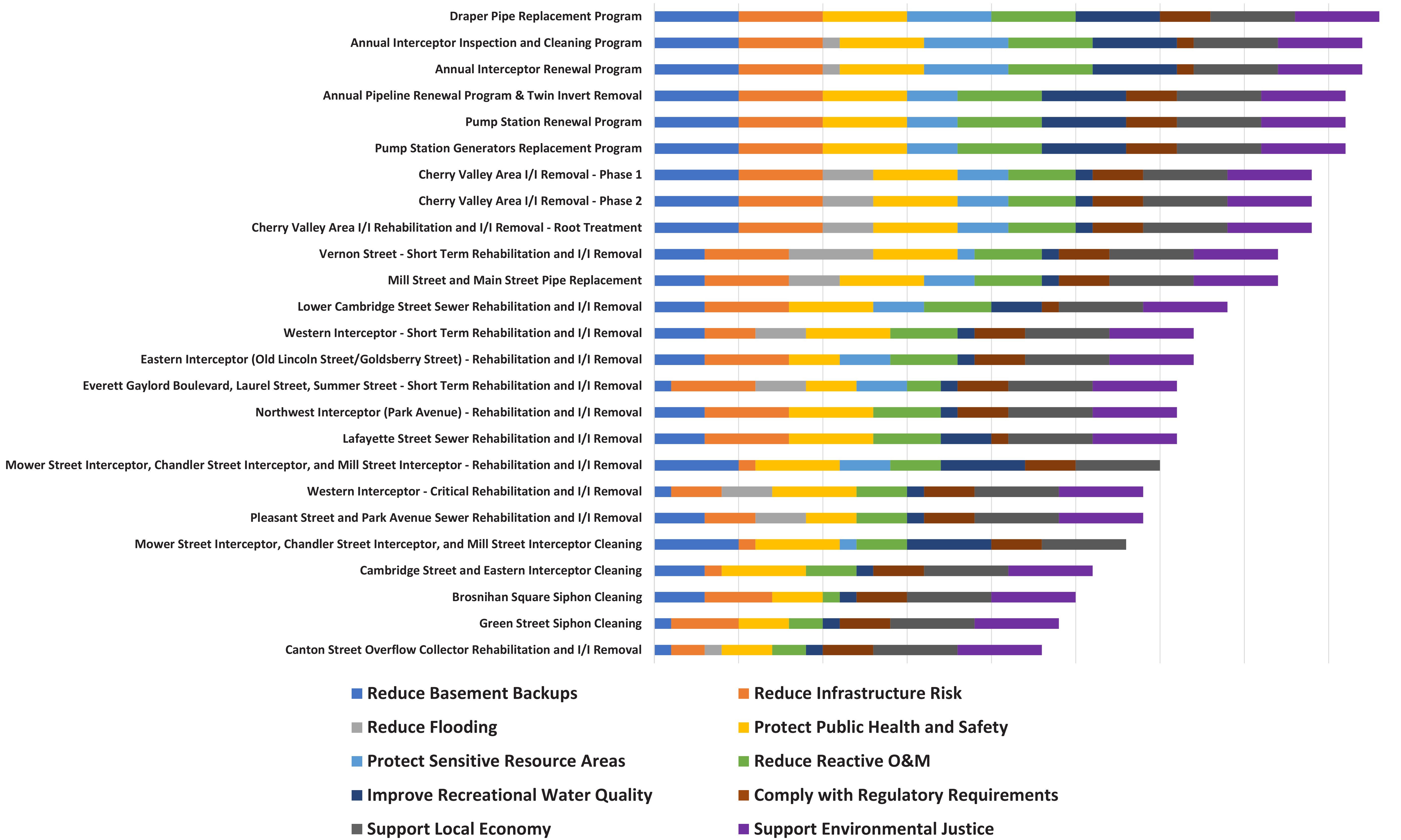


FIGURE 6.3: RANKED NEW CAPITAL INVESTMENTS

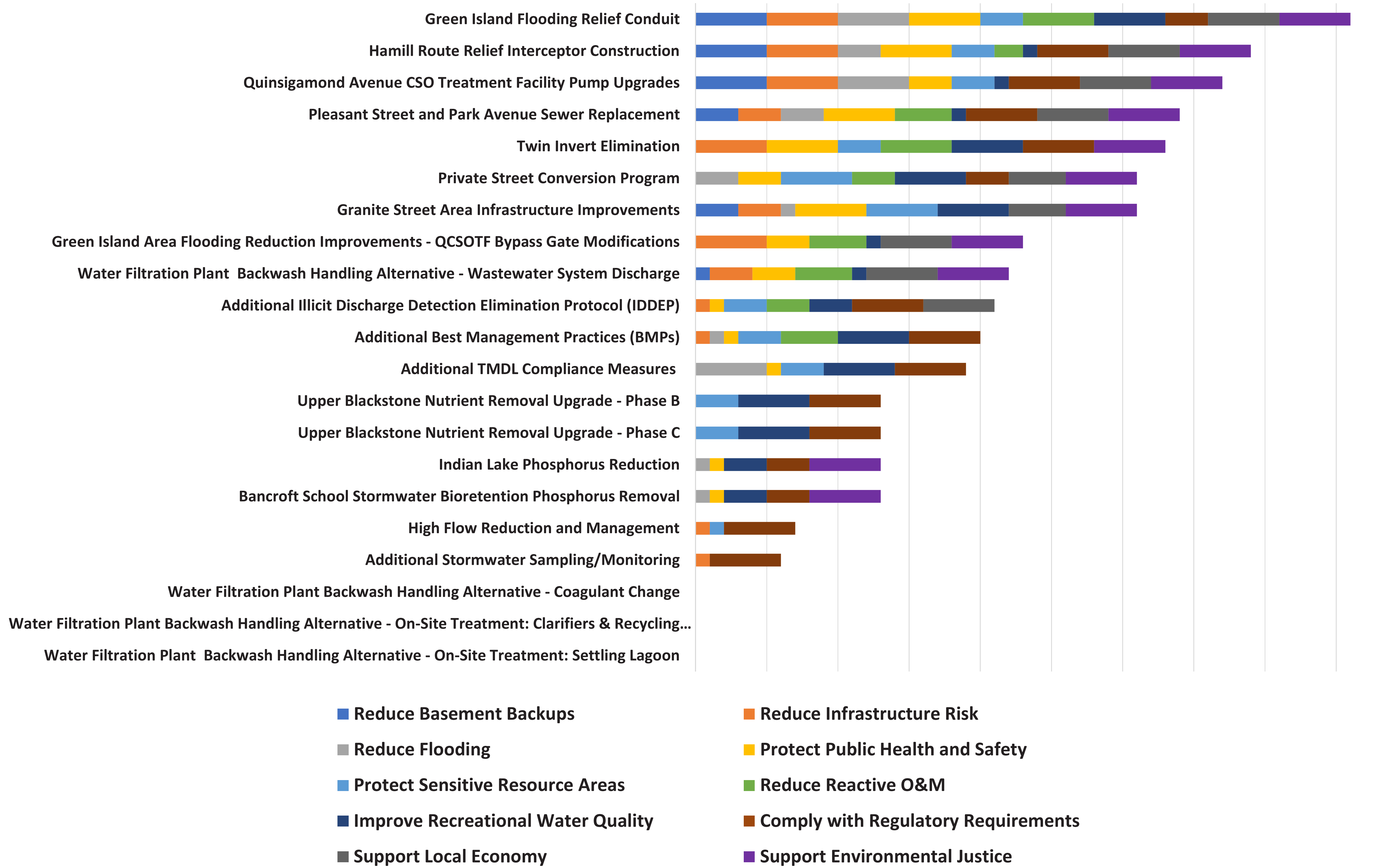
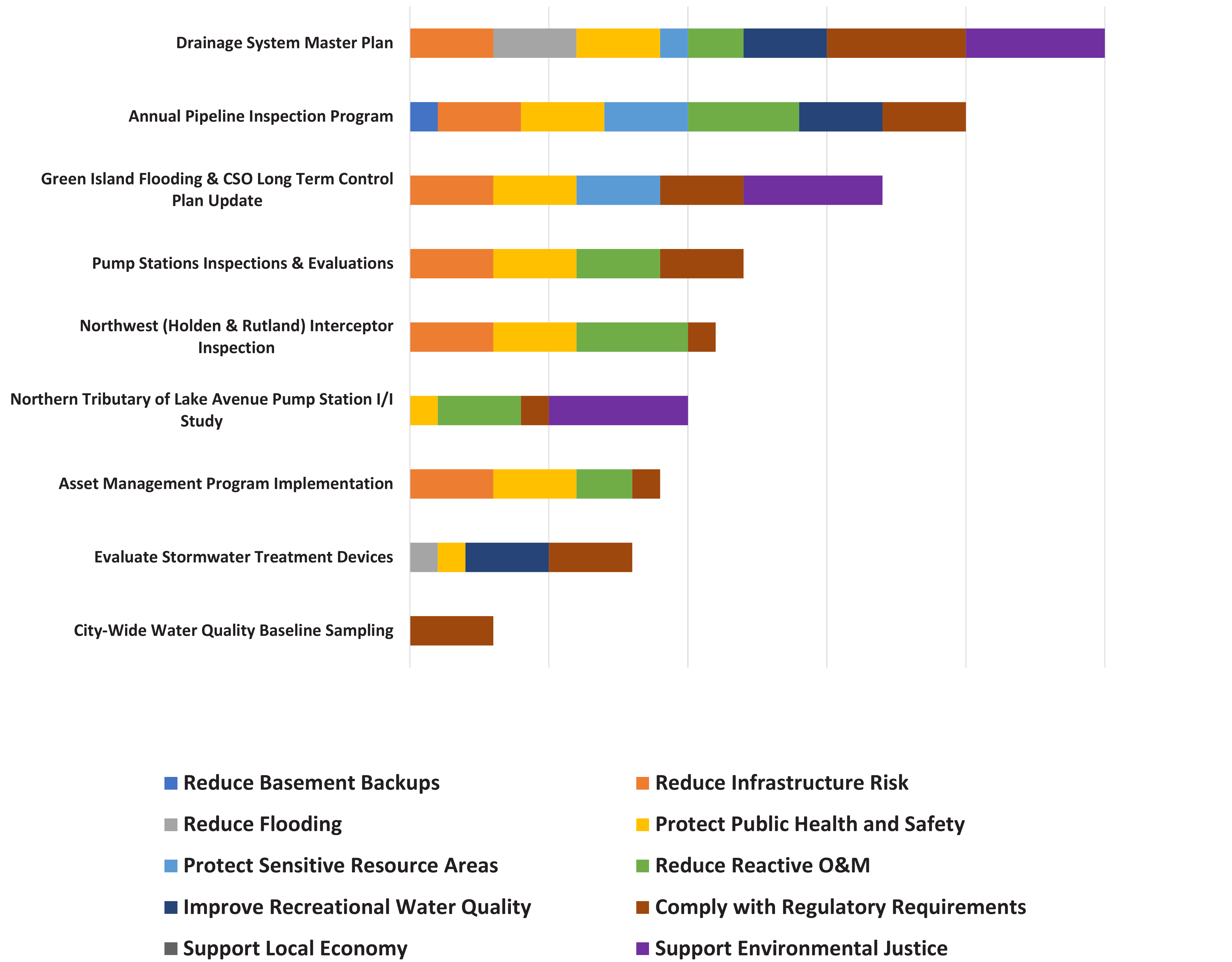


FIGURE 6.4: RANKED STUDY AND ASSESSMENTS



CHAPTER 7.
Financial Capability Assessment

7.1 Overview

This chapter provides an assessment of Worcester's financial capability to operate, maintain, and improve its water resources systems in order to comply with regulatory requirements and ensure long-term, quality service to residents and businesses.

This assessment follows the financial capability assessment framework issued by EPA on November 24, 2014, included as **Appendix 1.2**. This assessment is also consistent with recommendations from the October 2017 report by the National Academy of Public Administration, titled "Developing a New Framework for Community Affordability of Clean Water Services," included as **Appendix 1.1**. Both of these documents indicate the importance of providing for flexibility in such an analysis and allowing communities to put their particular needs into a local context.

The October 2017 report issued by the National Academy of Public Administration states that the challenge of assuring clean, affordable water services for all Americans has gained increasing attention in recent years for the following reasons:

- Aging water infrastructure in the United States will require maintenance, upgrades, and replacements at costs projected to surpass $1 trillion in the next 25 years. These investments could triple the cost of household water bills (based on reporting from American Water Works Association).
- Affordability is an increasingly critical issue, particularly for low-income customers who are far more vulnerable to increased water costs. This greater vulnerability reflects both the greater share of income that low-income users devote to paying for water services and the limited resources they have to respond to water rate increases. These water affordability issues have intensified over the last 15 years as water costs have risen more quickly than the Consumer Price Index and the costs of other utilities except electricity, while lower income populations have experienced slower income growth.

Due to these high costs and affordability concerns, the City's view is that the EPA's protocol for assessing affordability is too limited. It fails to account for real costs a community and its ratepayers face, particularly in areas with poor socioeconomic conditions, by inadequately considering the burden that rate increases will have on low income residents.

EPA sought to improve on its February 1997 guidance for measuring affordability entitled "Guidance for Financial Capability Assessment and Schedule Development" with its 2014 financial framework. Those improvements, however, were not enough. Due to concerns over high costs and stakeholder input on the need for improvements, the Senate Appropriations Committee directed EPA to contract with the National Academy of Public Administration to review EPA's approach to evaluating community affordability. The National Academy of Public Administration's October 2017 report lists the following deficiencies with EPA's financial framework:

- While the EPA's 2014 financial framework reaffirms flexibility and willingness to consider additional data to assess the level of burden imposed on permittees, it still retained the original 1997 guidance metrics.
- The metrics used in the 1997 guidance were inadequate for assessing low-income ratepayers' ability to pay and the financial conditions of the utility providing wastewater services.
- Many stakeholders perceive that, in certain regions, EPA regional staff, state regulators, and enforcement staff still rely almost exclusively on the 2% of median household income standard for assessing a permittee's level of burden.
- There is no documented rationale for the 2% of median household income standard and there have been significant changes in the past 20 years since it was published in the EPA's 1997 guidance.

The National Academy of Public Administration's report notes that "communities are struggling to comply with [Clean Water Act] and [Safe Drinking Water Act] requirements while confronting not only the ongoing tension between providing clean and affordable water, but also a number of other financial challenges."

In Worcester, these other financial challenges include socioeconomic conditions, tax burden, and the demands on the City's overall budget. These conditions, plus the City's backlog of water resource needs, present an immediate financial burden on Worcester's citizens.

As a result, the financial capability assessment provided in this Integrated Plan incorporates these improvements for determining affordability. These include the following:

- Include all drinking water, wastewater and stormwater costs that affect ratepayers.
- Focus on low-income users most affected by rate increases instead of median household income for the entire community.
- Identify the proportion of lowest income users relative to the total ratepayer base.
- Focus on the operational efficiency of the community's clean water utilities.
- Expand socioeconomic components to consider the community's market conditions, poverty rates, relative wealth and economic growth.

A detailed financial analysis and affordability assessment was prepared to support this financial capability assessment. This financial analysis is summarized in a memorandum titled 2019 Financial Analysis and Enhanced Affordability Assessment for City of Worcester Integrated Plan (2019 Affordability Analysis), attached in **Appendix 7.1**. This report illustrates the results of evaluating affordability over time for different levels of spending using a financial model to calculate sewer rate projections for the Sewer Enterprise Fund over a 10-year period. In addition, scenarios were analyzed for their anticipated financial impact for an additional 10 years in order to demonstrate the potential long-term financial effects of the plan. The 2019 Affordability Analysis relies on various sources of City financial data, including the Comprehensive Annual Financial Report (for the year ended June 30, 2018), which is attached in **Appendix 7.2**.

In addition to the 2019 Affordability Analysis, the following analysis also recognizes the projected water rate increases needed for the Water Enterprise Fund to continue operations and complete the capital improvement program for the drinking water system.

The financial capability assessment in this chapter is presented in two phases:

Phase 1 — the Affordability Analysis — illustrates and evaluates the anticipated cost of water resources system improvements to Worcester ratepayers. Phase 1 begins with current socioeconomic factors that are relevant to this analysis. The cost of various potential system improvements is then placed in the context of Worcester residents' ability to pay for those improvements.

Phase 2 — the Financial Strength Analysis — illustrates Worcester's financial strength using a variety of indicators of the City's ability to support additional operational and capital expenses in support of water resources systems.

7.2 Phase 1: Affordability Analysis

Residents and businesses of Worcester bear the costs of the drinking water, wastewater, and stormwater systems through the payment of water and sewer rates. Set annually, these rates are billed quarterly or monthly and generate the revenue that supports the Water and Sewer Enterprise Funds charged with the operation, maintenance, and long-term improvement of the City's water resources systems.

7.2.1 Affordability Analysis Introduction

The affordability analysis that follows is based on a review of the anticipated sewer rates in comparison to a weighted average of median household income. In order to put that analysis in the proper context, an overview of relevant socioeconomic factors follows.

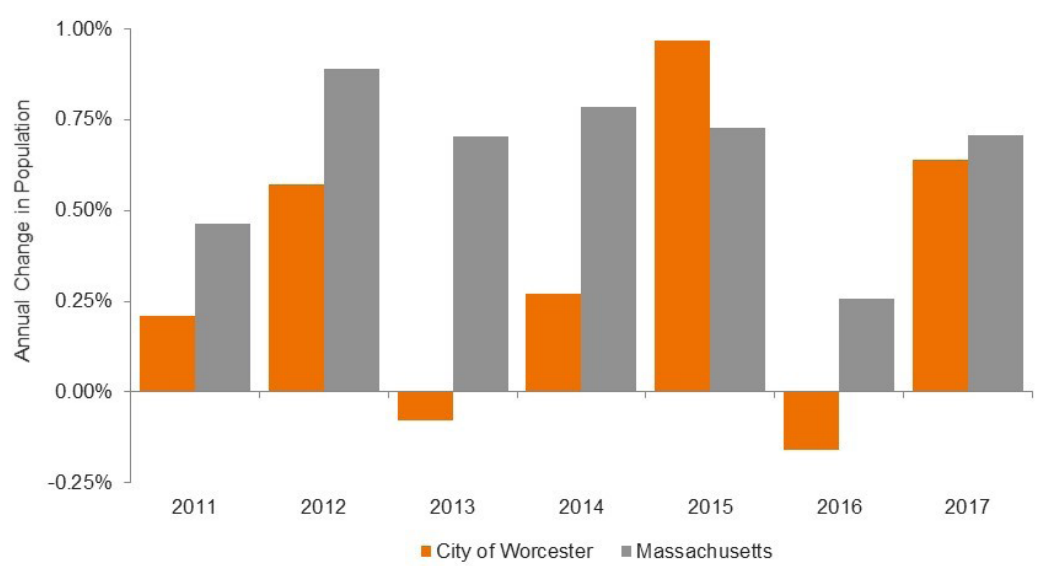
7.2.2 Affordability Analysis Part 1 — Socioeconomic Factors in the City of Worcester

To correctly evaluate the financial capability of the City to undertake system operations and infrastructure investments of this Integrated Plan, it is critical to understand the socioeconomic setting of the community. **Appendix 7.1** provides a detailed breakdown of a number of critical socioeconomic factors.

Key findings from the update are summarized in the following graphs (**Figures 7.1** through **7.6**).

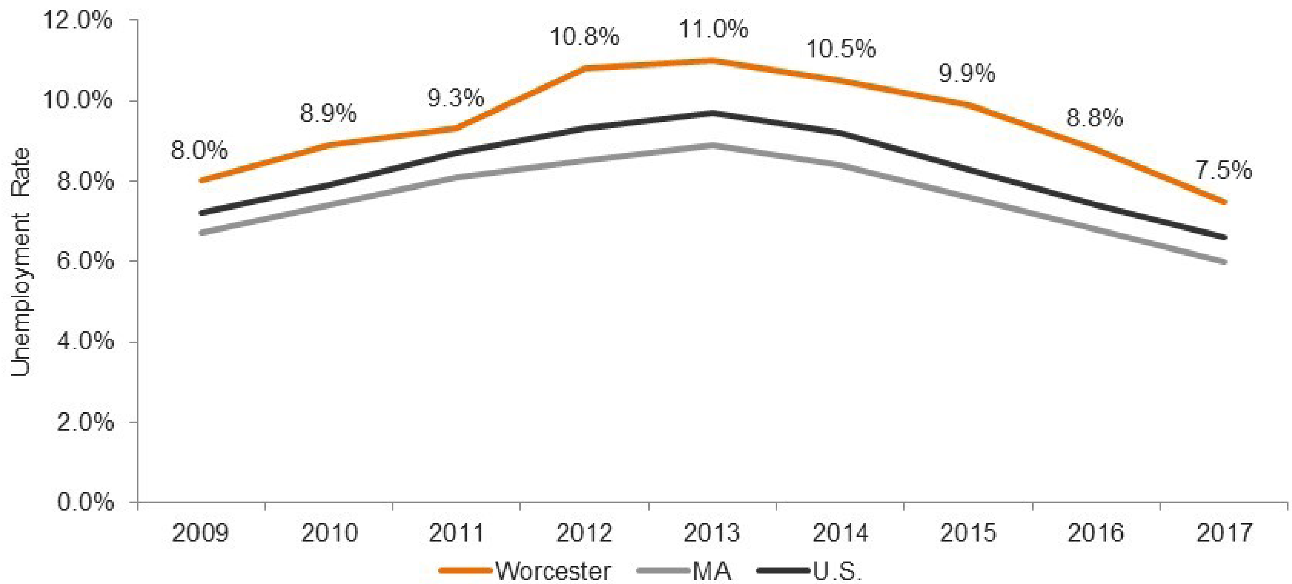
Worcester's population growth has lagged that of the state of Massachusetts in every year from 2011 to 2017, except 2015.

FIGURE 7.1: ANNUAL CHANGE IN POPULATION IN THE CITY OF WORCESTER AND STATE OF MASSACHUSETTS (2011-2017)



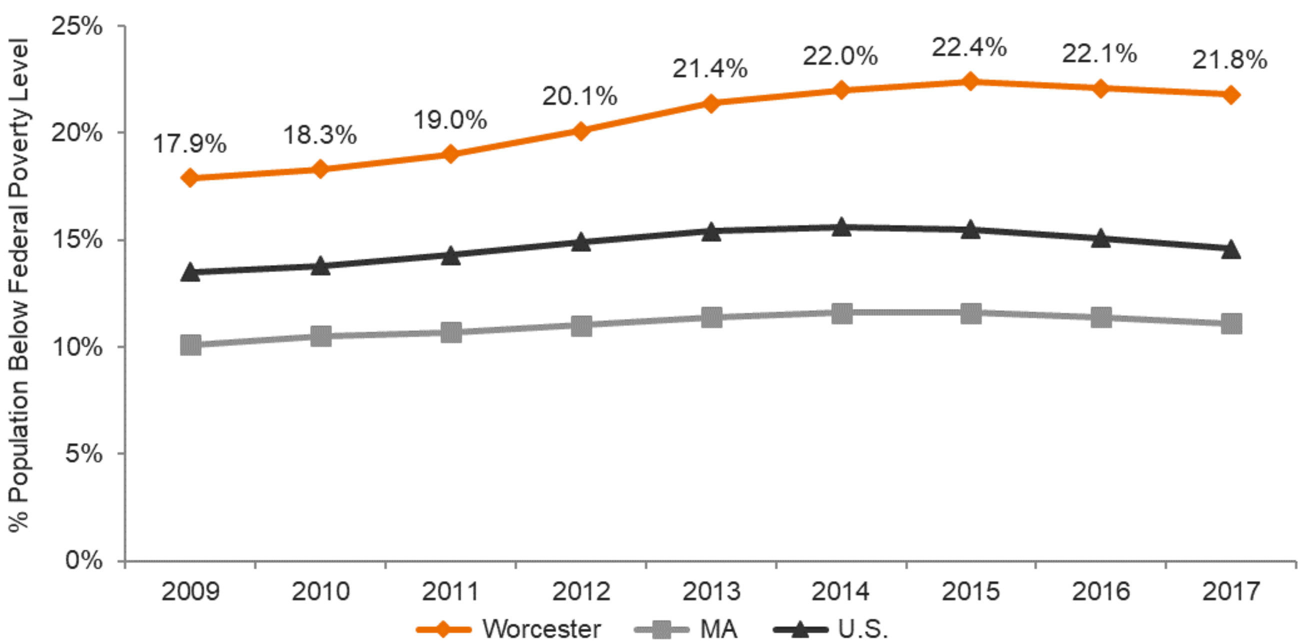
Over the last nine years, the unemployment rate in Worcester has ranged from 7.5% to 11.0% at its peak in 2013 and has exceeded the state's rate by an average of 1.5%.

FIGURE 7.2: UNEMPLOYMENT RATES IN THE CITY OF WORCESTER, STATE OF MASSACHUSETTS, AND U.S. (2009-2017)



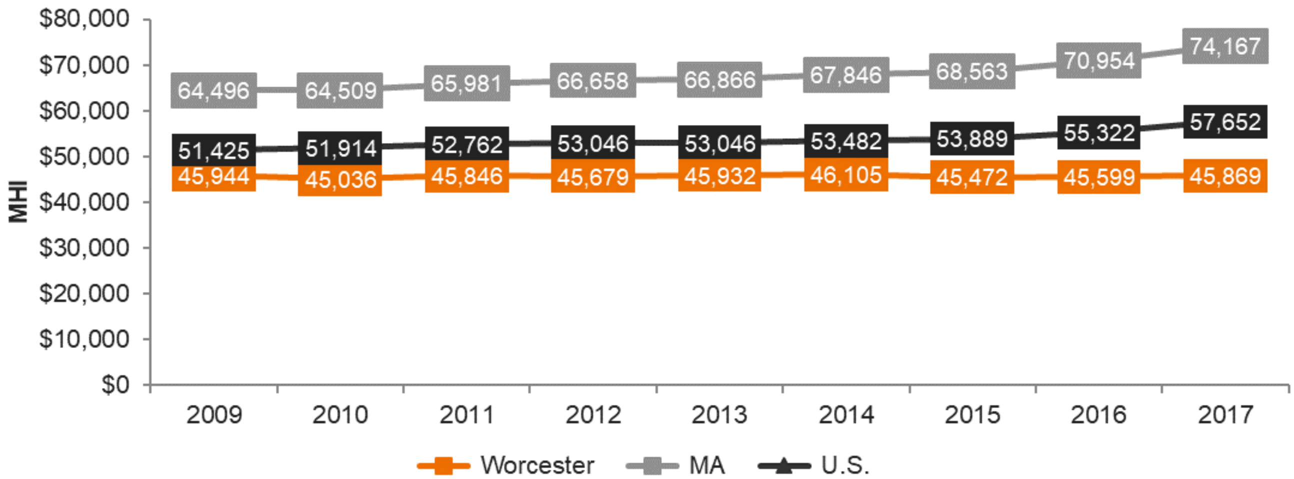
Between 2009 and 2017, poverty rates in Worcester increased from a low of 17.9% in 2009 to 21.8% in 2017. Overall, the poverty rate in Worcester has been, and continues to be, significantly higher than poverty rates in Massachusetts and the United States.

FIGURE 7.3: POVERTY RATES IN THE CITY OF WORCESTER, STATE OF MASSACHUSETTS, AND U.S. (2009-2017)



In 2017, the median household income in Worcester was $45,869 according to the American Community Survey 5-year estimate, more than $25,000 below the state median household income of $74,167. Income per-capita has consistently ranked at or near the 10th percentile among Massachusetts municipalities since 2010. Massachusetts Department of Revenue's latest data are from 2015. Worcester's per-capita income of $20,978 ranked 315 out of 351 municipalities.

FIGURE 7.4: MEDIAN HOUSEHOLD INCOME IN THE CITY OF WORCESTER, STATE OF MASSACHUSETTS, AND U.S. (2009-2017)



Worcester's income distribution shows a greater proportion of households at the low-income levels and fewer households at the higher income levels when compared to the state and the country as a whole.

FIGURE 7.5: INCOME DISTRIBUTION FOR THE CITY OF WORCESTER, STATE OF MASSACHUSETTS, AND U.S. (2017)

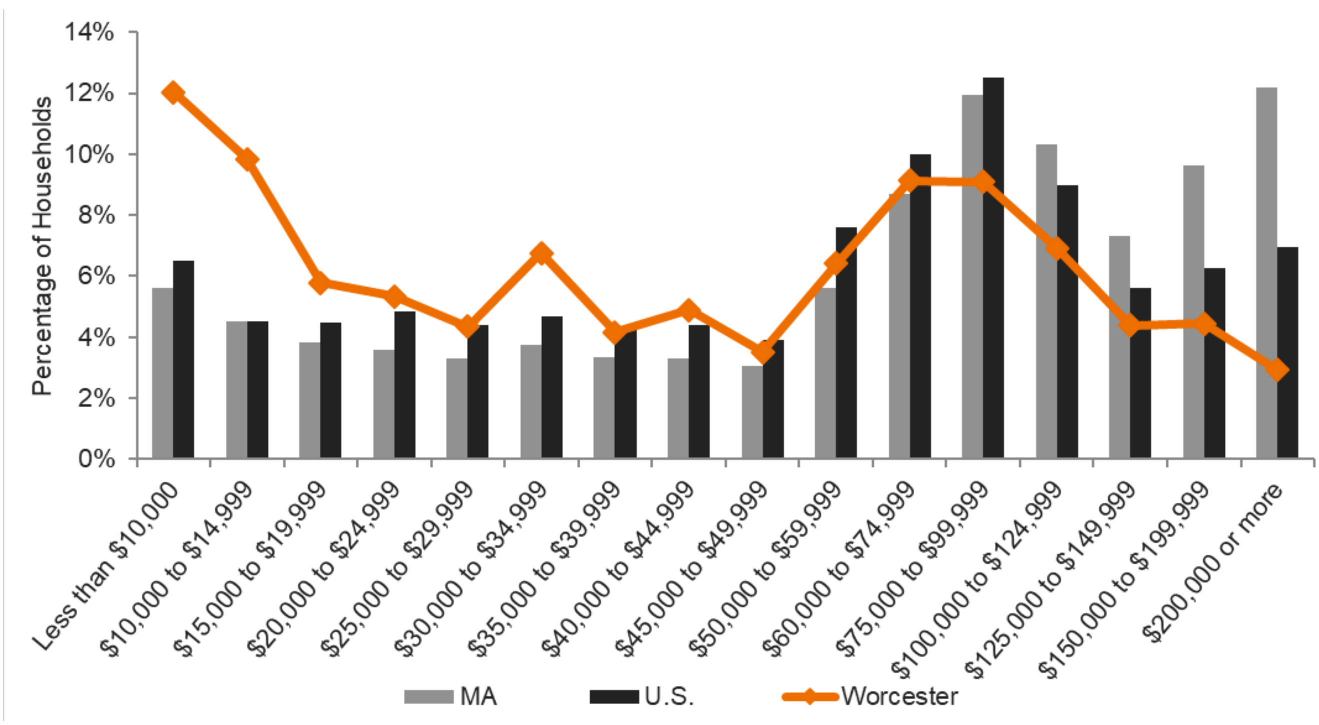
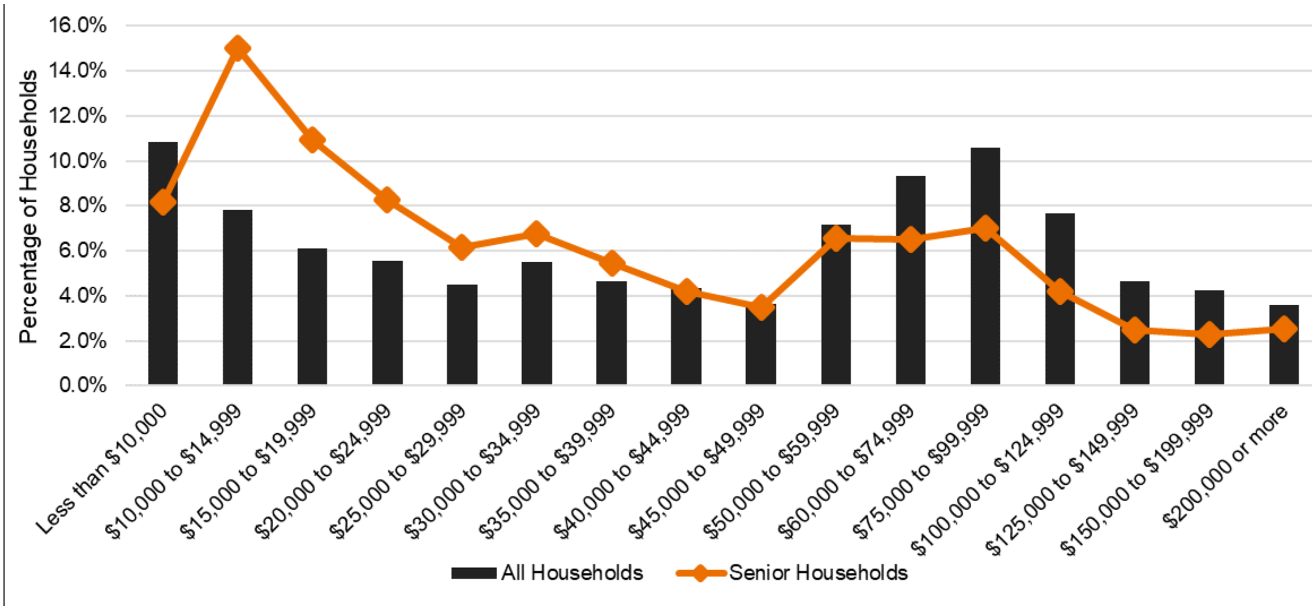


FIGURE 7.6: CITY OF WORCESTER INCOME DISTRIBUTION FOR SENIOR HOUSEHOLDS (2017)



Senior households in Worcester account for 21% of all households. Out of senior households in Worcester, 48.5% have income lower than $30,000 a year. The City's median cost of rent, at $1,015 per month, is only 13% below the state median of $1,173 per month. Note above that Worcester incomes were 35% below the state average. As a result, approximately 44.7% of renters in the City spend over 35% of their income on rent compared to approximately 40% of renters statewide, indicating that a high proportion of renters are spending more than a third of income on housing.

Environmental Justice Communities in Worcester

In addition to a comparatively low-income population, Worcester is home to a large population that falls under the categories defined as Environmental Justice communities by Massachusetts and the EPA. **Figure 7.7** illustrates the diversity and concentration of various Environmental Justice communities in the City. Environmental Justice communities are those whose median income is less than 65% of the statewide median, or where 25% or more of the residents identify as non-white, or where 25% or more of households have no one over the age of 14 who speaks English only or very well (English isolation) (*https://www.mass.gov/info-details/environmental-justice-communities-in-massachusetts#what-is-an-environmental-justice-community?-*).

Figure 7.7 shows that most of the population of Worcester falls into at least one Environmental Justice category. Much of the downtown core—both the most populous and most prone to flooding—fall into all three categories of Environmental Justice. In total, over 70% of Worcester's population resides in an Environmental Justice community.

(*https://www.mass.gov/files/documents/2016/07/ul/Environmental Justice-2010-communitystatistics.pdf*).

This high percentage and concentration of Environmental Justice communities sets Worcester apart from the rest of the towns in Central Massachusetts as shown in **Figure 7.8** (*http://maps.massgis.state.ma.us/map_ol/Environmental Justice.php*).

Worcester's socioeconomic characteristics demonstrate limitations to its overall financial capability due to the limited ability of residents to absorb rate increases. With its economic challenges, high poverty rates, low median household income, and high concentration of Environmental Justice communities, it is essential that the socioeconomic setting be considered when evaluating financial capability.

FIGURE 7.7: 2010 ENVIRONMENTAL JUSTICE POPULATIONS

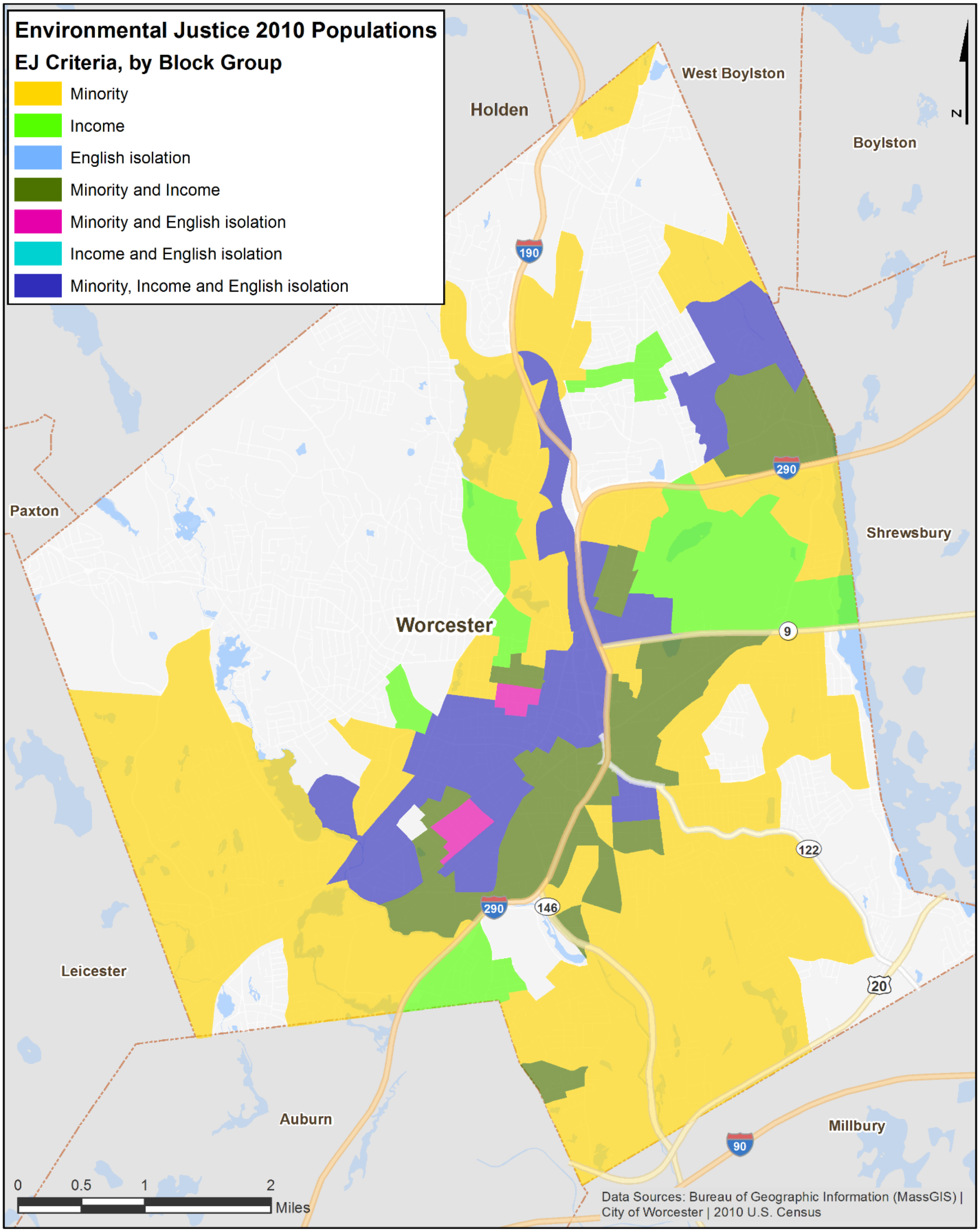
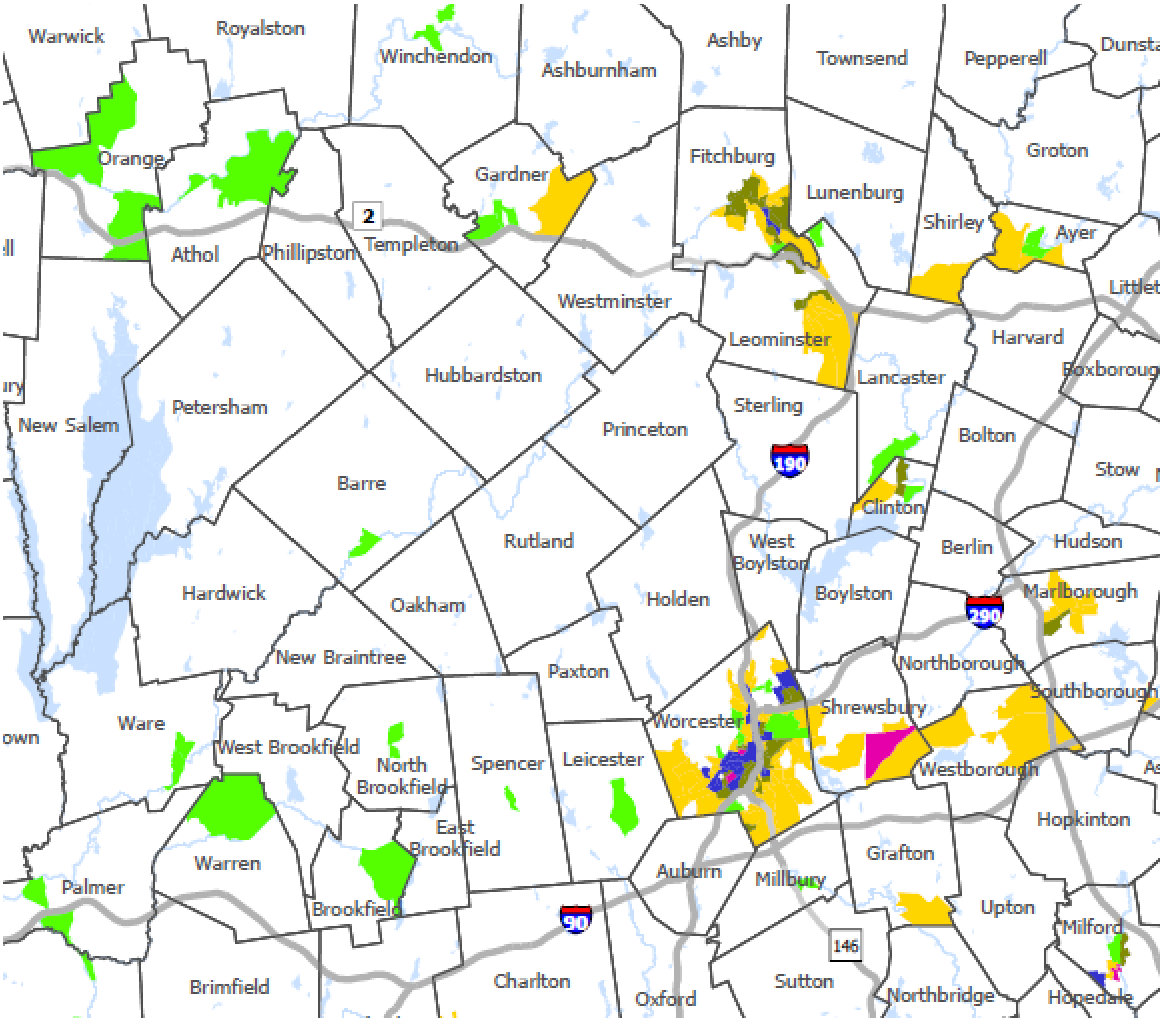


FIGURE 7.8: 2010 ENVIRONMENTAL JUSTICE POPULATIONS, CENTRAL REGION



7.2.3 Affordability Analysis Part 2 — Combined Burden or Water, Sewer, and Property Taxes

Worcester residents' ability to support water resources system improvements is shaped by the complete financial burden borne by the community, including the combination of water, sewer, and property tax bills. The following illustrates the recent history and current state of these three critical components of residents' ability to pay.

Figure 7.9 illustrates the history of Worcester water rates, climbing from below $2.00 per centum cubic feet (CCF) in fiscal year (FY) 2001 to $3.67 in FY 2019, an increase of 87%. If water rates had increased with inflation during this period, the rate in FY 2019 would have been $2.89 per CCF.

Figure 7.10 illustrates the history of sewer rates since FY 2000. During this time, the sewer rate has climbed 353%, from $1.64 to $7.43 per CCF in FY 2019. Had the sewer rates increased with inflation, the rate in FY 2019 would be approximately $2.50 per CCF. The actual rate has increased at more than twice the inflation rate during this period. As shown in the chart, the majority of the rate increases have been due to the cost of improvements at the Upper Blackstone Treatment Facility.

In addition to these sewer rate increases, residents and businesses faced consistent increases in the property tax levy. **Figure 7.11** illustrates the history of the property tax increases since FY 2008. During this time, property taxes have increased $122 million, or 66%. The chart illustrates the total tax levy in each fiscal year as well as the percent increase in the total levy each year.

FIGURE 7.9: WATER RATES, FISCAL YEAR 2001-2019

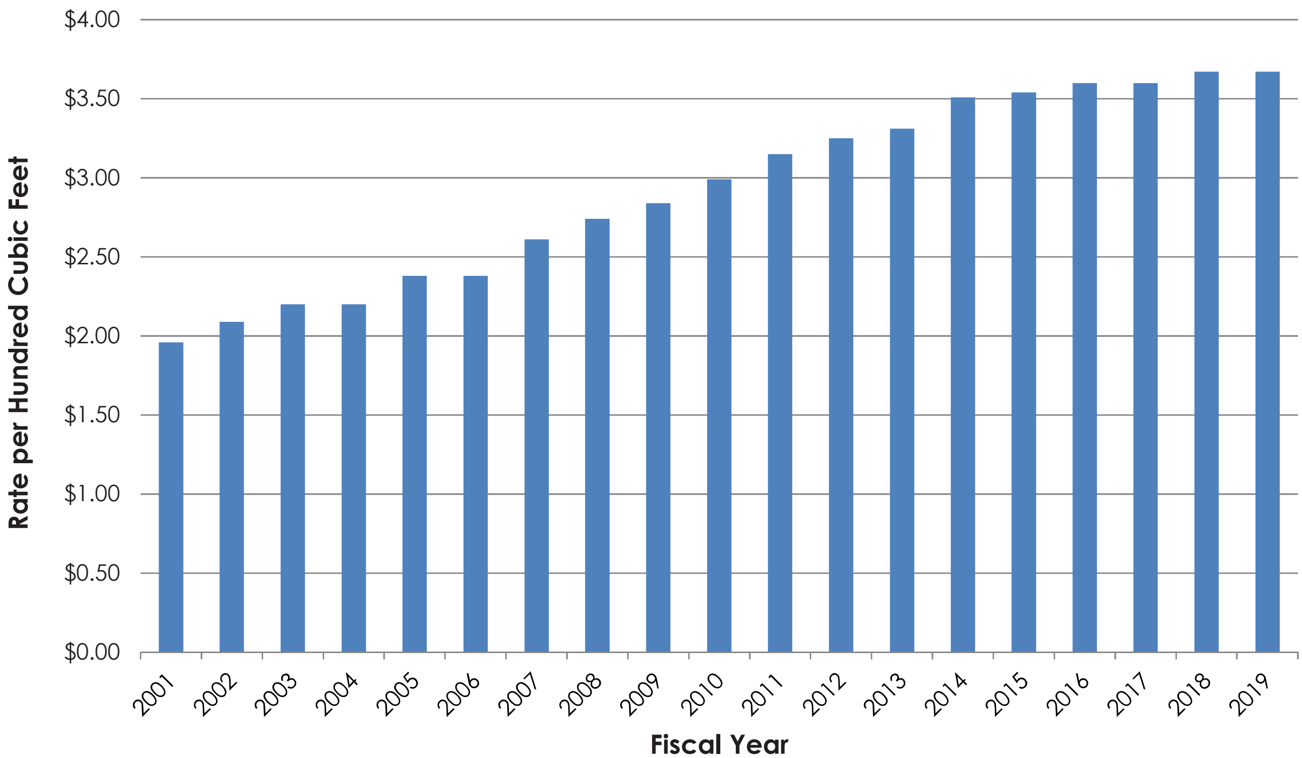


FIGURE 7.10: SEWER RATES, FISCAL YEAR 2000-2019

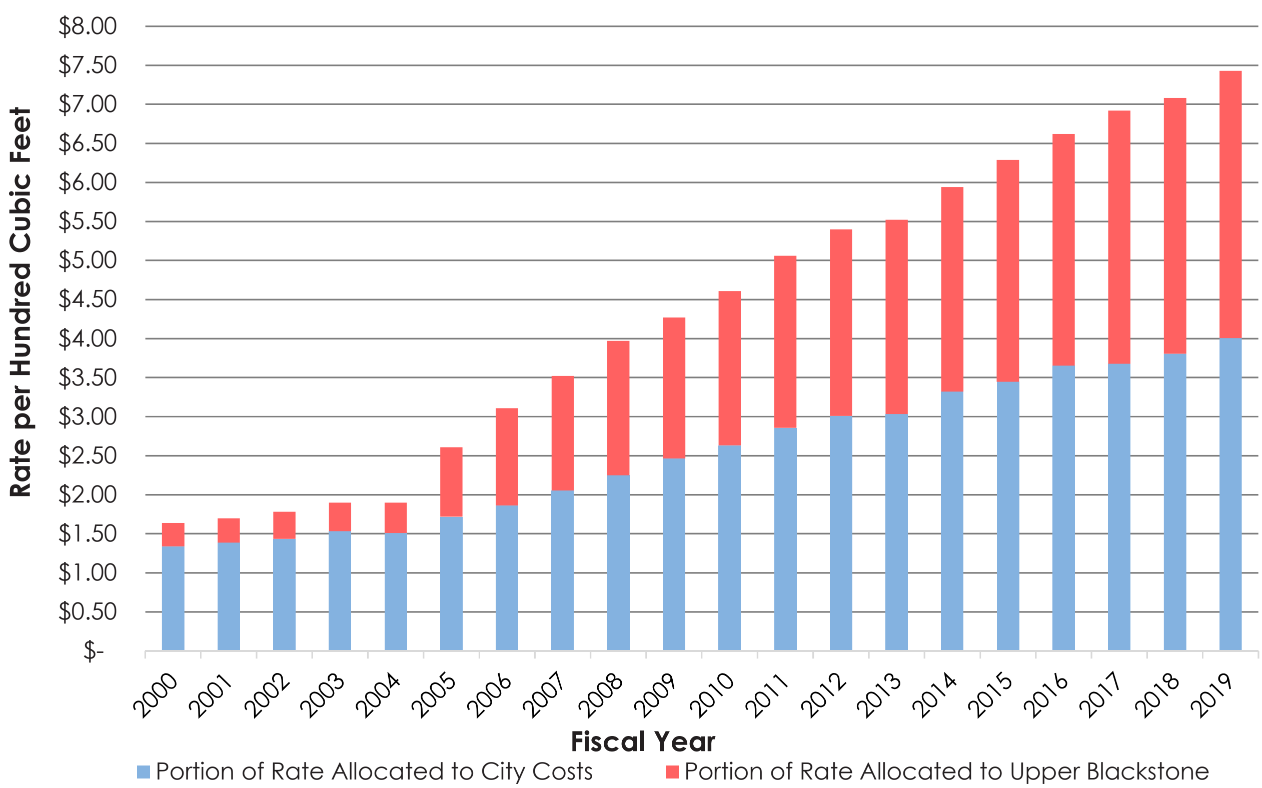
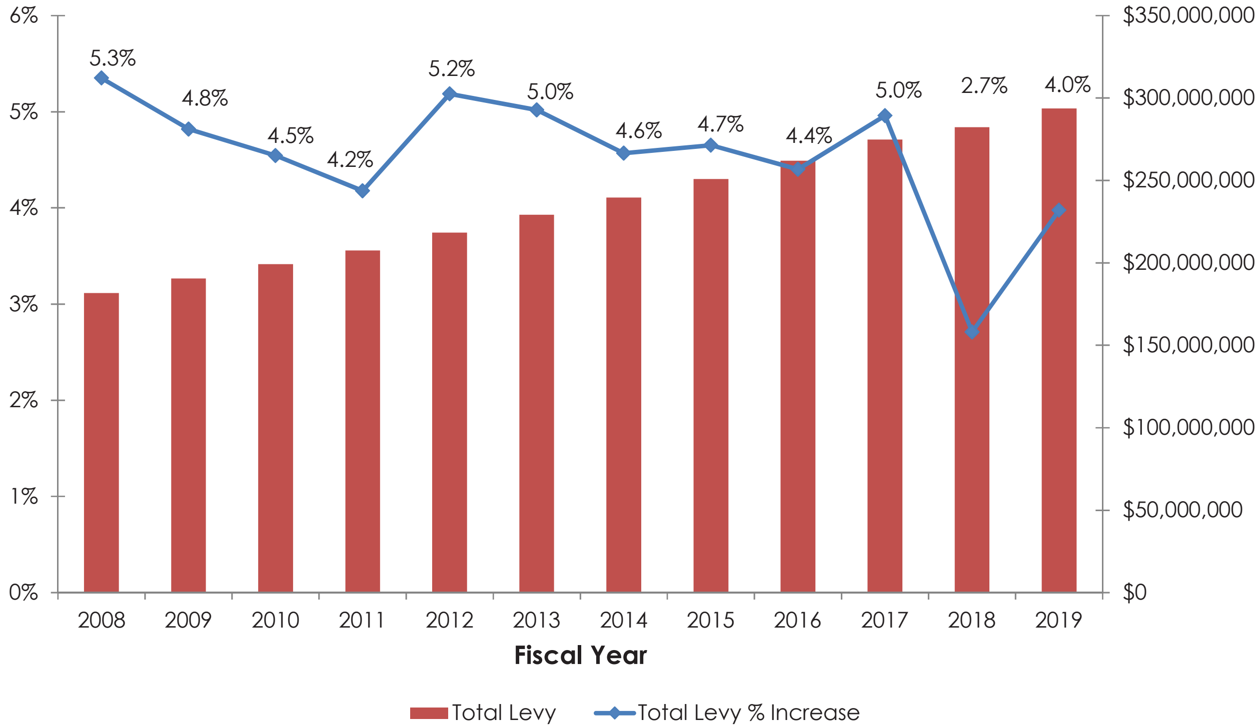
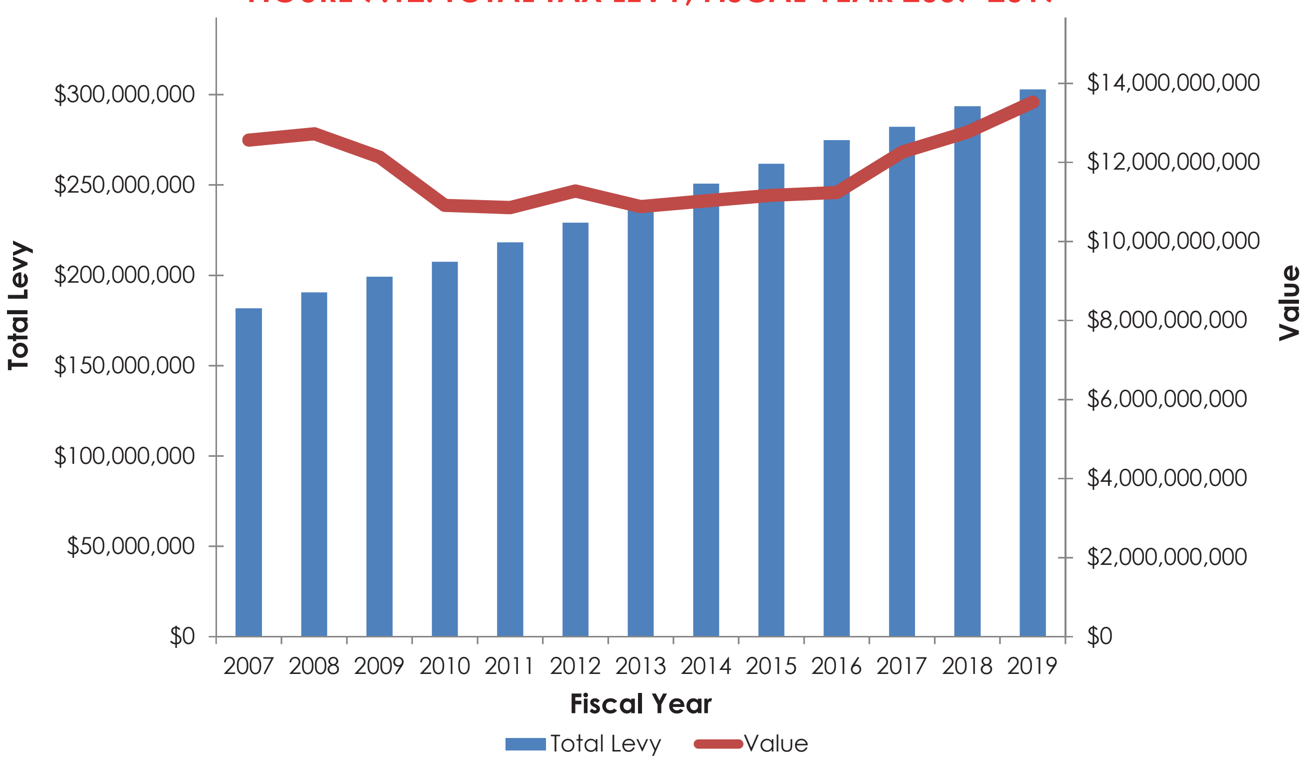


FIGURE 7.11: TAX LEVY INCREASES, FISCAL YEAR 2008-2019



It should be noted that these tax increases took place even as property values declined during the 2008 recession. **Figure 7.12** illustrates how despite reductions to overall property value in certain years between FY 2007 and FY 2019, the tax levy burden increased each year.

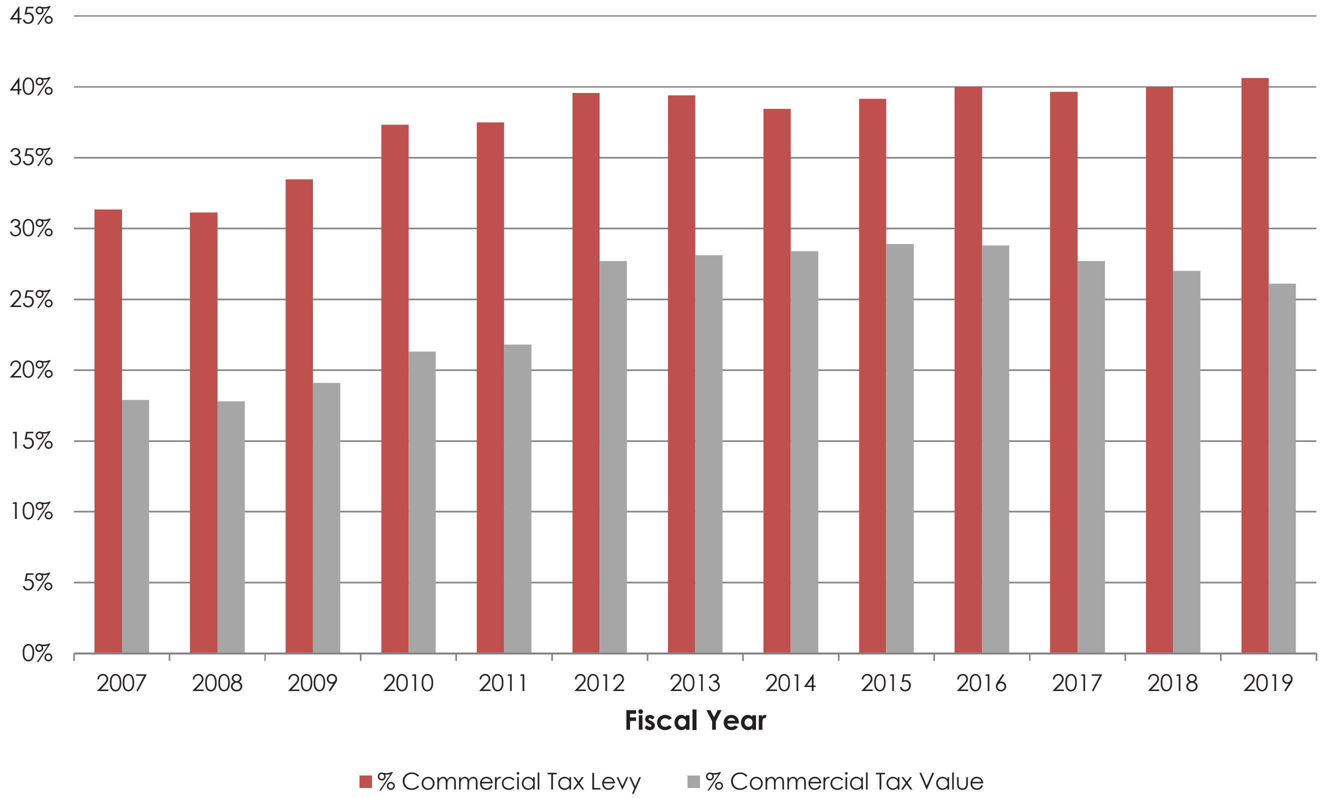
FIGURE 7.12: TOTAL TAX LEVY, FISCAL YEAR 2007-2019



Worcester's tax rate is structured to place added burden on commercial and industrial properties by shifting a percentage of the annual tax levy away from residential customers and onto businesses. This results in a burden on commercial taxpayers and limits flexibility to increase other cost centers for businesses.

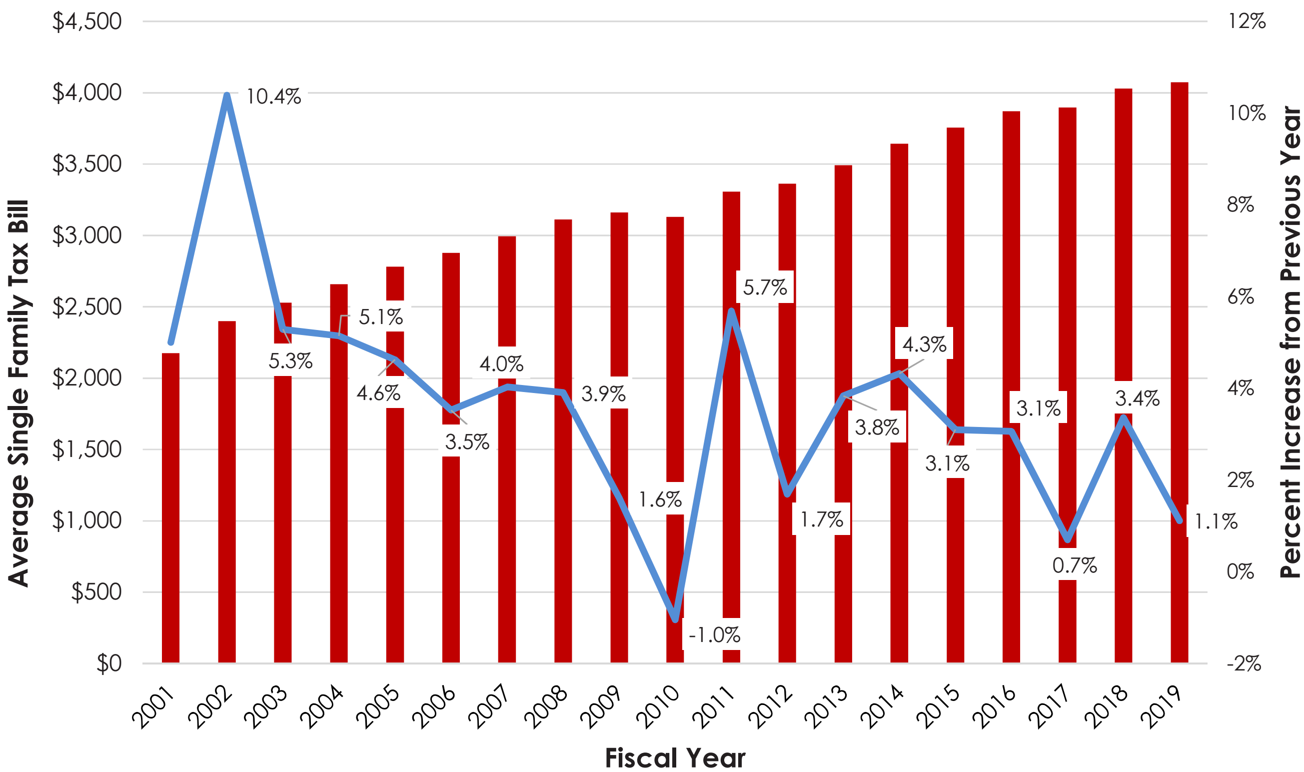
Figure 7.13 shows both the percentage of commercial property values in the City and the percentage of the total property taxes levied against commercial properties. The difference between the two bars in each year illustrates the shift of additional tax burden onto commercial properties.

FIGURE 7.13: COMMERCIAL PROPERTY PERCENT OF TAX VALUE VERSUS PERCENT OF TAX LEVY



Even with this commercial shift, residential taxpayers have seen increases in property taxes well beyond inflation since FY 2001. **Figure 7.14** shows the average single-family tax bill and the percentage increase in that bill in each fiscal year since FY 2001. In total, average single-family tax bills have increased 87% since FY 2001, over 4.5% per year.

FIGURE 7.14: AVERAGE SINGLE FAMILY TAX BILL, FISCAL YEAR 2001-2019



Socio-Economic Conclusion

The facts outlined above demonstrate a variety of ways in which residents face challenges in their ability to pay for future water resources system improvements. The combination of factors include income, property taxes, existing water and sewer rates, and other factors that result in 70% of the City being designated as Environmental Justice communities.

7.2.4 Affordability Impacts

The City's assessment of affordability uses an enhanced methodology to calculate a weighted average residential index to better understand financial impacts to residents. This analysis was prepared for six different wastewater and stormwater capital spending scenarios. The methodology is fully described in the "Affordability Impacts" section of **Appendix 7.1**. This memorandum includes thresholds calculated to assess financial impacts that are calibrated with EPA's guidance for consistency. This guidance defines households experiencing a high financial impact as those estimated to pay over 2% of their annual income toward sewer bills.

This affordability assessment uses the different alternative spending scenarios to evaluate the relative affordability to Worcester residents. The six scenarios contain the following different elements:

Scenario 1

- Continue current operations and extend current wastewater and stormwater capital spending levels into the future based on an average of current annual capital investments, totaling approximately $14.7 million per year.
- Include higher near-term rate increases on Upper Blackstone District treatment expenses assuming nitrogen and phosphorus reduction projects are not deferred and completed at the Upper Blackstone Treatment Facility by 2026.

Scenario 2

- Continue current operations and extend current sewer and stormwater capital spending levels into the future based on an average of current annual capital investments, totaling approximately $14.7 million per year.
- Include higher near-term rate increases on Upper Blackstone District treatment expenses assuming nitrogen and phosphorus reduction projects are not deferred and completed at the Upper Blackstone Treatment Facility by 2026.
- Complete over $800 million dollars in additional stormwater projects by 2038, which would need to be completed if the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit[1] becomes final.
- Include an additional $6 million per year in stormwater-related operation and maintenance expenses beginning in 2023.

Scenario 3

- Complete approximately $137 million in projects from 2021 to 2030 as per the Integrated Plan's recommended Wastewater and Stormwater Systems Capital Improvement Plan implementation schedule.
- Include higher near-term rate increases on Upper Blackstone Treatment Facility expenses assuming nitrogen and phosphorus reduction projects are not deferred and completed at the Upper Blackstone Treatment Facility by 2026.
- Complete over $800 million dollars in additional stormwater projects by 2038, which would need to be completed if the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit[2] becomes final.
- Include an additional $6 million per year in stormwater-related operations and maintenance expenses beginning in 2023.
- Invest an additional $13 million per year in pipe replacement to reduce the overall system age.
- Include an additional $3 million per year in pipe inspection costs in forecasted operating expenses.

Scenario 4

- Complete approximately $137 million in projects from 2021 to 2030 as per the Integrated Plan's recommended Wastewater and Stormwater Systems Capital Improvement Plan implementation schedule.
- Include lower near-term and higher long-term annual rate increases on Upper Blackstone District treatment expenses assuming nitrogen and phosphorus reduction projects at the Upper Blackstone Treatment Facility are deferred until after 2030.
- Complete over $800 million dollars in additional stormwater projects by 2038, which would need to be completed if the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit[3] becomes final.
- Include an additional $6 million per year in stormwater-related operations and maintenance expenses beginning in 2023.
- Invest an additional $13 million per year in pipe replacement to reduce the overall system age.
- Include an additional $3 million per year in pipe inspection costs in forecasted operating expenses.

Scenario 5

- Complete approximately $137 million in projects from 2021 to 2030 as per the Integrated Plan's recommended Wastewater and Stormwater Systems Capital Improvement Plan implementation schedule.
- Include lower near-term and higher long-term annual rate increases on Upper Blackstone District treatment expenses assuming nitrogen and phosphorus reduction projects at the Upper Blackstone Treatment Facility are deferred until after 2030.
- Include an additional $1 million per year in pipe inspection costs in forecasted operating expenses.

1 Stormwater Management Program Assessment Update, 2012, CDM Smith
2 Ibid.
3 Ibid.

Scenario 6

- Complete approximately $137 million in projects from 2021 to 2030 as per the Integrated Plan's recommended Wastewater and Stormwater Systems Capital Improvement Plan implementation schedule.
- Include lower near-term and higher long-term annual rate increases on Upper Blackstone District treatment expenses assuming nitrogen and phosphorus reduction projects at the Upper Blackstone Treatment Facility are deferred until after 2030.
- Complete over $800 million dollars in additional stormwater projects by 2038, which would need to be completed if the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit [4] becomes final.
- Include an additional $6 million per year in stormwater-related operations and maintenance expenses beginning in 2023.
- Include an additional $1 million per year in pipe inspection costs in forecasted operating expenses.

TABLE 7.1: PROJECTED SEWER RATE INCREASES

Scenario*	1	2	3	4	5	6
Average	**5.96%**	**11.00%**	**12.40%**	**11.50%**	**5.00%**	**10.10%**
2021	8.00%	14.00%	17.00%	14.00%	5.50%	11.00%
2022	8.00%	14.00%	17.00%	14.00%	5.50%	11.00%
2023	8.00%	14.00%	17.00%	14.00%	5.50%	13.00%
2024	8.00%	14.00%	16.00%	15.00%	5.50%	13.00%
2025	8.00%	13.00%	15.00%	14.00%	5.50%	11.00%
2026	7.00%	11.00%	11.00%	9.00%	4.50%	10.00%
2027	3.00%	8.00%	8.00%	9.00%	4.50%	8.50%
2028	3.30%	8.00%	8.00%	9.00%	4.50%	8.50%
2029	3.30%	7.00%	8.00%	9.00%	4.50%	7.50%
2030	3.00%	7.00%	7.00%	8.00%	4.50%	7.50%

* Refer to Section 7.2.4 for a description of the alternative scenarios and associated costs.

The projected sewer rate increases that result from each of these scenarios are presented in **Table 7.1**.

The City evaluated the impacts of each scenario's associated rate increases on affordability. The City also projected rate increases needed for its Water Enterprise Fund to continue operations and complete the capital improvement program for the drinking water system. This was done in accordance with the EPA's 2014 financial framework to consider information related to financial strength including "other costs or financial obligations, such as those that relate to drinking water or other infrastructure, that significantly affect a permittee's ability to raise revenue." The City therefore needs to consider anticipated increases in water rates since they contribute to financial burden. For most municipalities, including Worcester, water and sewer customers pay for their use of both systems through a single bill. Consequently, increases in either rate have a combined financial impact on these ratepayers.

As part of its financial plan, the City evaluated its Water Enterprise Fund to properly operate, maintain, and develop the infrastructure of the drinking water system in the same manner as described previously for the Sewer Enterprise Fund. Proper operation and maintenance of the City's drinking water system is vitally important to protecting public health and quality of life in Worcester. This Integrated Plan prioritizes long-term investments in its aging drinking water system in the same manner as investments in the City's wastewater and stormwater systems.

4 Ibid

Similar to the long-term financial planning projections for the Sewer Enterprise Fund, drinking water system operations and maintenance expenses were projected beyond the 10-year period discussed in this chapter. Benefits and pension-related expenses are expected to increase by 8% and 6.3% per year, respectively. Other expenses are expected to increase at the rate of inflation. Over the years FY 2021 through FY 2030, annual operations and maintenance expenses are expected to average $22 million. The City also adopted a financial target to achieve operating reserves equal to three months of operating expenses by 2030.

In addition to operating costs, the City expects to spend $13.2 million annually on average for its Drinking Water System Capital Improvement Plan based on the needs of the drinking water system. This updated capital plan was developed to support this financial capability assessment and identifies infrastructure investment needs over the 50-year planning period of this Integrated Plan, similar to the recommended implementation schedule in **Chapter 8** for the wastewater and stormwater systems. Development of this plan was based on recommendations of the City's Capital Efficiency Plan, prepared in 2015. The Capital Efficiency Plan identified distribution system improvements and storage needs. The following is a list of investment categories in the plan:

- Water system security
- Watershed land acquisition
- Reservoir/storage tank rehabilitation
- Pump station rehabilitation
- Water Filtration Plant improvements
- Transmission main rehabilitation
- Water main and gate valve replacement
- Water meter replacement
- Building and facility rehabilitation
- Cross connection surveys
- Water accounting and analysis
- Hydrant replacement

The City's updated Drinking Water System Capital Improvement Plan is included in **Appendix 8.3**.

The City conducted financial modeling to project water rate increases needed to generate enough Water Enterprise Fund revenue for each year. **Table 7.2** presents these projected Water Enterprise Fund needs.

The City's drinking water system has numerous important needs and requires costly infrastructure investments that will contribute to the combined water and sewer rate increases as detailed in this section. Therefore, water rate increases will limit the City's ability to raise Sewer Enterprise Fund revenue. Selecting a capital spending scenario in this Integrated Plan should provide balance between the needs of the City's drinking water, wastewater and stormwater systems to allow investments in all three, while avoiding excessive financial burden to customers.

TABLE 7.2: PROJECTED WATER RATE INCREASES

Average	3.40%
2021	3.00%
2022	3.00%
2023	3.00%
2024	3.00%
2025	3.00%
2026	3.00%
2027	4.00%
2028	4.00%
2029	4.00%
2030	4.00%

7.2.5 Affordability Results for Representative Scenarios

In order to analyze the affordability of each scenario, this assessment includes both an enhanced methodology to calculate a weighted average residential index to understand financial impacts to specific subgroups of residents and a community wide analysis based on a standard 2% of median income approach. Additional detail on both methods may be found in the "Affordability Impacts" section of **Appendix 7.1**.

For illustration purposes, Scenarios 1, 3, and 5 are presented as primary alternatives representative of the range of spending scenarios that were evaluated. The following maps show the financial impact of each of these representative scenarios using the weighted average residential index (referred to as WARI on the maps), highlighting unaffordability by census tract. This analysis as shown in these maps

TABLE 7.3: WEIGHTED AVERAGE RESIDENTIAL INDEX THRESHOLDS FOR FINANCIAL IMPACT

Financial Impact		Index	Color
Low	Less than	1.65%	
Low-Mid	Up to	2.48%	
Mid-Range	Up to	2.89%	
Mid-High	Up to	3.30%	
High	Higher than	3.30%	

employs the scale depicted in **Table 7.3**.

For comparison, the current state of affordability in the City is presented in **Figure 7.15**.

Another way of evaluating affordability impacts using this methodology is to consider the number of households estimated to pay over 2% of their annual income toward sewer bills based on the threshold in the EPA's guidance. Although this is not a household level indicator, it provides a benchmark for the household impact for comparison across scenarios. **Figure 7.19** presents the proportion of the City's households that are expected to pay 2% or more of their annual income by 2030 for the above primary alternative spending scenarios.

The estimates in **Figure 7.19** quantify the relative impacts of primary capital spending scenarios and support the findings of the overall results. For example, Scenario 1 yields a financial impact of more than 30% of households in the City expected to pay sewer bills that are greater than 2% of income. Under Scenario 3, nearly 50% of households would face unaffordable sewer bills. Any scenarios containing additional costs related to a new National Pollutant Discharge Elimination System stormwater permit, like scenario 3, will have larger proportions of households experiencing a high financial impact.

Only Scenario 5 falls under 30% unaffordability. Even Scenario 5, however, reveals significant levels of unaffordability in sections of the City based on the map in **Figure 7.18**, particularly the most concentrated Environmental Justice communities.

FIGURE 7.15: CURRENT AFFORDABILITY OF SEWER RATES IN WORCESTER

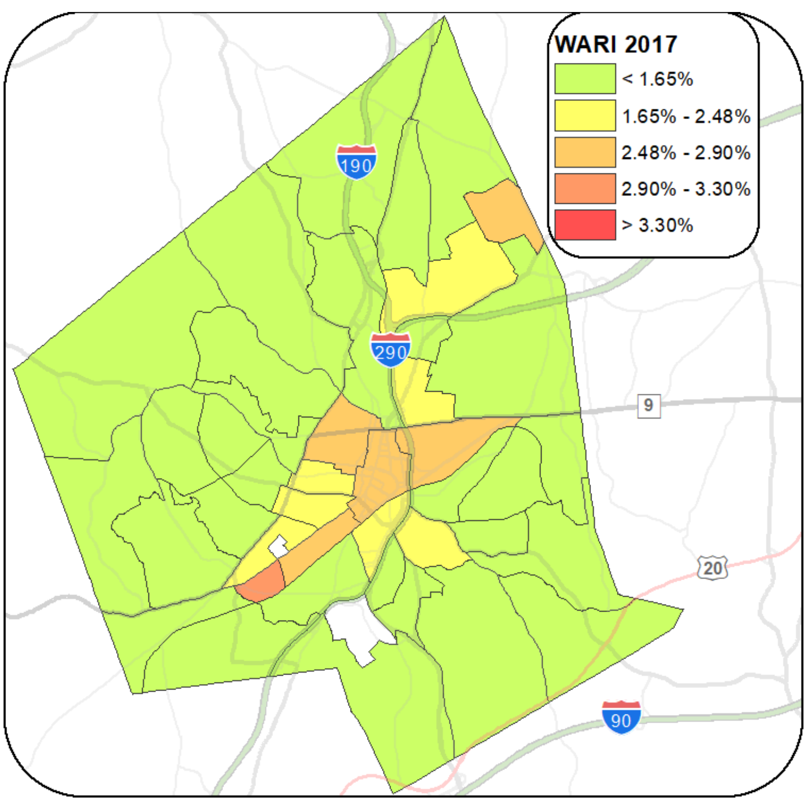


FIGURE 7.16: AFFORDABILITY OF SCENARIO 1

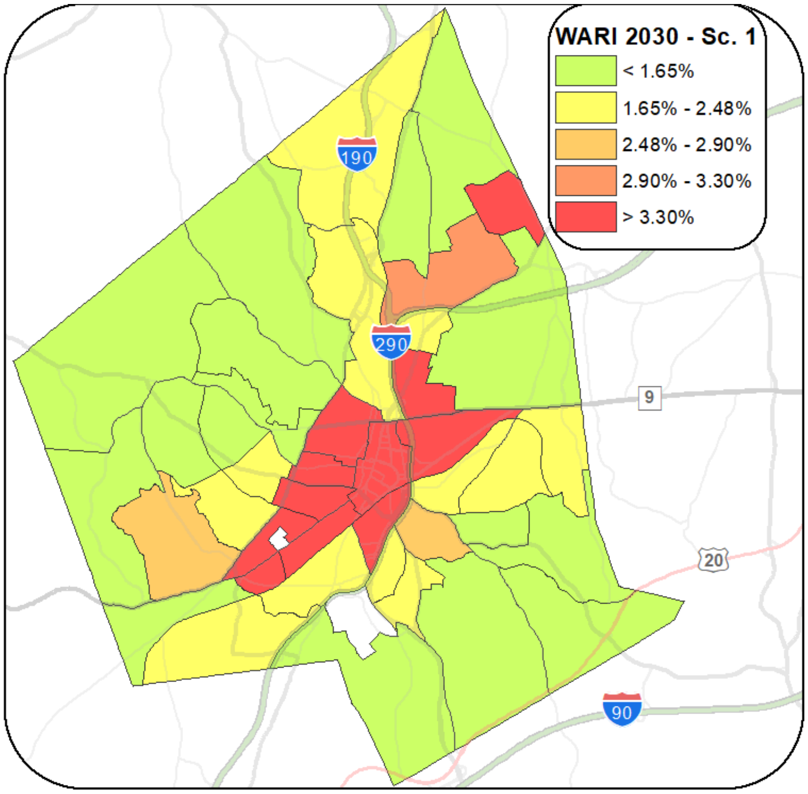


FIGURE 7.17: AFFORDABILITY OF SCENARIO 3

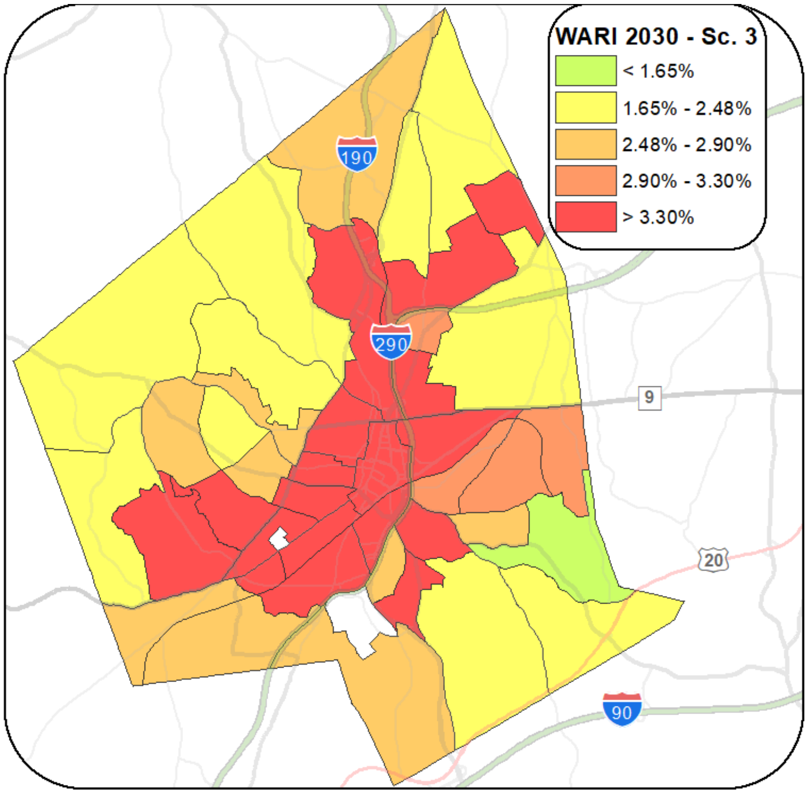
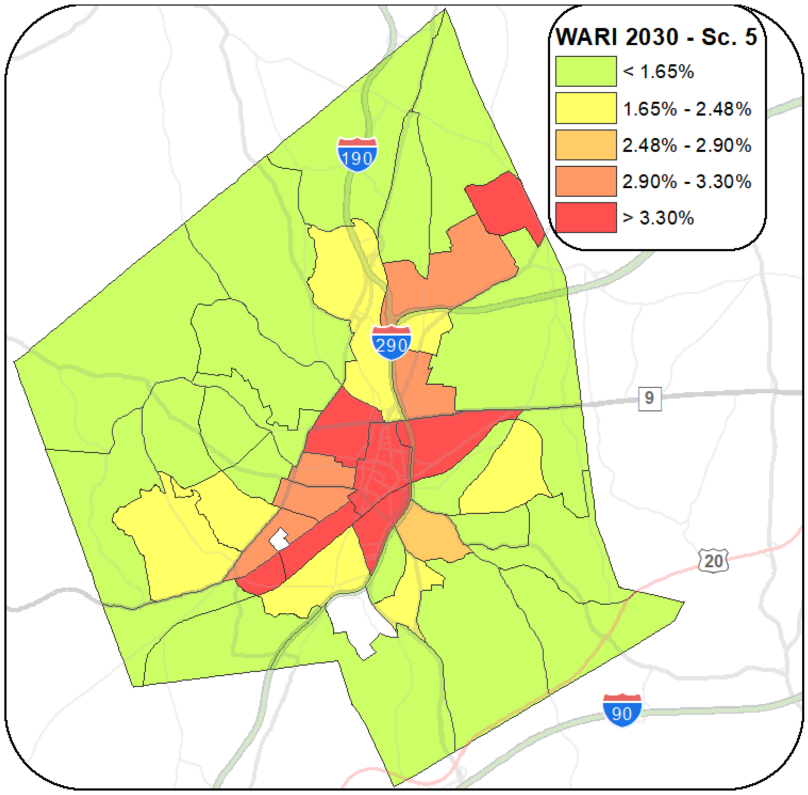


FIGURE 7.18: AFFORDABILITY OF SCENARIO 5



7.3 Phase 2: Financial Strength Analysis

The second phase of this financial capability assessment focuses on the financial strength of the City of Worcester and the Sewer Enterprise Fund in particular. Sewer and drinking water operations are funded through enterprise funds supported by sewer and water rates. These funds were created to separate the financing of water resources obligations from those of the general fund budget. The residents and businesses of Worcester bear the burden of property taxes as well as the water and sewer rates. Critical information about both the enterprise funds and the general fund budget are presented in the following section.

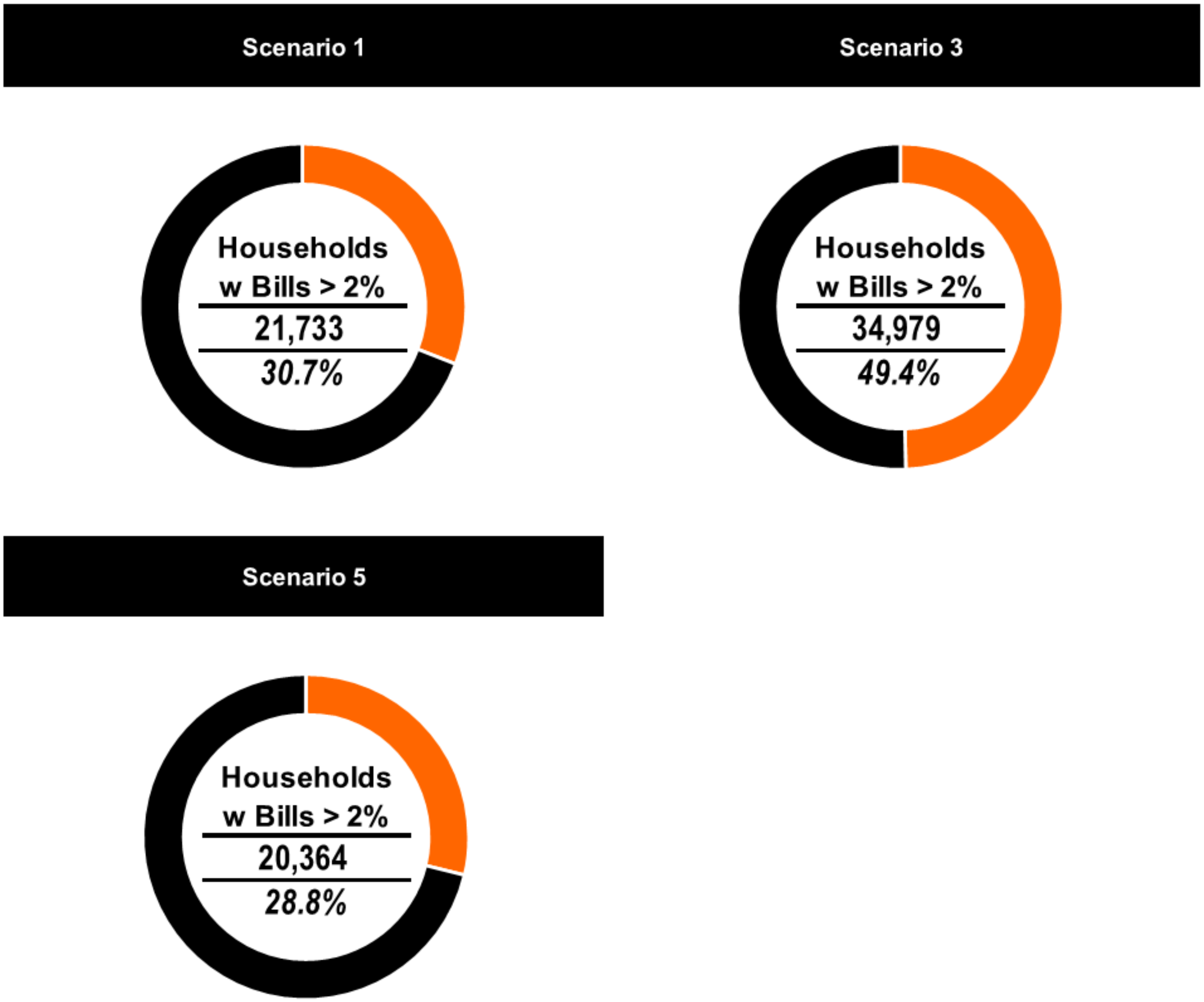
Both the Water and Sewer Enterprise Funds rely on the financial infrastructure and administrative overhead of the City of Worcester to provide critical services including executive management, treasury, technical service, legal support, and auditing functions.

In addition, the City provides the borrowing authority used by the Water and Sewer Funds to finance capital improvements. As a result, capital improvements in both funds show up as debt service costs in the operating budget, but neither fund has the authority to issue notes or bonds on their own. As a result, there is no bond rating for the Water or Sewer Enterprise Funds themselves, but they are considered as a component part of the City of Worcester's financials when bond rating agencies review the City's financial strength.

7.3.1 Enterprise Fund Financial Overview

An enterprise fund is a separate accounting and financial reporting mechanism for which revenues and expenditures are segregated into a fund separate from all other governmental activities. (See Massachusetts Department of Revenue, "Enterprise Funds: A Best Practice" for more information on the structure and function of enterprise funds in Massachusetts.)

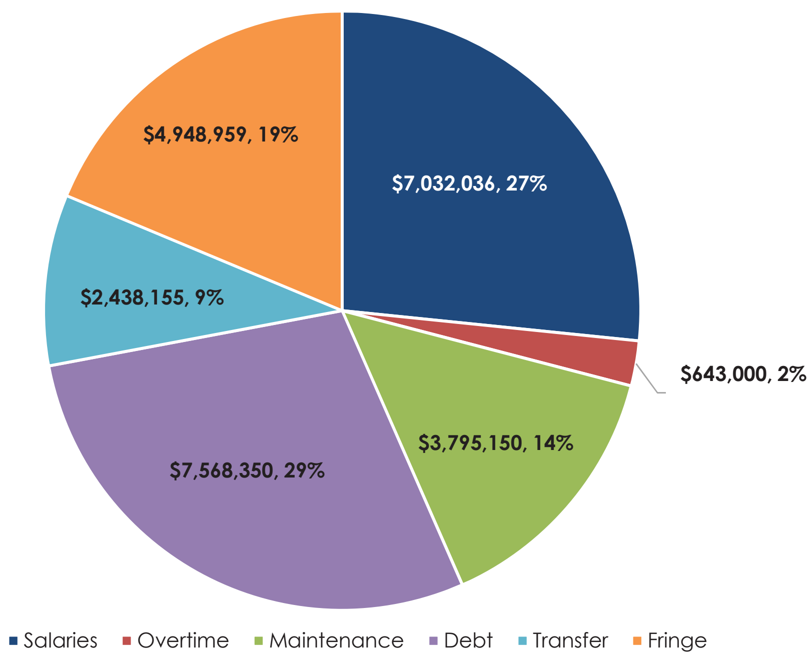
FIGURE 7.19: PROJECTED COUNT OF HOUSEHOLDS WITH SEWER BILLS OF TWO PERCENT OR MORE OF ANNUAL INCOME BY 2030



Water Enterprise Fund

For FY 2019, the total appropriation for the Water Enterprise Fund was $26.4 million as summarized in **Figure 7.20**.

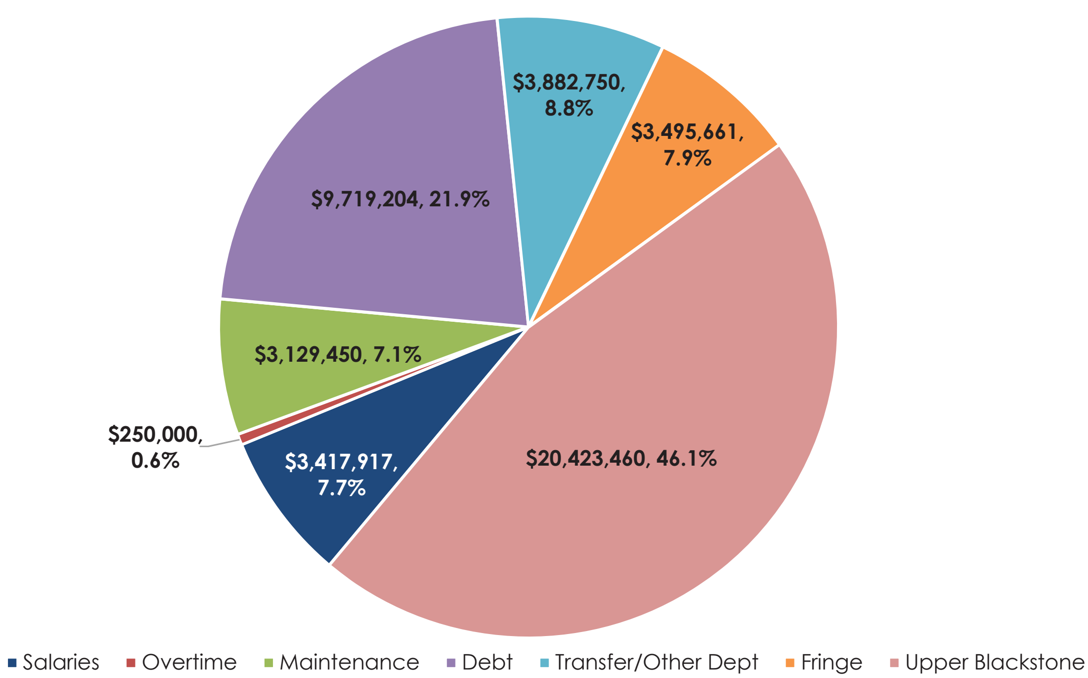
FIGURE 7.20: FISCAL YEAR 2019 WATER ENTERPRISE FUND EXPENDITURES



Sewer Enterprise Fund

For FY 2019, the total appropriation for the Sewer Enterprise Fund was $44.3 million as shown in **Figure 7.21**.

FIGURE 7.21: FISCAL YEAR 2019 SEWER ENTERPRISE FUND EXPENDITURES



As the largest wastewater contributor to the Upper Blackstone Treatment Facility, approximately 46% of sewer expenditures are allocated to cover the cost of wastewater treatment. Fifteen years ago, the sewer budget included $2.9 million for the Upper Blackstone Treatment Facility, so the current cost represents an increase of 585%. Ten years ago, the FY 2009 budget included a cost of $12.3 million for wastewater treatment. This cost has increased by approximately 66% over the past 10 years and now the assessment for Worcester exceeds $20.4 million.

The debt expenditure for wastewater system capital improvements is 22% or $9.7 million. The remaining 32% or $14.2 million of expenditures are for operations including salaries, overtime, benefits, and other ordinary maintenance expenses.

7.3.2 Tax Levy Overview

In addition to water and sewer bills, residents and businesses pay taxes and fees to support the general fund budget. The following is a summary of the FY 2019 Operating Budget, included as **Appendix 7.3**. An overview of the annual budgeting process is included in Section II.4 of this appendix. For FY 2019, the total appropriation for the tax levy budget was $649.9 million and included the revenue and expenditure estimates as shown in **Table 7.4** and **Table 7.5**.

Tax Burdens for Residents and Businesses

As previously noted, Worcester shifts of a percentage of its tax burden from residential properties onto commercial properties. This shift places an added burden on commercial and industrial taxpayers. **Figure 7.13** shows the percentage of the commercial property tax value compared to the percentage of the commercial property tax levy, illustrating that while the value of commercial property is just over 25%, the proportion of taxes paid by commercial taxpayers is more than 40%.

TABLE 7.4: CITY OF WORCESTER FISCAL YEAR 2019 BUDGET SUMMARY — REVENUES

Revenue Summary	FY18 Budget	FY19 Budget
Property Tax Levy Total	**289,389,960**	**299,069,846**
State Aid City	41,515,613	42,968,659
State Owned Land	209,609	173,598
Urban Renewal		
State Exemptions	557,801	541,732
Veteran's Benefits	1,821,933	1,400,000
State Aid City Total	**44,104,956**	**45,083,989**
MSBA Reimbursement Total	**5,662,268**	**5,662,268**
State Aid Education	245,207,183	249,894,895
State Aid Charter Schools	1,779,749	2,276,589
State Aid Education Total	**246,986,932**	**252,171,484**
Motor Vehicle Excise	15,250,000	15,600,000
Other Excise:Hotel Motel	3,550,000	3,950,000
Penalties and Interest	2,225,000	2,025,000
Trash Collection Revenue	3,100,000	3,100,000
Licenses and Permits	6,550,000	6,700,000
Fines and Forefeits	2,350,311	2,650,000
Investment Income	1,003,000	1,100,000
121A Urban In Lieu	810,000	725,000
Federal Reimbursement	3,850,000	4,514,909
Cemetery Revenue	500,000	450,000
Recreation Revenues	78,000	80,776
Other Fees	1,650,000	1,650,000
Other Revenues	80,000	80,000
Charges for Service	300,000	300,000
Special Assessments	481,125	450,000
Misc Recurring/Misc Non Recurring	2,697,100	3,797,100
Local Receipts Total	**44,474,536**	**47,172,785**
Other Funds Total	**699,930**	**699,930**
Free Cash	**1,537,762**	-
Total Revenues	**632,856,344**	**649,860,302**

TABLE 7.5: CITY OF WORCESTER FISCAL YEAR 2019 BUDGET SUMMARY - EXPENSES

Expenditure Summary	FY18 Budget	FY19 Budget	FY18/19 Change	% Change
Pensions	26,156,144	28,318,630	2,162,486	8.3%
Pension Bond Debt Service	10,209,733	10,501,443	291,710	2.9%
Health Insurance	26,383,698	25,165,960	(1,217,738)	-4.6%
OPEB Trust Deposit	550,000	605,000	55,000	10.0%
Worker's Compensation	1,358,973	1,260,224	(98,749)	-7.3%
Injured on Duty	658,235	593,850	(64,385)	-9.8%
Unemployment	110,000	110,000	-	0.0%
Debt Service	34,796,476	36,257,018	1,460,542	4.2%
Intergovernmental Charges	3,640,660	3,874,099	233,439	6.4%
Streetlights	1,952,828	1,952,828	-	0.0%
Snow Removal	6,000,000	6,000,000	-	0.0%
Seven Point Plan Funds	14,947,410	14,785,123	(162,287)	-1.1%
Total Fixed Costs	**126,764,157**	**129,424,175**	**2,660,018**	**2.1%**
Worcester Public Schools	335,120,190	341,640,882	6,520,692	1.9%
Charter Schools	27,690,420	29,098,438	1,408,018	5.1%
Total Education	**362,810,610**	**370,739,320**	**7,928,710**	**2.2%**
City Council	363,391	384,398	21,007	5.8%
Mayor	134,197	138,787	4,590	3.4%
City Clerk	612,128	639,691	27,563	4.5%
Elections	705,311	718,633	13,322	1.9%
Auditing	585,843	600,715	14,872	2.5%
City Manager's Office	1,162,369	1,202,043	39,674	3.4%
Health and Human Services	3,614,843	4,137,554	522,711	14.5%
Public Library	5,570,930	5,808,262	237,332	4.3%
Contingency	1,250,000	1,300,000	50,000	4.0%
Human Resources	1,327,863	1,387,119	59,256	4.5%
Economic Development	1,954,449	2,135,789	181,340	9.3%
Workforce	100,000	200,000	100,000	100.0%
Union Station	444,273	808,892	364,619	82.1%
Law/Insurance/Court	4,718,324	4,308,664	(409,660)	-8.7%
Fire	38,548,830	40,072,247	1,523,417	4.0%
Police	48,062,376	49,485,740	1,423,364	3.0%
Emergency Communications	3,171,254	3,426,968	255,714	8.1%
License Comm	1,200	-	(1,200)	-100.0%
Inspectional Services	3,756,999	3,838,474	81,475	2.2%
Public Works and Parks	18,671,713	19,831,144	1,159,431	6.2%
DCU Center	-	-	-	0.0%
Finance	2,551,989	2,643,076	91,087	3.6%
Assessing	752,695	761,085	8,390	1.1%
Technical Services	3,660,130	4,255,585	595,455	16.3%
Energy/Asset Management	1,410,470	1,411,941	1,471	0.1%
Enterprise (Golf)	150,000	200,000	50,000	33.3%
Total City Services	**143,281,577**	**149,696,807**	**6,415,230**	**4.5%**
Total Expenditures	**632,856,344**	**649,860,302**	**17,003,958**	**2.69%**

This tax rate shift has been the source of political tensions over the years. The Worcester Regional Chamber of Commerce has consistently advocated that the City Council narrow the gap in the tax rates between the two classes of properties, but any shift necessarily increases the burden on residential taxpayers. As result, there has been only modest change in the shift in the last ten years. This illustrates both the political sensitivity around increasing taxes in general as well as the disproportionate burden borne by the commercial properties.

In addition, the capacity to increase property tax rates is also limited by state law in Massachusetts—Massachusetts General Laws Chapter 59, Section 21C, referred to as Proposition 2 ½. This statute limits taxing authority two ways:

1. It imposes a levy ceiling, capping the total tax levy allowed at 2.5% of the total valuation of property in the city.
2. It imposes a levy limit that restricts the annual increase in taxation to 2.5% of the prior year's levy plus additional value from new growth.

The FY 2019 budget assumes a Proposition 2½ increase in the amount of $7.68 million and new growth of $6.0 million. The gross tax levy of $299.1 million is reduced by an amount reserved for exemptions and abatements to derive a net tax levy which is subject to appropriation.

Despite this limitation on tax increases, the property tax levy in Worcester has increased 66.7% since 2007. This includes increases throughout the 2008 recession even as property values declined. Tax rates increased to make up for the loss in real estate value during this time. As a result, Worcester did not experience a reduction in property taxes during this economic downturn as illustrated in **Figure 7.11**.

Tax Levy Expenditures

The tax levy expenditure budget is broken into three large categories: Education, City Services (operations), and Fixed Costs (debt, pensions, health insurance, financial integrity plan reserve deposits, street lighting, and snow removal). **Figure 7.22** shows the breakdown by percentage of these expenditures from the FY 2019 budget.

These three categories are summarized in the FY 2019 budget as follows:

1. Education costs account for 57% of all City expenditures. The FY 2019 total education budget is $370.7 million. It is based on the state's calculation of the "foundation budget" for the Worcester Public Schools. Massachusetts determines the minimum local contribution toward the foundation budget and funds the balance with state aid. Communities may fund education above the minimum required. The current statewide average is to contribute 27% above the minimum required. In FY 2019, the City appropriated 1% above the minimum. **Figure 7.23** shows the City's level of spending from FY 2008 to FY 2019 compared to what it would be if the City contributed consistent with the statewide average percentage for spending above the minimum. City spending shown in red indicates years where the minimum level of spending was not achieved.
2. Fixed costs account for 20% of the overall City budget. Fixed costs are comprised of health insurance, pensions, debt service, snow removal, street lighting, and intergovernmental charges and total $129.4 million for FY 2019. **Figure 7.24** from the FY 2019 budget shows the breakdown by percentage of fixed costs.
   - City health insurance costs are budgeted at $25.2 million, excluding the cost of health insurance for the Worcester Public Schools which are carried in the education budget.

FIGURE 7.22: FISCAL YEAR 2019 BUDGET EXPENDITURES

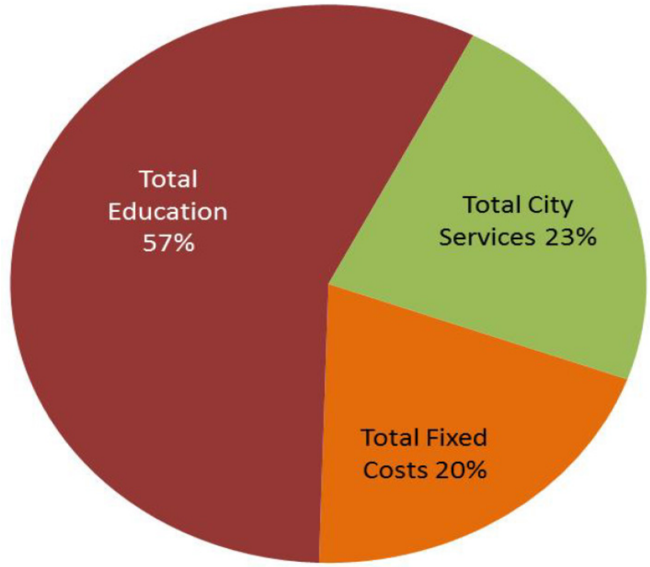


FIGURE 7.23: CITY OF WORCESTER OVER/UNDER MINIMUM REQUIRED CONTRIBUTION

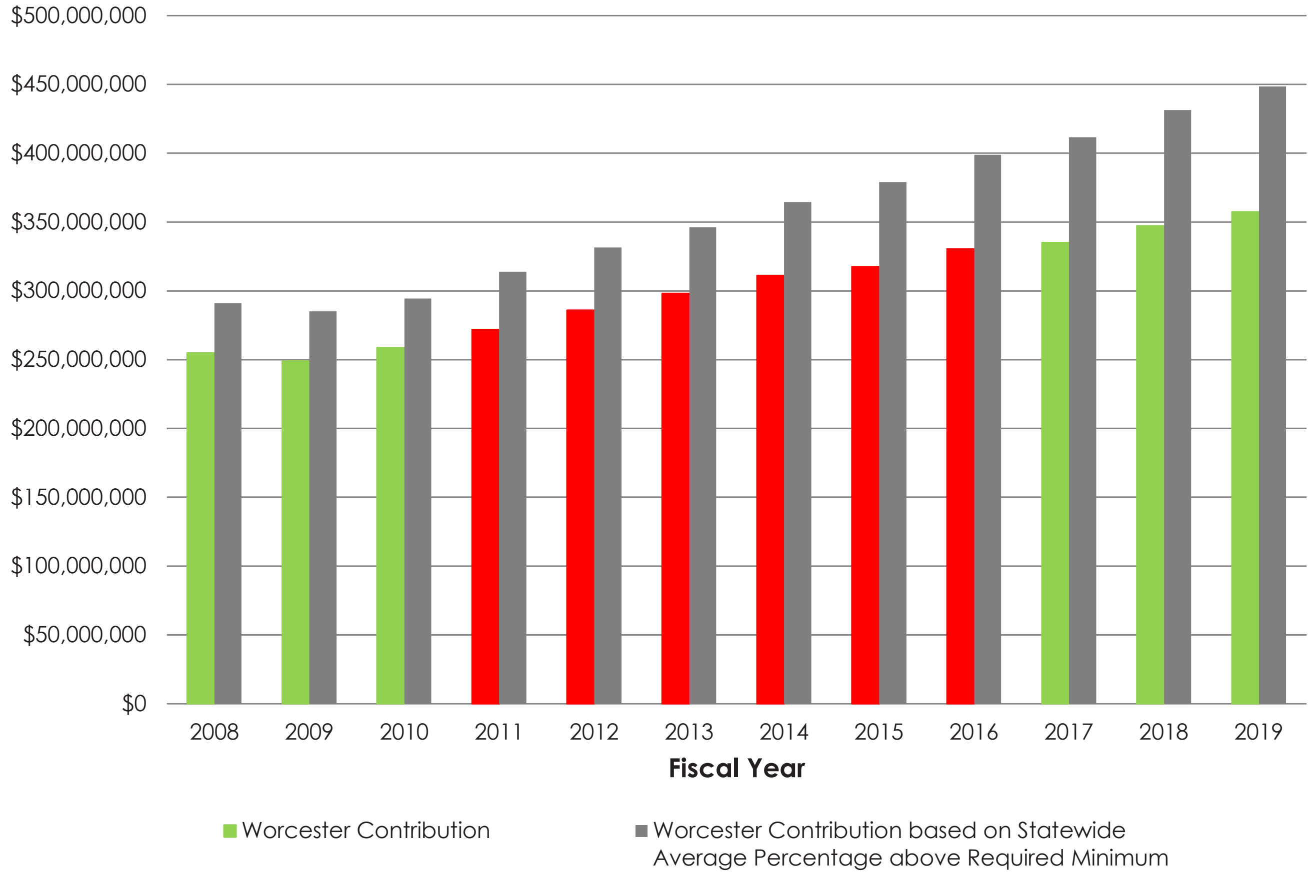
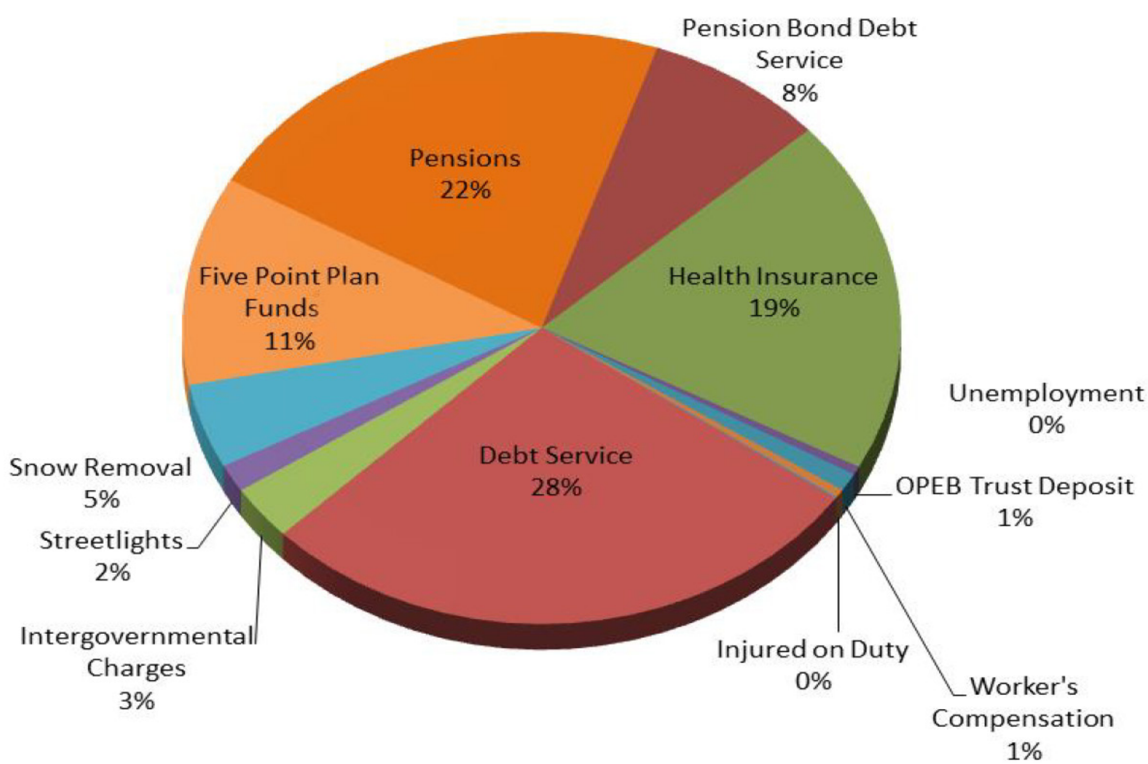


FIGURE 7.24: FISCAL YEAR 2019 TOTAL CITY FIXED COSTS



- The combined pension contribution required is $28.3 million. In addition, the City must make a debt service payment of $10.5 million on the Pension Obligation Bonds issued to fund the unfunded pension liability in 1998. This debt service will continue until FY 2028.
- According to the latest actuarial valuation, the total pension liability as of January 1, 2019 was calculated to be $1.5 billion. Of that liability, 63.22% is currently funded. The current funding schedule shows increased pension costs of 6.33% per year.
- Debt service is another major component of fixed costs. Borrowing for equipment, infrastructure improvements (including bridges, streets and sidewalks, dams not associated with drinking water), and public buildings (including the construction and rehabilitation of public schools) are funded through municipal bond issues. Annual debt service payments meeting all tax levy and enterprise fund obligations for this borrowing totals $73.7 million. In FY 2019, $36.3 million in principal and interest payments are to be paid from the tax levy budget, and the remainder is funded through enterprise funds and grant programs. More than 23% of debt service payments are paid by the Water (10.3%) and Sewer Enterprise Funds (13.2%).
- The Financial Integrity Plan requires contributions to designated reserve funds for a total of $15.39 million to fund future debt service obligations and to build reserves including the annual deposit into the City's Other Post-Employment Benefits Trust fund for retiree health benefits.
- Per the latest actuarial valuation, Other Post-Employment Benefits liability stands at $802 million, of which $0.00 was recognized as funded as of June 30, 2018.

3. The budget for operational departments is based on the funds remaining after all education costs and other fixed costs have been funded. The remaining 23% is available to fund departmental operations, including the salary and ordinary maintenance costs of all non-school departments. In FY 2019, the amount available for operational budgets is $149.6 million. **Figure 7.25** from the FY 2019 budget shows the breakdown by percentage.

The chart shows that the police and fire departments required 60% of the operational budget combined. DPW&P received 13% of the operational budget.

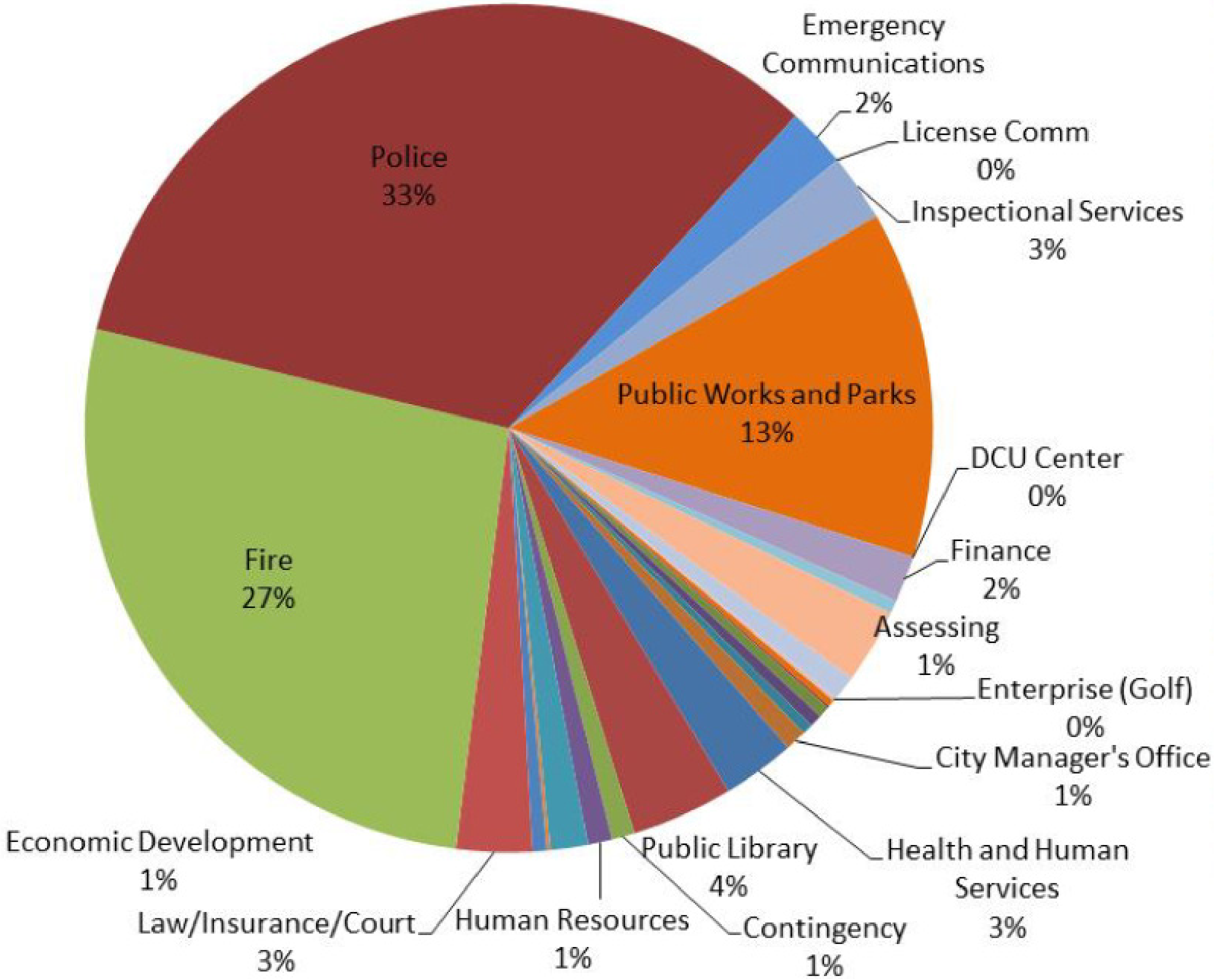
7.3.3 Financial Integrity Plan

In 2017, the City Manager recommended to the City Council an update to the City's 2006 Five Point Financial Plan and renamed it the Financial Integrity Plan. The updated plan contains the following provisions:

- Create a new High School Construction stabilization account for the construction of two (2) high school replacement projects, South and Doherty High.
- Increase the General Fund reserve level target from 5% to 10% of General Fund revenues.
- Update the City's annual tax levy supported debt from a fixed amount (adjusted for inflation) to subsequent debt issues being tied to debt service coverage (8-10% of the operating budget).
- Establish Other Post-Employment Benefits Trust Fund and Commission consistent with the Government Accounting Standards Board's (GASB) promulgation, GASB 45.
- Memorialize the budgetary assumptions and methodology.
- Recommend a practice where excess Proposition 2½ new growth shall be added to the unused levy capacity.

The plan has provided important parameters to the City's financial management over the last 10 years providing a framework for building reserves and improving bond ratings. It also necessarily limits the City's ability to spend beyond established parameters, reducing flexibility to provide tax levy funding for projects.

FIGURE 7.25: FISCAL YEAR 2019 TOTAL CITY SERVICES



7.3.4 Capital Budget

Enterprise and tax levy capital investments are funded with the issuance of short-term notes which are then converted into long term General Obligation bonds. The resulting debt service is then funded through the corresponding operating budget, tax levy, Sewer Enterprise Fund, or Water Enterprise Fund. Tax levy borrowing increases pressure on property tax rates. Water and sewer borrowing increases pressure on water and sewer rates. All borrowing is ultimately funded by residents and businesses. As a result, funding for citywide needs compete for resources and affect the City's financial strength and affordability of projects.

The following capital budget summary is drawn from the recommended FY 2019 Capital Improvement Plan, attached in **Appendix 7.4**.

The FY 2019 Capital Improvement Plan includes new loan authorizations of $85.59 million. **Table 7.6** is a summary of the recommended fiscal year 2019 Capital Improvement Plan. It should be noted that loans authorized in one year may be borrowed and expended over several subsequent years for multi-year projects.

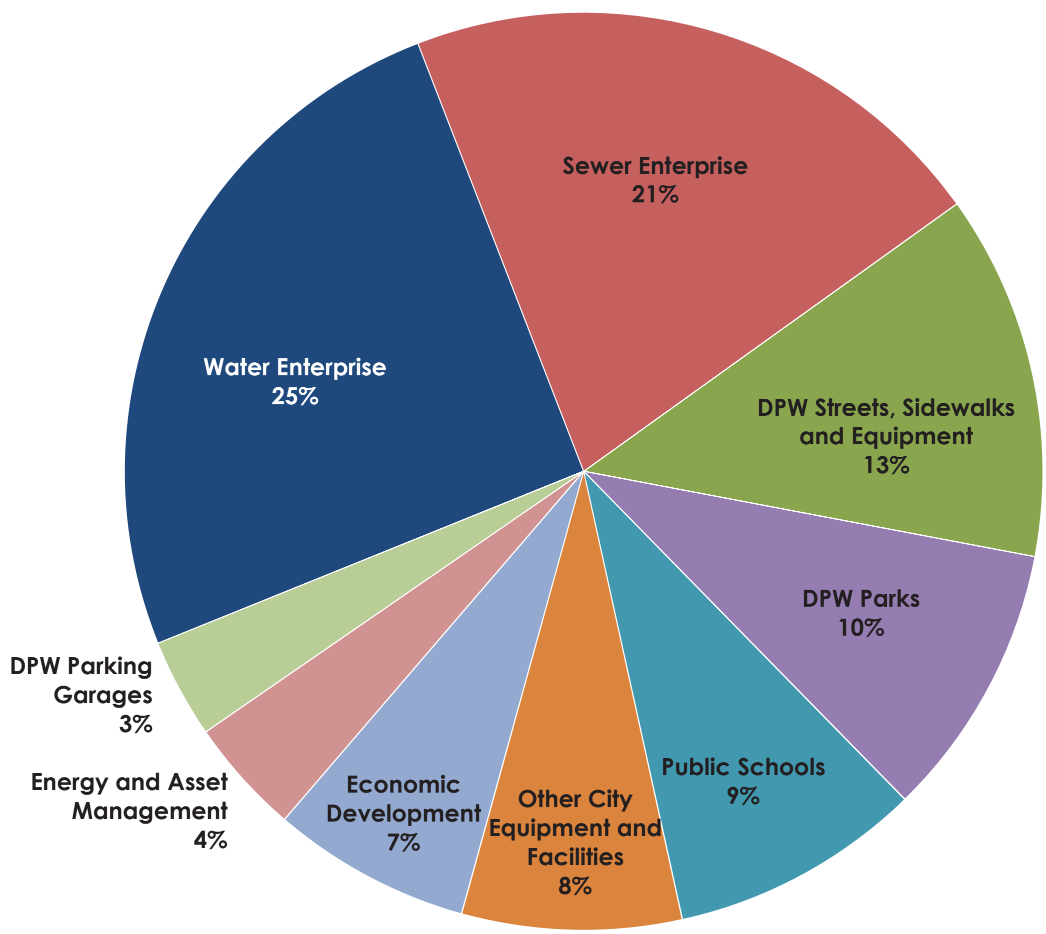
In FY 2019, $17.9 million in sewer capital spending was authorized by loan orders approved under the capital budget. These funds were for projects including wastewater collection system reconstruction, sewer interceptor rehabilitation, infiltration and inflow removal, surface drainage, pump station improvements, the Route 20 sewer project, and needed capital equipment. The Water Enterprise Fund capital budget of $21.6 million includes $7.3 million for a major drinking water transmission main project, funding for water main replacement, dam repair, and improvements

TABLE 7.6: CITY OF WORCESTER FISCAL YEAR 2019 BUDGET SUMMARY - EXPENSES

Fund	FY19 Capital Budget By Function	Loan Authorized	% of Budget
Water	Water Enterprise	21,595,000	25.2%
Sewer	Sewer Enterprise	17,960,000	21.0%
Tax Levy	DPW Streets Sidewalks and Equipment	11,020,000	12.9%
Tax Levy	DPW Parks	8,300,000	9.7%
Tax Levy/MSBA	Worcester Public School	7,600,000	8.9%
Tax Levy	Other City Equipment and Facilities	6,616,541	7.7%
Tax Levy	Economic Development	6,000,000	7.0%
Tax Levy	Energy and Asset Management	3,500,000	4.1%
Parking	DPW Parking Garages	3,000,000	3.5%
	Grand Total	**85,591,541**	**100%**

at the Water Filtration Plant. These investments represent 46% of all funding approved in the FY 2019 capital budget. The remaining funding is allocated to tax levy supported projects in the remaining categories including streets and sidewalks, parks, and school facilities as shown in **Figure 7.26**.

FIGURE 7.26: FISCAL YEAR 2019 CAPITAL BUDGET BY FUNCTION



Water Resources Needs versus the Entire Capital Budget

It is important to note that some of the investments reviewed for the Integrated Plan that would be required to meet proposed regulatory requirements might require spending of more than double the entire capital budget in one year. For instance, the nutrient removal projects at the Upper Blackstone Treatment Facility would require spending of $212.5 million over 6 years. The following chart illustrates the FY 2019 capital budget allocations with one year of this potential Upper Blackstone nutrient removal project added at an average annual cost of $35.4 million. **Figure 7.27** demonstrates how the addition of such a project can dominate all other spending in the City's capital budget.

FIGURE 7.27: FY 19 CAPITAL BUDGET BY FUNCTION WITH UPPER BLACKSTONE NUTRIENT REMOVAL PROJECT

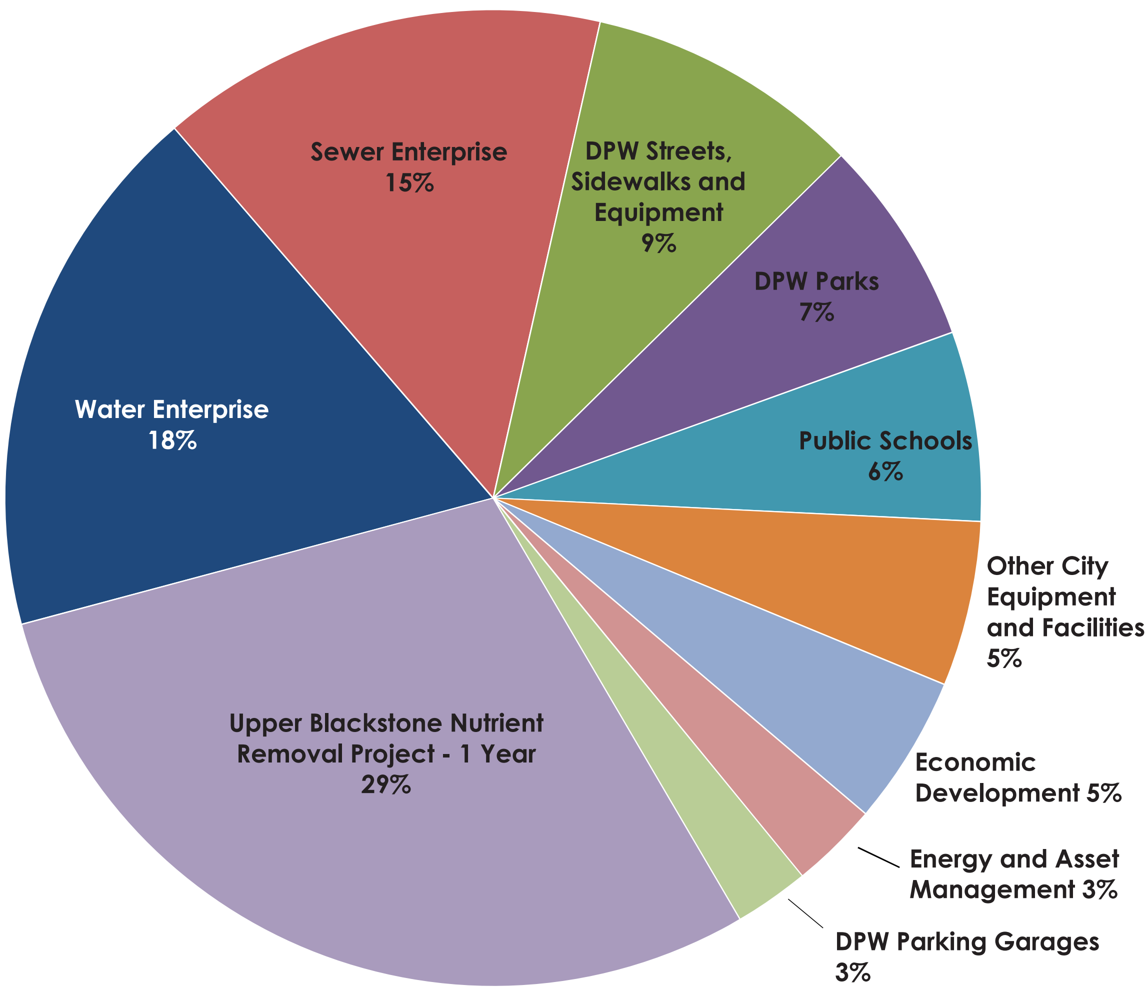
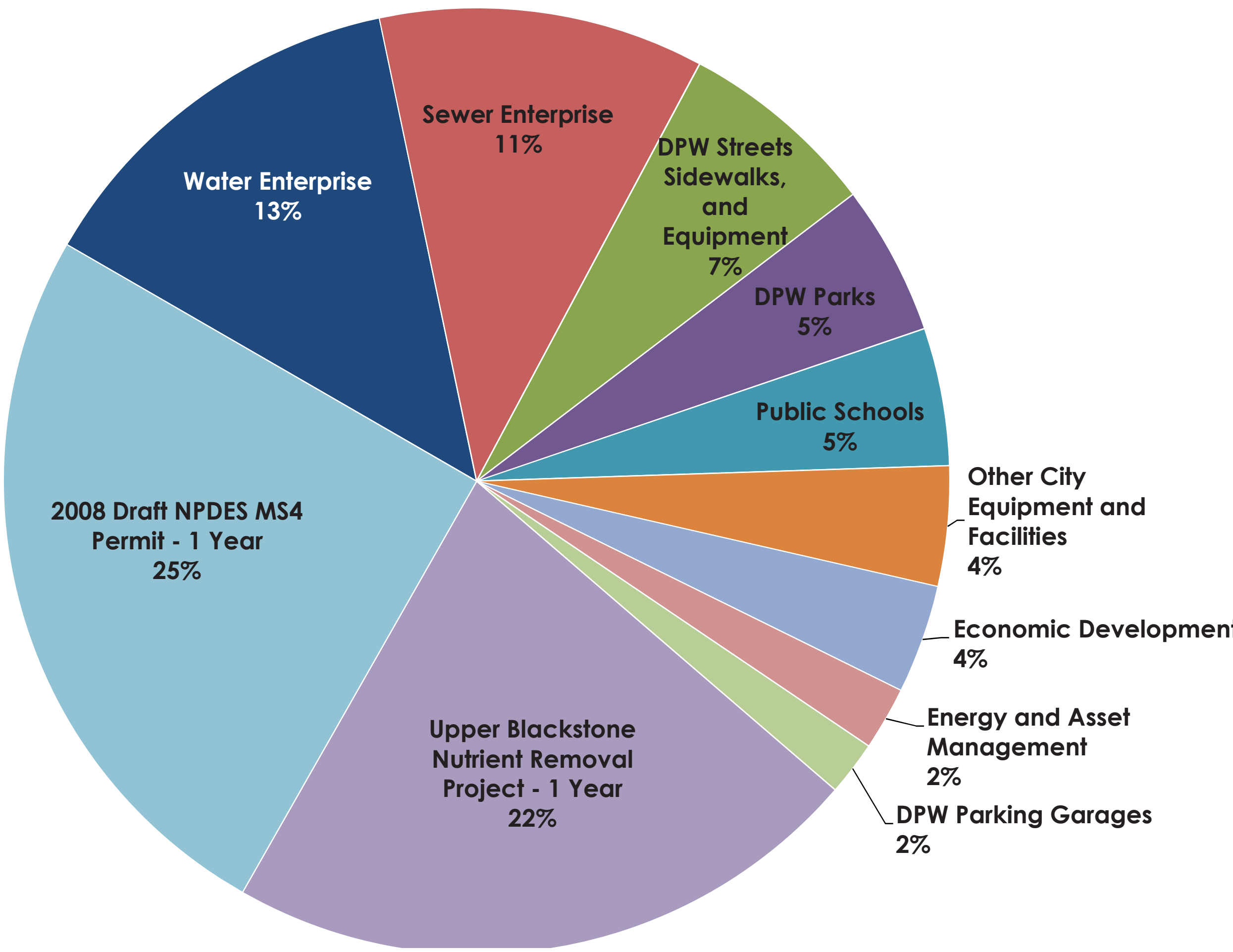


Figure 7.28 illustrates the impact of adding one year of estimated costs for additional stormwater projects if the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit[5] becomes final plus one year of the Upper Blackstone nutrient removal upgrades to the capital budget. One year of these two projects would combine for nearly 50% of the City's total capital budget. When added to the existing water and sewer capital spending, water resources would represent nearly 75% of the City's total capital budget.

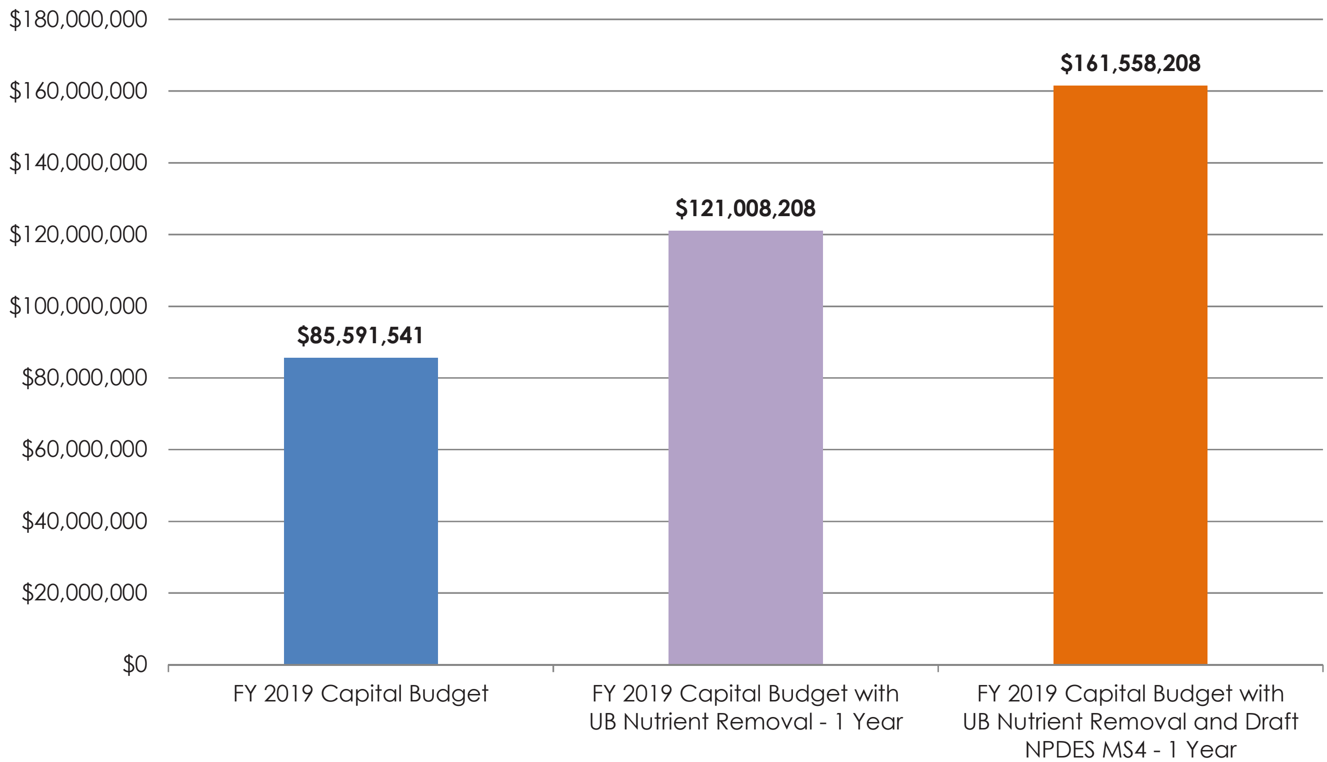
FIGURE 7.28: FY 19 CAPITAL BUDGET BY FUNCTION WITH UPPER BLACKSTONE NUTRIENT REMOVAL PROJECT AND STORMWATER PERMIT



5 Ibid

Figure 7.29 illustrates the magnitude of the capital budget increases required to meet one year of the Upper Blackstone nutrient removal upgrades plus one year of estimated spending required to meet the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit requirements if it becomes final. Adding one year of the Upper Blackstone project results in a 49% increase in the City's overall capital budget. Adding one year of the Upper Blackstone project plus one year of the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit results in an increase of 95%.

FIGURE 7.29: CAPITAL BUDGET COMPARISON



Future Capital Needs

There are significant capital needs that must be addressed in future capital improvement plans. The following list highlights the largest areas of needed public investment outside of the Water and Sewer Enterprise Funds:

- A 2018 Worcester facilities plan identified a cost of $230 million in deferred capital repairs across city facilities.
- Three of five comprehensive high schools are scheduled for replacement over the next 10 years; these projects have a total estimated construction cost of approximately $850 million, the cost of which will be split with the Massachusetts School Building Authority.
- The DPW&P needs a new facility to accommodate its administration and operations in the near future that is estimated to cost $90 million and would be partially funded by the Water and Sewer Enterprise Funds.
- The Upper Blackstone Treatment Facility biosolids handling facility may require replacement in the near- to mid-term. This cost, estimated between $110 million and $125 million, would be passed on to the City through Upper Blackstone rate increases.
- An estimated 195 miles of streets and 250 miles of sidewalks need to be replaced at an approximate cost of $200 million.
- A $250 million backlog of parks improvements.

Combined, these needs total over $1.5 billion of future citywide capital investments that will compete for limited tax and rate revenue in the future.

7.3.5 Municipal Bonds — Bond Ratings

Bond ratings are important indicators of financial capability. Private sector investors depend on ratings issued by independent rating agencies when purchasing municipal bonds. Higher ratings mean lower borrowing costs. An upgrade in bond ratings can potentially save taxpayers millions in interest costs.

The 2006 Five Point Financial Plan was established in response to concerns about the City's bond ratings, which were a single A3 (or A-) from both Moody's and S&P. Since that time and by adhering to its own financial policies and reserve building requirements, Worcester has now achieved double AA level bond ratings from the three rating agencies: AA- and AA3 from S&P and Moody's and AA from Fitch Ratings. While benefiting from these higher ratings, the financial policies and reserve building requirements limit resources available for operations or capital investments.

Table 7.7 provides the bond rating scale of each of the three rating agencies. Bond ratings as of 2018 are Aa3, AA-, and AA respectively, shown in bold font.

TABLE 7.7: BOND RATING SCALE

	Moody's	S&P Global	Fitch
Best Quality	Aaa	AAA	AAA
High Quality	Aa1 Aa2 **Aa3**	AA+ AA **AA-**	AA+ **AA** AA-
Upper Medium Grade	A1 A2 A3	A+ A A-	A+ A A-
Medium Grade	Baa1 Baa2 Baa3	BBB+ BBB BBB-	BBB+ BBB BBB-

The attached 2019 Affordability Analysis (**Appendix 7.1**) includes a detailed review of a number of financial metrics used by bond rating agencies when assigning bond ratings. The review shows a number of key metrics where the Water and Sewer Enterprise Funds fall well short of established metrics for AA rated water and sewer utilities. The following metrics illustrate some of the areas where the Sewer and/or Water Enterprise Funds do not meet the level expected of an AA rated utility.

- Operating Margin (Sewer)
- Days Cash on Hand (Water and Sewer)
- Current Ratio (Water and Sewer)
- All-In Debt Service Coverage Ratio (Water and Sewer)
- Debt to Funds Available for Debt Service Ratio (Sewer)

7.4 Clean Water Act and Safe Drinking Water Act Impacts

The City has a long history of completing major projects to address its obligations under the Clean Water Act and other regulations that assure safe drinking water and safeguard public health. The major costs associated with permit compliance projects required the City to defer important needs within its water resources systems.

Table 7.8 summarizes the City's history of projects addressing Clean Water Act and Safe Drinking Water Act obligations.

This summary demonstrates the high cost of compliance with new and evolving permits and regulations. Because of these compliance-driven investments, the City's ability to make other investments to maintain its water resources systems has been limited.

7.4.1 Prospective Capital Costs

This Integrated Plan identifies prospective capital costs for investments needed to maintain the water resources system infrastructure and to comply with permit requirements over the 50-year planning period.

These costs total roughly $538 million for the drinking water system and $1.274 billion for the wastewater and stormwater systems, or approximately $36.2 million on an average annual basis. These costs do not include an estimated $811 million which would be required to comply with the 2008 Draft National Pollutant Discharge Elimination System Municipal Separate Storm

TABLE 7.8: CLEAN WATER ACT AND SAFE DRINKING WATER ACT PROJECT HISTORY

Years	Description	Regulatory Requirement	System	Approximate Cost
1975 - 1990	First CSO Long-Term Control Plan	Clean Water Act	Combined Sewer	$116 million *(State & federal government paid 90%)*
1990 - 2000	New Drinking Water Filtration Plant	Safe Drinking Water Act	Water Filtration Plant	$65 million
2000 - 2008	Second CSO Long-Term Control Plan, Ph. I and II	Clean Water Act	Combined Sewer	$6 million
	Upper Blackstone Treatment Facility Upgrades *(2001 NPDES Permit)*	Clean Water Act	Upper Blackstone Treatment Facility	$187 million *(Worcester paid approximately 85%)*
2008 - Present	Upper Blackstone Treatment Facility Upgrades *(2008 NPDES Permit)*	Clean Water Act	Upper Blackstone Treatment Facility	$250 million *(Worcester is paying approximately 85%)*

Sewer System permit if it becomes final[6]. These prospective capital costs total $2.6 billion.

In addition to the capital spending summarized above, more than $70.7 million is budgeted annually in operating expenses to maintain municipal water resources systems through the Water and Sewer Enterprise Funds. Many of these operating costs will increase over time, including salaries, utilities, and the $20.4 million assessment cost for wastewater treatment at the Upper Blackstone Treatment Facility.

7.5 Conclusion: Worcester's Financial Capability Assessment

The financial capability assessment illustrates the challenges faced when meeting the basic needs of the City's residents. The socioeconomic data show that Worcester faces real economic limitations. The following key factors are evident:

- Worcester is poorer than most of Massachusetts and the nation
- Small changes in water or sewer rates result in large percentage swings in affordability
- Worcester has a high concentration of Environmental Justice communities, covering 70% of the City
- Worcester has a high proportion of residential renters
- Worcester has higher unemployment than most of Massachusetts and the nation
- Worcester faces a number of major obligations outside of its water resources systems including education, road network, and parks infrastructure needs
- Worcester faces legal limits on increasing revenues through property taxes
- Worcester bond benchmarks fall short in many areas expected of AA rated water and sewer utilities
- Worcester residents face a variety of financial burdens including water and sewer rates and property taxes that have historically climbed faster than inflation

This financial capability assessment was used to guide the development of this Integrated Plan as described in **Chapter 8**.

6 Ibid

CHAPTER 8.
Development of Integrated Plan

8.1 Overview

Worcester's Integrated Plan establishes a process to address the City's priorities through infrastructure investments that achieve multiple benefits to the environment, public health, and public safety.

This chapter describes how the plan accomplishes the most beneficial operations, maintenance, and infrastructure improvements by addressing deferred maintenance and improving system performance, water quality, public health, and safety. The plan is designed to establish a schedule of investments that is proportional to the maximum financial commitments the City can realistically undertake. The plan addresses the most pressing public health and environmental protection issues first. The implementation schedule for this Integrated Plan is based on guidance from the benefits model (**Chapter 6**) and financial capability assessment (**Chapter 7**).

This Integrated Plan balances short-term and long-term capital investments along with ongoing maintenance. Much of the City's water resources infrastructure is past its useful life and is approaching or in failed condition. Replacement and rehabilitation of this infrastructure is absolutely necessary for environmental and economic health and is therefore addressed early in the plan. The initial years of the plan target investments in failing infrastructure. Over time, reactive maintenance that undermines the ability to manage the systems efficiently and cost-effectively will be reduced. Future investing will be more successful if unanticipated reactive spending can be decreased.

8.2 Management Approach

The City faces significant deferred capital investments in its water resources systems. The National Academy of Public Administration estimates that nationwide "costs associated with maintenance, upgrades, and replacements are projected to surpass $1 trillion in the next 25 years … [which] could triple the cost of household water bills."[1]

1 National Academy of Public Administration, "Developing a New Framework for Community Affordability of Clean Water Services," October 2017

Over the last several decades, Worcester's capital projects, including investments at the Upper Blackstone Treatment Facility, have focused on schedule-driven regulatory compliance rather than reinvesting in the City's water resources infrastructure. The past approach focused on projects required to comply with permits and regulations that offered singular water quality benefits and required many years to retire associated debt. This Integrated Plan changes the approach to infrastructure management to realize greater environmental benefits for the investments made.

8.2.1 Focus on Operations and Maintenance

This Integrated Plan includes a review of system operations and maintenance. As documented through the Key Performance Indicator gap analysis, unplanned maintenance and emergency repairs present a challenge.

The plan includes a targeted inspection program of the wastewater and stormwater collection systems. The City will conduct inspections of high-risk assets with the goal of reducing unplanned maintenance and failures. This program emphasizes targeted inspection cycles to collect critical condition information to guide future renewal efforts. The $2 million annual investment assumes a 24-year inspection cycle for the wastewater collection system pipelines and a 16-year inspection cycle for the interceptor pipelines (pipes with a diameter greater than 18 inches).

The increased focus on operations and maintenance will advance progress toward the following performance metrics:

- **Pipe Age:** Pipes beyond their useful life are typically in poor condition and have a high probability of failure. By inspecting high-risk assets first, the plan identifies and schedules repairs and replacement, increasing the overall reliability of the systems.
- **Infiltration and Inflow:** Through inspections, infiltration and inflow sources are targeted for mitigation.
- **Loss-of-Service Complaints:** A routine inspection program with cleaning improves level of service by removing sediment and debris to restore capacity. It also identifies areas with other problems, such as fats, oils and grease and root intrusion.
- **Non-Capacity Sewer Overflows:** Regular maintenance removes blockages that cause or exacerbate sewer overflows unrelated to capacity limitations.
- **Unplanned Maintenance:** Unplanned maintenance is more expensive than scheduled maintenance activities and defers regular planned activities. Emergency repairs are typically done at a premium cost as reinstating service is a high priority.
- **Catch Basin Cleaning:** This routine procedure has a significant impact on stormwater system capacity and water quality and must be maintained at current levels.

8.2.2 Achieving Performance Standards

At its core, integrated planning "gives the regulated parties the flexibility to achieve regulatory objectives in the most cost-effective manner and should provide for the achievement of the greatest water quality benefits as quickly as financially feasible."[2] This Integrated Plan achieves this through the development of a multi-criteria benefits model, outlined in **Chapter 6**, to assist in identifying infrastructure investments that achieve multiple benefits. Water quality benefits are inherent in all the recommended investments along with other benefits, such as protecting public health.

In addition to achieving water quality benefits, the Integrated Plan addresses the inherent environmental risks associated with leaking sewer pipes and sanitary sewer overflows. These infrastructure failures are often undetected, underestimated and overlooked in the greater water quality and environmental protection equation. The plan focuses on repairing and rehabilitating infrastructure that will produce significant water quality benefits. The entire Blackstone River watershed benefits from these infrastructure improvements.

2 National Academy of Public Administration, "Developing a New Framework for Community Affordability of Clean Water Services," October 2017

8.2.3 Balancing Commitments

This Integrated Plan defers certain compliance-based Upper Blackstone Treatment Facility upgrades to allow targeted investments in infrastructure with greater environmental benefits. The plan allows the City to initially focus on wastewater and stormwater capital reinvestment projects, which have been deferred for decades. In addition, the plan recognizes the need to continue studying and assessing the City's water resources systems.

Along with maintaining and improving the City's wastewater and stormwater collection systems, the plan balances commitments to the drinking water system and the Upper Blackstone Treatment Facility.

Each of these systems is important to the quality of life and protection of public health in Worcester.

When considering how to fund wastewater and stormwater system improvements, the cost to adequately maintain the City's drinking water system cannot be overlooked. EPA's 2014 Financial Capability Assessment Framework encourages consideration of "other costs or financial obligations, such as those that relate to drinking water … that significantly affect [the City's] ability to raise revenue." As outlined by the National Academy of Public Administration, "many communities are struggling to comply with [Clean Water Act] and [Safe Drinking Water Act] requirements while confronting not only the ongoing tension between providing clean and affordable water, but also a number of other financial challenges." This Integrated Plan considers the financial impacts of the City's Drinking Water System Capital Improvement Plan developed using institutional knowledge and industry service-life standards to operate, maintain, and provide safe, clean drinking water to Worcester's residents and businesses.

8.2.4 Engaging the Community

A key element of integrated planning is public participation, as described in **Chapter 4**. The City engaged stakeholders through public meetings and other events to share in the planning process, including its goals and approach for prioritizing investments.

Public input obtained through this process is aligned with the priorities of the plan.

8.3 Scheduling Criteria

This Integrated Plan includes the following considerations for scheduling of needed infrastructure investments:

- Infrastructure investments with the highest score, using the multi-criteria benefits model
- Previously identified critical capital projects
- Blend of new capital investment, capital reinvestment, and studies and assessments
- Capital investments in treatment facilities operations
- Phasing of investments
- Achieving multiple benefits while addressing critical infrastructure needs

The Integrated Plan implementation schedule is based on project-specific schedules, phasing, and costs to maintain financial viability.

8.3.1 Community Needs

The plan focuses on the most important and beneficial operations, maintenance, and infrastructure improvements to address the City's needs. This is accomplished in several ways:

- Public health and safety are guiding principles and are prominently reflected in the evaluation process for infrastructure investments.
- The plan identifies tangible improvements to neighborhoods where efforts to improve water quality are focused and the community can see, understand and experience the benefits.
- The success of this Integrated Plan is measured against Key Performance Indicators where the largest gaps in performance are the most critical to address. Reinvesting in existing infrastructure will produce a better managed system, with improvements to service continuity.
- Educating the community on the integrated planning process and the overall function of the water resource systems encourages future support for infrastructure investments.
- Multi-benefit projects with emphasis on improving the City's water resources systems and protecting the environment, public health, and safety are scheduled early in the plan.

- Studies and assessments will provide data critical to making future infrastructure decisions. This Integrated Plan recognizes that adaptive management is critical to a long-term plan.
- The plan includes a schedule that is affordable to ratepayers and necessary sewer rate increases have greater potential of being supported by City government.

8.3.2 Achieving Multiple Benefits

Balancing competing demands is the primary purpose of this Integrated Plan. The plan uses a benefits model to address compliance-driven demands within a focused program of infrastructure management and investment.

The benefits model was used to evaluate and develop a preliminary ranking of infrastructure investments that provide the most benefits measured against recognized needs.

A key example of an investment with multiple benefits is the replacement of Draper pipe. Both the risk model and benefit model scored pipe renewal as essential for improving the collection system. However, the City has been experiencing a much greater rate of failures with Draper pipe within its wastewater collection system. This Integrated Plan includes a focused program to replace all remaining Draper pipe within the first 15 years of the implementation schedule. Replacement of the City's aging collection system provides a wide range of benefits, including reduction of structural failures, basement backups, sanitary sewer overflows, infiltration, and contamination of receiving waters through leakage.

8.3.3 Addressing the Greatest Risks

The Integrated Plan favors early investments in infrastructure to eliminate the greatest risks to wastewater and stormwater systems. Risk models were developed using existing records and GIS data to identify system needs and potential investments to address those needs. The risk models define risk as the product of the probability of failure of an asset and the severity and extent of the consequences of its failure.

Because GIS based asset condition data are not conclusive, other asset information, such as pipe material, installation year, and expected service-life aid in determining the probability of failure of the assets. The assets' consequence of failure considers pipe size, service impacts, and proximity to sensitive facilities such as schools, hospitals, and public safety buildings, as well as sensitive environmental resource areas. Using the probability and consequence of failure, each wastewater and stormwater system asset is assigned a risk score. Based on the score, investments in infrastructure monitoring and renewal are scheduled to manage risk. **Appendix 5.2** summarizes the development of the risk models and the results.

8.3.4 Financial Considerations

This Integrated Plan must balance the large backlog of capital infrastructure needs and the impact that reliable infrastructure can have on the local economy along with cost to Worcester's ratepayers.

Worcester is experiencing significant economic growth and accompanying development. This growth, which is reliant on dependable infrastructure, will result in an expanding rate base that should reduce costs to all ratepayers. Failing infrastructure could lead to a shrinking economy and rate base and rising cost to fewer ratepayers.

The plan is funded solely by ratepayers who also fund other city services through property taxes. Considering these economic realities, it is necessary to select an implementation schedule that is financially viable.

This Integrated Plan implementation schedule is based on Scenario 5 of the alternative capital spending scenarios evaluated for affordability in **Chapter 7**. The selected spending scenario results in sewer rate increases going forward at an average of 5.0% per year. This represents twice the cap on real estate taxes allowed by law and, as of this writing, is more than twice inflation. This spending, identified as needed to reverse the deterioration of the water resources infrastructure, will result in costs deemed unaffordable[3] to 29% of the ratepayers by 2030. These proposed rate increases are subject to approval by the City

3 Where sewer bills will meet or exceed 2% of income

Council each year. Other grants and non-rate based environmental initiatives are completed outside the implementation schedule presented.

EPA's integrated planning framework allows flexibility to accommodate affordability needs through adaptive management principles while still producing meaningful results.

Should proposed rate increases fail to gain approval from City Council, the Integrated Plan can scale back spending accordingly, while still giving priority to investments with the greatest environmental and public health benefits. These adjustments will then translate into plan adjustments for following years and will extend the time period for implementation.

8.3.5 Project Enhancements

This Integrated Plan identifies projects that offer the greatest environmental benefits. All infrastructure investments recommended under the Integrated Plan have been reviewed to identify opportunities to enhance the project scope. Project enhancements offer additional site-specific benefits, which expand the effectiveness in achieving local and regulatory goals as detailed in the following sections.

8.3.5.1 Green Infrastructure

EPA's integrated planning framework includes consideration and implementation of green infrastructure where appropriate. Applying green infrastructure technologies to stormwater management, such as increasing pervious areas, can improve water quality, reduce stormwater runoff rates and volume at the source, and augment or provide new green spaces.

This Integrated Plan includes a green infrastructure evaluation, which summarizes historic use of green infrastructure, considers potential green infrastructure technologies, and identifies locations that appear feasible for implementation. The methodology consisted of the following steps:

1. Identify green infrastructure technologies appropriate for urban settings.
2. Characterize green infrastructure technologies — description, effectiveness of removing stormwater pollutants, and challenges.
3. Develop a citywide needs assessment and feasibility analysis to determine suitable drainage areas to implement green infrastructure technologies.
   - The needs assessment ranked each drainage area within the City using two criteria:
     - Criticality of surface waters based on the City's surface-water tier classification.
     - Reported flood-prone locations based on Customer Service Request System data.
   - The feasibility analysis evaluated drainage areas for potential effectiveness of green infrastructure technologies using three criteria:
     - Hydrologic soil groups
     - Depth to seasonal high groundwater
     - Ground surface slope

Appendix 8.1 contains a green infrastructure technical memorandum that outlines drainage areas within the City with potential based on need and feasibility. The memorandum summarizes recommended green infrastructure technologies that help address needs identified in those drainage areas.

This methodology is implemented citywide, using planning-level data and various assumptions to provide conceptual recommendations for potential project enhancements. The recommendations will need to be verified prior to implementation considering all factors, including contaminated lands, availability of permeable City-owned land, political and abutter support, and cost-effectiveness.

Where green infrastructure was determined not to be feasible, grey infrastructure (such as storm water treatment systems) is recommended for consideration as an alternative to improve water quality and reduce volume where feasible and cost-effective.

8.3.5.2 Twin Invert Manholes

Worcester has over 3,000 twin invert manholes. Twin invert manholes are manholes that contain both the parallel wastewater and stormwater pipes. A removable plate within the manhole typically separates the two systems. These manholes generally function as separate lines during dry-weather flow. However, when wet weather causes flow to increase and surcharge within the manhole, the wastewater and stormwater can mix. This interaction can result in increased flow to the Upper Blackstone Treatment Facility, sanitary sewer overflows or release of sewage into the stormwater system.

As part of the Integrated Plan, replacing twin invert manholes with separate manholes within the Annual Pipeline Renewal Programs will be incorporated. If twin invert manholes are located within a project's limit of work, replacement of these twin invert manholes is included in the project scope of work.

8.3.5.3 Preparedness and Vulnerability Mitigation

Concurrent with the development of this Integrated Plan, the City conducted a preparedness planning and vulnerability study to preserve and protect assets susceptible to the impacts of climate related-natural hazards. Grant funding made available through the Massachusetts Executive Office of Energy and Environmental Affairs Municipal Vulnerability Preparedness program was used to complete this study.

As part of the study, community stakeholders identified three (3) climate-related natural hazards impacting Worcester:

- Flooding from extreme precipitation (heavy rain)
- Ice and snowstorms coupled with extreme cold
- Extreme heat coupled with drought

The study also included risk and vulnerability assessments, building upon the work completed in the 2018 Draft Hazard Mitigation Plan, to develop resilient solutions aimed at mitigating the impacts of identified hazards.

As a certified Municipal Vulnerability Preparedness community, the City is positioned for potential funding from the program to support efforts that incorporate the recommended resilient solutions.

Several of the infrastructure investments identified within the Integrated Plan will further support Worcester's resiliency efforts. In particular, the Integrated Plan's focus on infrastructure investments in the collection systems addresses the need to increase capacity to handle higher intensity storm events. Addressing the highest risk infrastructure early in the implementation schedule further supports resilient solutions. Focused investments in the drinking water system will protect the water supply and minimize leaks and breaks, creating a more resilient system to mitigate the effects of drought.

The City will seek additional opportunities to incorporate resilient infrastructure solutions throughout implementation of the plan.

Descriptions for all proposed wastewater and stormwater infrastructure investments included in the 50-year planning period can be found in **Appendix 8.2**.

8.4 Drinking Water System Capital Improvement Plan

The Drinking Water System Capital Improvement Plan consists of annual investment in infrastructure and maintenance to ensure safe drinking water for Worcester residents and businesses. The plan is grouped into five categories of investment representing major components of the system. The investment approach adheres to operations and maintenance best practices and industry standards, as well as balancing financial commitments. This plan will guide annual budget development for water system operations, maintenance, and long-term infrastructure investments.

The five categories consist of the following:

- Supply (Reservoirs and Dams)
- Treatment (Water Filtration Plant)
- Pumping and Storage (Pump Stations and Tanks)
- Distribution (Mains, Valves, Hydrants, and Meters)
- Building/Facilities Rehabilitation

8.4.1 Annual Capital Cost Summary

The Drinking Water System Capital Improvement Plan is a 50-year management plan starting in Fiscal Year (FY) 2021 that totals $538 million. The plan averages approximately $13.2 million per year for the first 10 years of the plan. Several large projects contribute to a higher annual average cost during this decade relative to the others, including the following:

- Water Meter Replacement Program ($2.5M per year, FY 2021-2024)
- Pine Hill Dam Rehabilitation ($5M per year, FY 2022-2023)

Years 11 through 20 (FY 2031-2040) average approximately $8.6 million per year. The remaining 30 years of the plan (FY 2041-2070) average approximately $10.7 million per year.

The Drinking Water System Capital Improvement Plan prescribes annual spending amounts for each year to guide budget development. **Figure 8.1** presents the annual cost and how each system category comprises that total. **Figure 8.2** presents the investments over the life of the plan, the implementation schedule, and annual costs for recurring programs. **Appendix 8.3** provides a detailed breakdown of the Drinking Water System Capital Improvement Plan implementation schedule with costs per year, and an overview of annual budget by decade over the 50-year planning period.

8.4.2 Supply

The drinking water supply category consists of reservoir and dam improvements. The implementation schedule includes periodic investments for various dam and reservoir rehabilitation projects including a recurring expense for reservoir gate house valve replacements. Drinking water supply also includes an annual capital cost for land acquisition to protect the water supply. Cost and frequency are dependent on the size and the criticality of the system component.

8.4.3 Treatment

The drinking water treatment category consists of upgrades to and rehabilitation of the Water Filtration Plant. Projects primarily focus on cyclical expenses, such as modifications or upgrades to the major treatment components, filtration plant building rehabilitation, and maintaining the telemetry/supervisory control and data acquisition system.

8.4.4 Pumping and Storage

The drinking water pumping and storage category consists of periodic replacement or rehabilitation of pump stations and storage tanks. These periodic rehabilitation projects are scheduled at specific intervals according to industry standards.

8.4.5 Distribution

The drinking water distribution category consists of recurring costs for infrastructure rehabilitation of citywide drinking water system components, such as hydrant replacement, transmission and water main rehabilitation programs, and a water meter replacement program. Each of these require annual funding throughout the 50-year planning period, as shown in **Figure 8.2**.

8.4.6 Building/Facilities Rehabilitation

This investment category consists of miscellaneous costs to maintain the drinking water system buildings and facilities. The implementation schedule covers annual costs for facilities rehabilitation and periodic costs for water system security.

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FIGURE 8.1: DRINKING WATER SYSTEM CAPITAL IMPROVEMENT PLAN ANNUAL COST

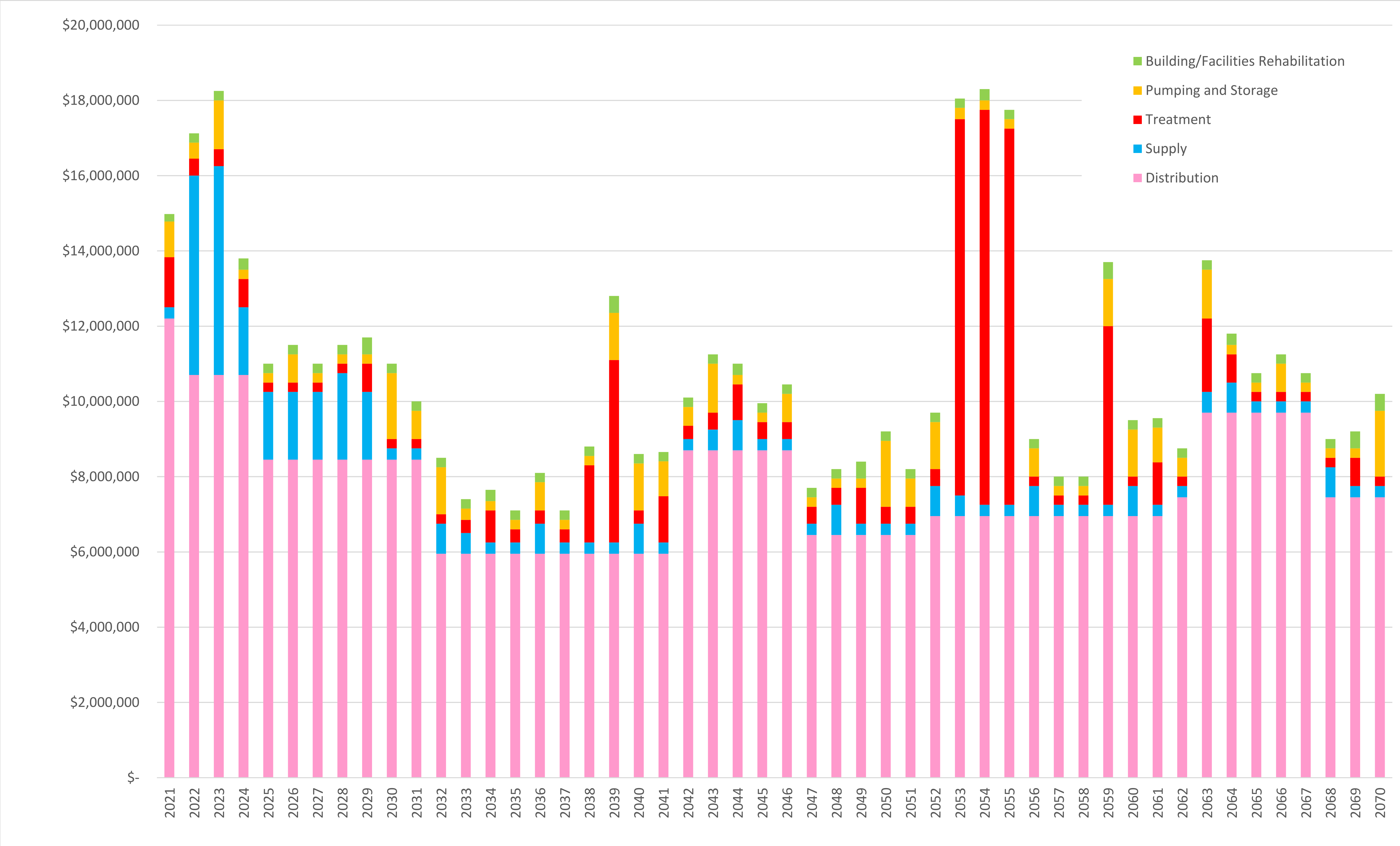
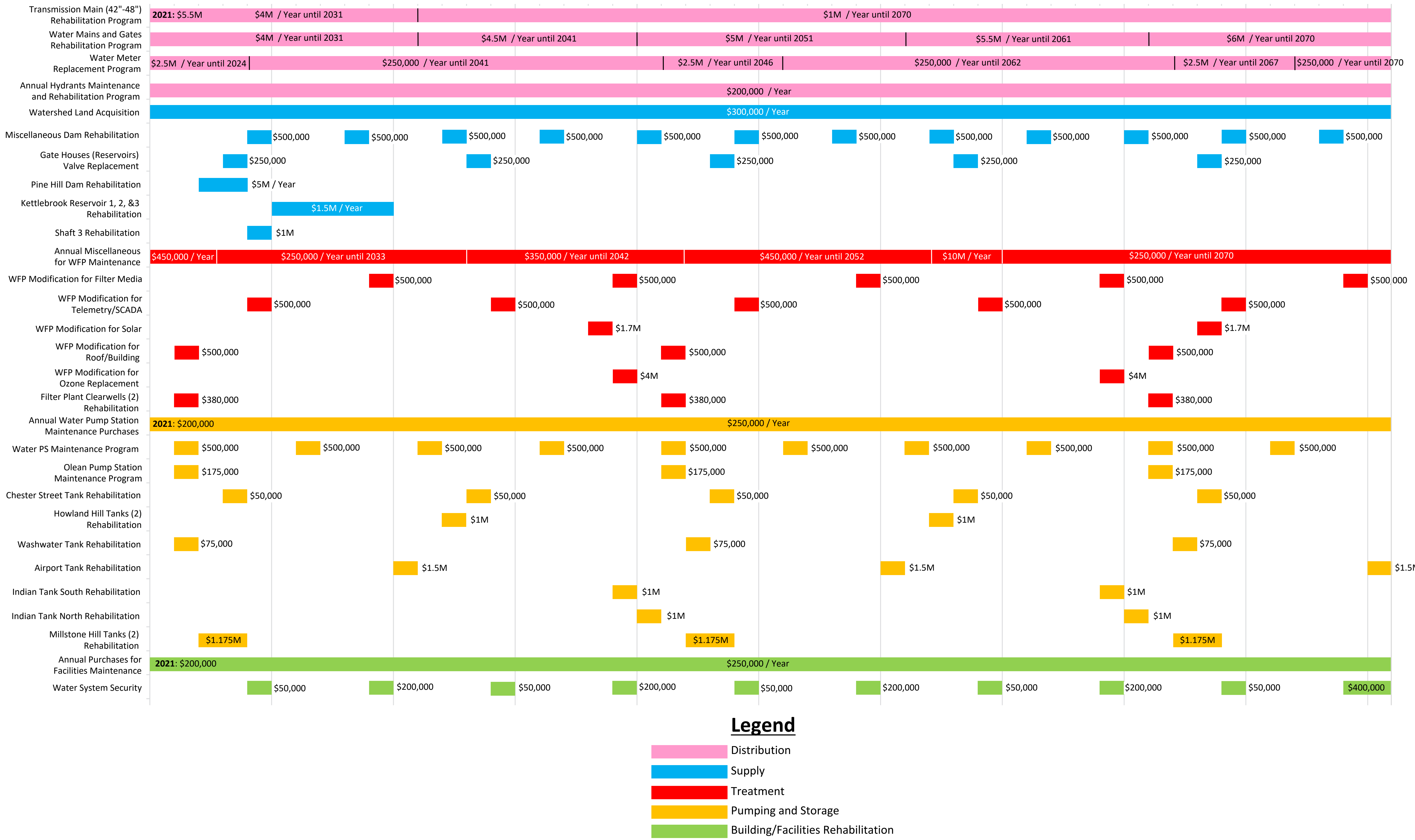


FIGURE 8.2: DRINKING WATER SYSTEM CAPITAL IMPROVEMENT PLAN IMPLEMENTATION SCHEDULE



8.5 Wastewater and Stormwater Systems Capital Improvement Plan

The implementation schedule set forth in this Integrated Plan recommends sequencing of water resources infrastructure investments based on established priorities. This Integrated Plan covers a 50-year period starting in fiscal year (FY) 2021. The implementation schedule will be reviewed and may be modified at appropriate intervals throughout the planning period as financial conditions change or other factors arise that impact affordability, as discussed in **Chapter 10**.

Investments in the wastewater and stormwater systems are incorporated to achieve the greatest environmental and public health benefits. Investments are classified by four categories:

- Capital Reinvestment
- New Capital Investment
- Study and Assessment
- Upper Blackstone Treatment Facility Asset Investment

The plan is designed to be adaptable to changing environmental, financial, and social conditions to ensure sustainability. It will be used to guide annual budget development for operations, maintenance, and long-term investments.

Figure 8.3 presents the annual cost for each system category, and **Figure 8.4** shows the overall implementation schedule for the Wastewater and Stormwater Systems Capital Improvement Plan.

8.5.1 Capital Reinvestment

This implementation schedule focuses initial spending on capital reinvestment projects. The implementation schedule of capital reinvestment projects is shown in **Figure 8.5**.

The City has a backlog of specific capital reinvestment projects that have been evaluated and preliminarily designed totaling approximately $34 million. These reinvestment projects achieve multiple benefits as determined through the benefits model screening detailed in **Chapter 6**. As such, they are scheduled for implementation within the first nine years of the Integrated Plan (by FY 2029). The scopes of these projects have been developed using system inspections and maintenance records with a primary focus of renewing collection system assets in poor or failing condition. Assets include some of the largest and most critical pipelines in the wastewater and stormwater systems, many of which are nearing failure or require significant attention to operate and maintain. Implementation is scheduled using project-specific engineering analyses of risk including probability and consequence of failure based on the risk model (detailed in **Chapter 5**).

The first nine years of the Integrated Plan schedule include rehabilitation of 372,500 linear feet of wastewater and stormwater pipelines, of which 61,500 linear feet are high-risk interceptor pipelines. This accounts for approximately 8.3% of the total wastewater and stormwater collection system length. Beyond FY 2029, the schedule includes rehabilitation of 28,000 linear feet of wastewater and stormwater pipelines per year from the Draper Pipe Replacement Program, Annual Pipeline Renewal Program, and Annual Interceptor Renewal Program.

The implementation of these capital reinvestment projects will address the high costs associated with operating and maintaining failing water resources systems. An example is the significant investment allocated to the Draper Pipe Replacement Program starting in Year 1 of the schedule.

This program includes replacement of all 204,000 linear feet of Draper pipe. This pipe material has caused widespread failures, leading to sinkholes, sanitary sewer overflows, and basement backups. Systematically replacing Draper pipe will save costly emergency repairs that would otherwise be required from pipe failures.

The scope of the Annual Pipeline Renewal, Annual Interceptor Renewal, and Pump Station Renewal Programs will be determined as system inspections are conducted. The specific location of future system investigation projects discussed in the following section will be based on the risk models for the wastewater and stormwater collection systems (**Chapter 5**).

Prioritizing renewal and reinvestment projects is an important step toward more effective management of the City's water resources systems. Investments address deferred issues that disrupt operations, services to residents, and public safety.

8.5.1.1 Operations and Maintenance

Operations and maintenance costs have risen faster than inflation and are expected to continue to rise as the cost of labor and utilities increase. Operating and maintaining the systems becomes more expensive as they continue to degrade. More frequent emergency responses are necessary to restore proper operation. In conjunction with the Capital Reinvestment category, the City must continue to invest in operations and maintenance efforts to keep up with its aging infrastructure. This Integrated Plan recognizes that an increased focus on operations and maintenance is critical to proper management of the water resources systems as a whole and represents a necessary component of the plan.

As detailed in **Chapter 7**, this Integrated Plan includes augmenting Sewer Division and Water Division staff for improved system maintenance. The selected spending scenario assumes 10 additional Sewer Division full-time staff hires within the first five years and three additional Water Division full-time staff hires within the first three years. The additional staff will allow the City to perform increased wastewater system inspections and maintenance, pump station maintenance, and drinking water system maintenance.

8.5.2 New Capital Investment

New capital investments are important to meet population and economic growth, and to protect the environment.

This Integrated Plan schedules new capital investments based on the benefits model screening. Investments that provide the highest multi-benefit scores are prioritized in the Integrated Plan. New capital investments are scheduled to start in year 10 (FY 2030), after focusing on the capital reinvestment and study and assessment categories initially. The schedule balances new capital investments and annual renewal programs. The implementation schedule for new capital investments is shown in **Figure 8.6**.

The implementation schedule is driven by affordability factors. High-cost investments require additional time to accumulate funding and retire debt before implementation.

The Upper Blackstone Treatment Facility nutrient upgrade projects fall into the category of New Capital Investment. The benefits model, along with other considerations within this Integrated Plan, determined that the schedule for nutrient removal Phase B, nutrient removal Phase C, and High-Flow Reduction and Management be modified to FY 2034, 2038, and 2051, respectively. Upper Blackstone Treatment Facility investments are presented as full project costs; however, the City's share of these investments would be approximately 85% of the value (as described in **Chapter 7**) and would be assessed to the City by the Upper Blackstone District.

Additional capital investments to enhance the Stormwater Management Program are scheduled based on the results of the benefits model.

8.5.3 Study and Assessment

This Integrated Plan includes studies and assessments of the City's water resources systems to identify, inform, and measure success of both capital reinvestment and new capital investment. Data collected from system inspections will be used to build and prioritize annual renewal programs and future capital projects. Studies and assessments are integral in developing an efficient and optimal long-term approach to addressing the City's water quality performance gaps and to determine capital spending that addresses the highest priority environmental and public-health risks. The implementation schedule for study and assessment projects is shown in **Figure 8.7**.

FIGURE 8.3: WASTEWATER AND STORMWATER SYSTEMS CAPITAL IMPROVEMENT PLAN ANNUAL COST

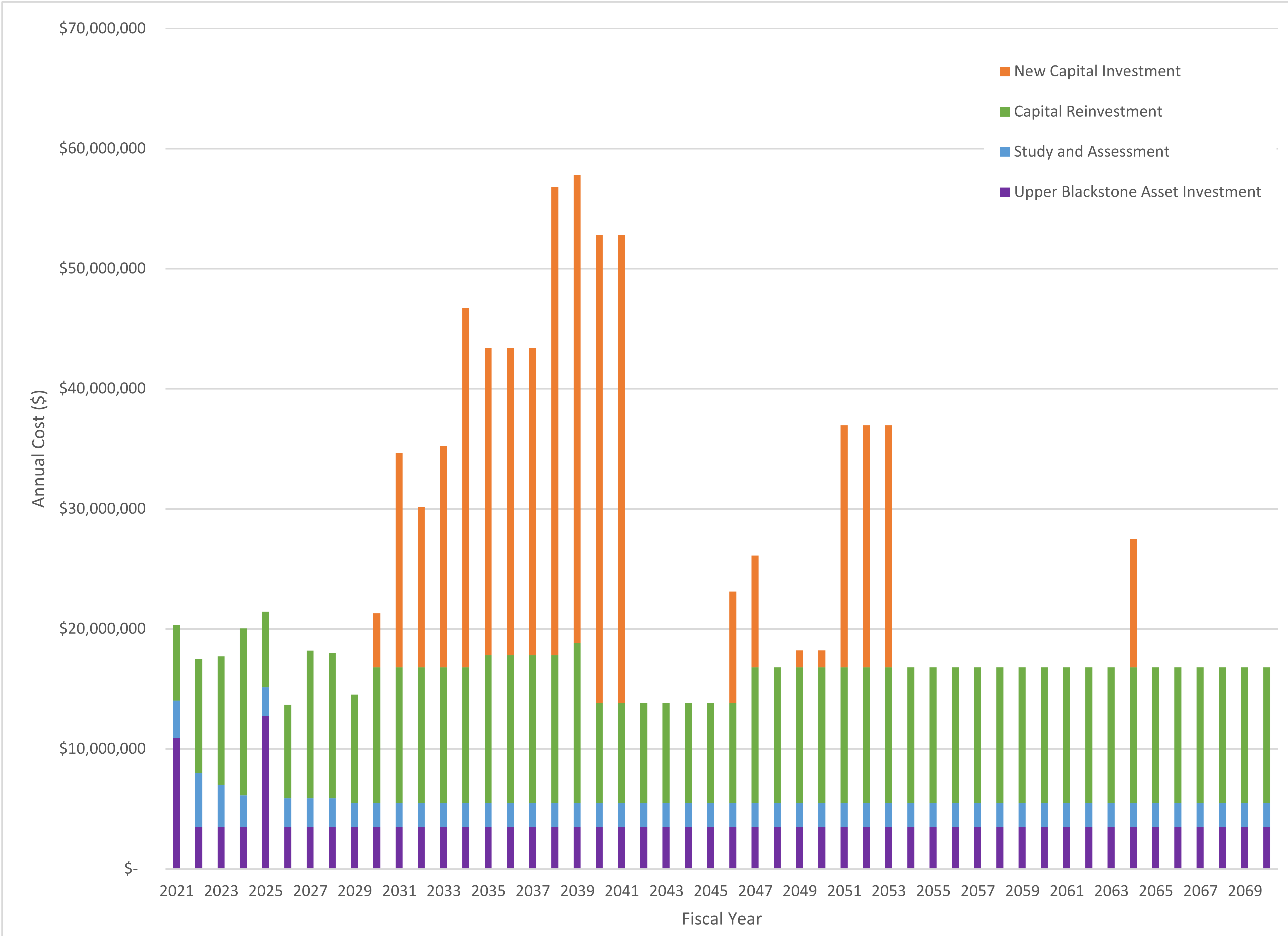


FIGURE 8.4: WASTEWATER AND STORMWATER SYSTEMS CAPITAL IMPROVEMENT PLAN IMPLEMENTATION SCHEDULE

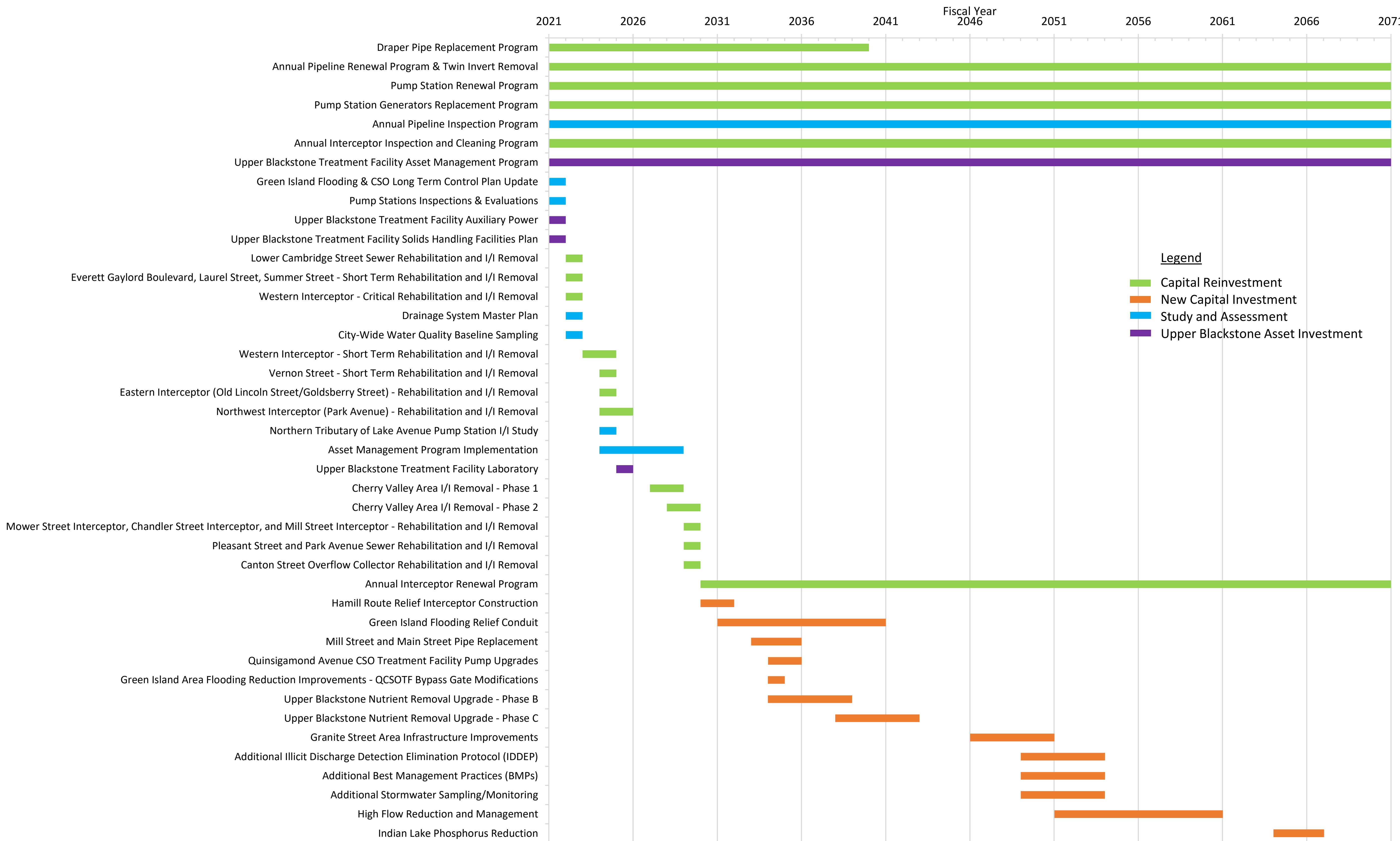


FIGURE 8.5: CAPITAL REINVESTMENT IMPLEMENTATION SCHEDULE

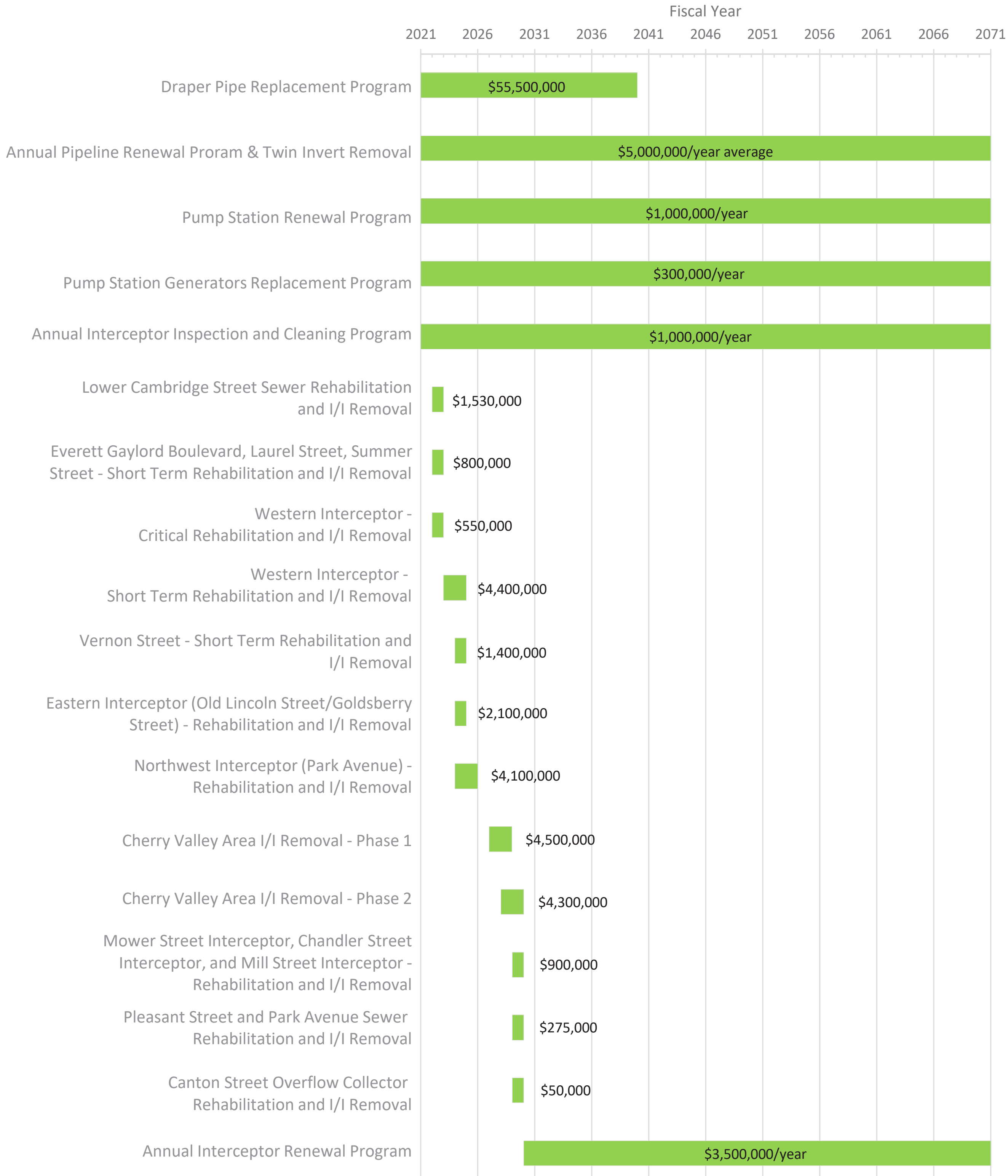


FIGURE 8.6: NEW CAPITAL INVESTMENT IMPLEMENTATION SCHEDULE

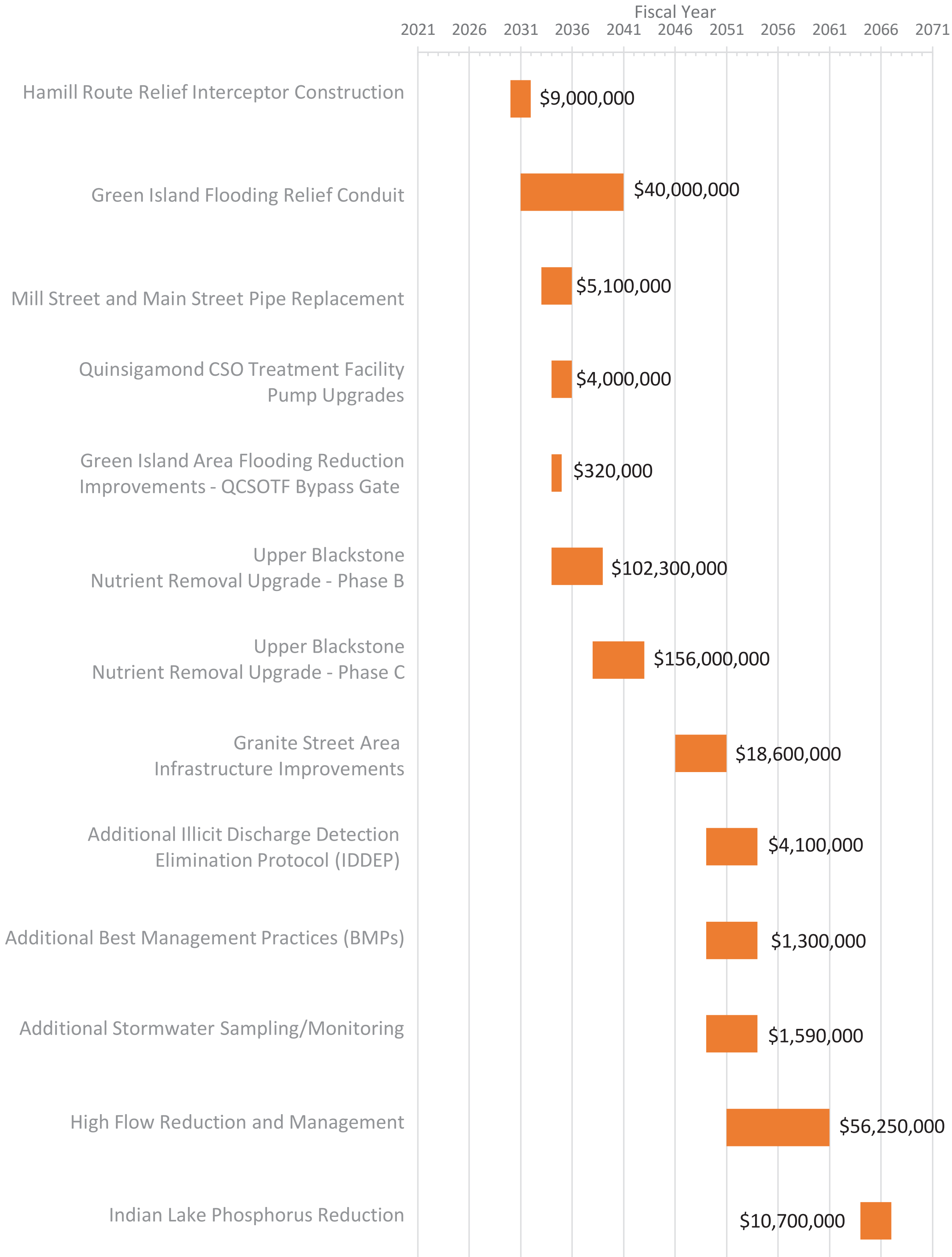
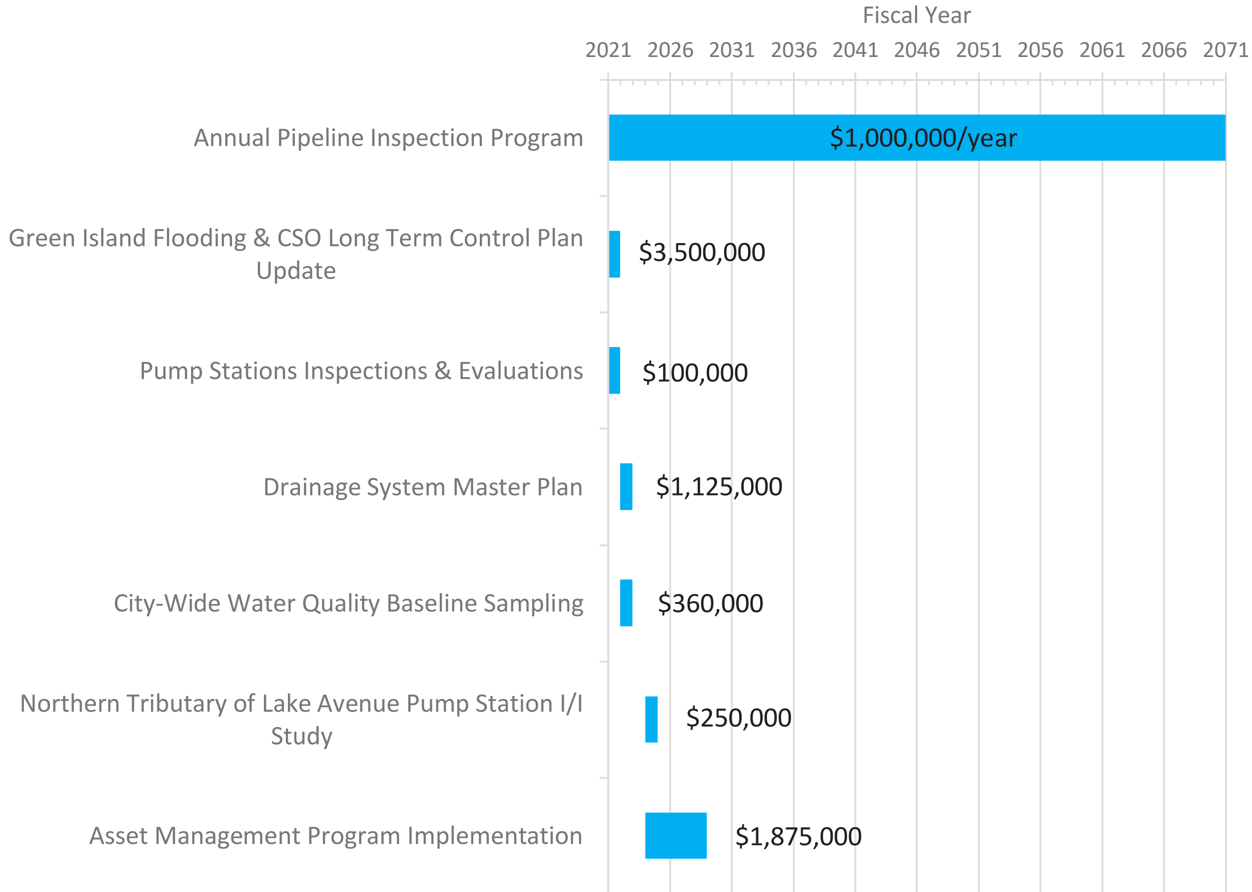


FIGURE 8.7: STUDY AND ASSESSMENT IMPLEMENTATION SCHEDULE



The implementation schedule for studies and assessments follows the results of the benefits model screening adjusted to prioritize low-cost studies with multiple citywide benefits. These studies and assessments provide important information to understand issues, can inform future recommendations and projects, and can be completed in parallel with other infrastructure investments and maintenance. All identified studies and assessments will be initiated in the first four years of the Integrated Plan.

The implementation schedule includes annual spending for assessment and cleaning of the wastewater and stormwater systems, with specific budgets allocated to assessing the condition of all pump stations. Assessment programs include:

- Inspecting 20,000 linear feet of wastewater interceptor sewer (pipes greater than 18 inches in diameter) per year, resulting in a 16-year system-wide annual inspection cycle.
- Inspecting 100,000 linear feet of non-interceptor wastewater and stormwater pipes per year, resulting in a 24-year system-wide annual inspection cycle.
- Inspection and evaluation of all pump stations in the City. This assessment will be implemented in Year 1 of the plan.

Inspection data will be used to update the risk models and identify specific infrastructure investments under the Annual Pipeline Renewal, Annual Interceptor Renewal, and Pump Station Renewal Programs.

Investing in studies and assessments reiterates the City's commitment to analyze the aging water resources infrastructure to determine where improvements are most needed to protect the environment and service the needs of a growing economy.

8.5.4 Upper Blackstone Treatment Facility Asset Management

Capital investments at the Upper Blackstone Treatment Facility are scheduled as required to maintain the current capacity and level of effluent water quality. An annual investment of $3.5 million is planned for asset assessment, rehabilitation and renewal under the Upper Blackstone Treatment Facility Asset Investment category.

The Upper Blackstone Treatment Facility operations are currently at-risk during power outages due to the absence of adequate backup auxiliary power. Installation of backup auxiliary power is scheduled in Year 1 (FY 2021) to mitigate this risk.

Replacement of the Upper Blackstone Treatment Facility's laboratory has been identified as a short-term need to maintain compliance with National Pollutant Discharge Elimination System permitting requirements for sampling, as well as tracking effectiveness of the treatment process. Replacement of this facility is included in FY 2025.

The Upper Blackstone District currently serves as a regional solids waste facility, accepting sludge from other communities as a revenue source. The Upper Blackstone Treatment Facility is in need of an upgrade or replacement of its existing incinerators with a new solids handling facility, which is estimated to cost between $110-120 million.

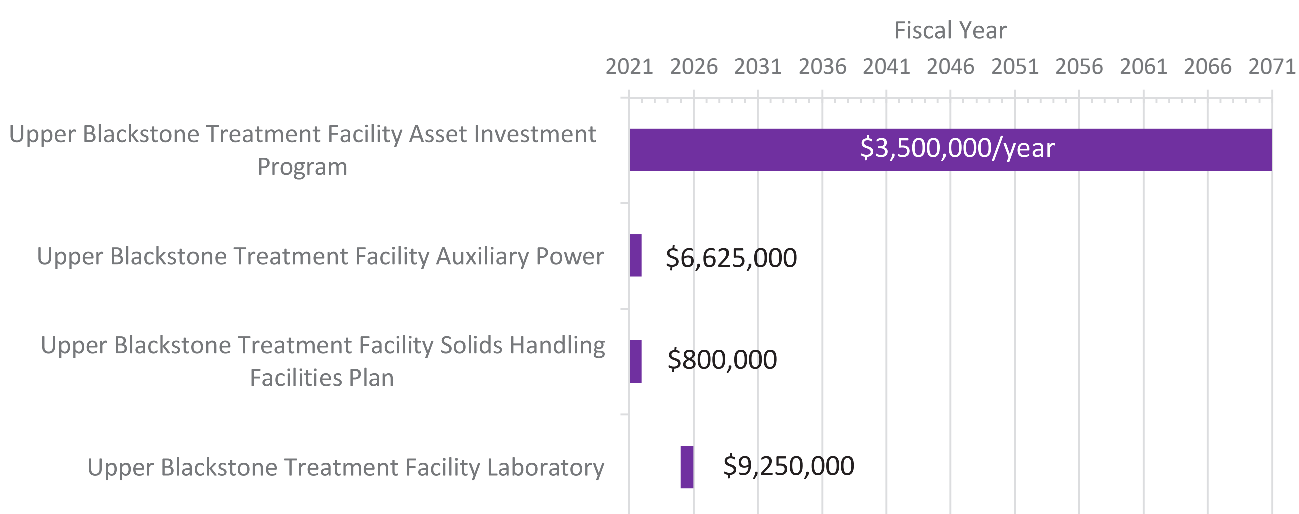
Due to the uncertainty of the preferred alternative, the cost of a new solids handling facility is not included in the plan. Instead the Upper Blackstone Treatment Facility Solids Handling Facilities Plan will examine if a new solids handling process or transporting solids to an off-site treatment plant is the most cost-effective option for the District. Recommendations from this study will be incorporated into this Integrated Plan through a future update.

The implementation schedule for the Upper Blackstone Treatment Facility Asset Investment category is shown in **Figure 8.8**.

8.5.5 Detailed Annual Cost

In addition to the required cost to maintain safe, clean drinking water, this Integrated Plan focuses on four key investment categories. **Appendix 8.4** provides an overview of annual spending over the 50-year planning period and a detailed breakdown of the investment costs per year. The planned investments also include New Sewer Construction, which represents an annual budget for expanding the wastewater system. The cost for this investment is typically recouped through sewer betterment assessments. An annual investment in Building Rehabilitation is also included, which covers miscellaneous repair needs, outside of the capital projects identified through this Integrated Plan.

FIGURE 8.8: UPPER BLACKSTONE TREATMENT FACILITY ASSET INVESTMENT IMPLEMENTATION SCHEDULE



The Integrated Plan's annual cost averages approximately $18.9 million per year for the first 10 years of the plan (FY 2021-2030). Years 11 through 25 (FY 2031-2045) average approximately $37.4 million per year due to several complex projects which have substantially higher annual costs. These projects include:

- **Year 2031:** Green Island Flooding Relief Conduit ($40 million)
- **Year 2034:** Phase B Nutrient Removal Upgrade ($102.3 million)
- **Year 2038:** Phase C Nutrient Removal Upgrade ($156 million)

8.5.6 Plan Improvements and Adjustments

Infrastructure investments and their associated costs are at a stage of conceptual or preliminary design and require further analysis prior to implementation. Final engineering design will consider green infrastructure opportunities as described in **Section 8.3.5.1**. Based on the results of the analysis, green infrastructure will be implemented where feasible and cost-effective.

The Integrated Plan implementation schedule is a "living document" and will be reviewed on a regular basis to determine if the plan should be adjusted in accordance with the adaptive management methodology provided in EPA's integrated planning framework and as recommended herein. Some of the factors that may shift the Integrated Plan implementation schedule include:

- City Council rejects recommended water and sewer rate increases.
- Unforeseen conditions during implementation cause additional costs or delays.
- Unanticipated needs or costs associated with existing water resources systems.
- Unanticipated regulatory obligations.
- Changes in economic conditions.

The following chapters outline the process to measure the success of this Integrated Plan as well as accommodations for adaptive management.

CHAPTER 9.
Measuring Success — Post-Construction Monitoring Plan

9.1 Overview

This chapter presents an iterative process for measuring the success of this Integrated Plan and monitoring infrastructure investments after implementation to evaluate their impact. As the recommended plan progresses, the process to measure success will inform whether adjustments to the plan are necessary. This is the basis of adaptive management that will be discussed further in **Chapter 10**.

9.2 Performance Evaluation

This Integrated Plan discussed system performance in **Chapter 3**. Operations and systems were reviewed to identify the following four components:

1. Key Performance Indicators
2. Baseline Performance, which identifies the current conditions
3. Performance Targets, which include consulting industry standards and benchmarks
4. Performance Gaps, which document the difference, or gap, between the baseline performance and performance target

The next two steps in the process will be an ongoing effort to evaluate and improve the effectiveness of the Integrated Plan:

5. Measuring Performance
6. Improving the plan (**Chapter 10** — Adaptive Management)

9.3 Performance Measurement

Performance measurements in this Integrated Plan include three categories of wastewater and stormwater infrastructure investments to be measured: capital reinvestment, new capital investment, and study and assessment.

9.3.1 Capital Reinvestment

Capital reinvestments focus on renewal of existing infrastructure. Examples include cleaning and removing excessive sediment and debris, rehabilitating structural deficiencies, and replacing infrastructure that has exceeded its useful service life. **Table 9.1** identifies the capital reinvestment metrics that measure success.

Performance metrics related to capital reinvestments will be measured over time to identify trends. Data for each of these metrics will be tracked in the following ways:

Pipe Age

Post-construction monitoring will track the linear footage of pipeline renewed each year.

Loss-of-Service Complaints

Loss-of-service complaints will be recorded using the Customer Service Request System database.

Unplanned Maintenance

Unplanned activities and associated resources required will be tracked using the City's Computerized Maintenance Management System. In addition, monitoring unplanned maintenance will inform the City of recurring issues in their system.

Non-Capacity Sewer Overflow Rate

Overflows are reported to EPA and MassDEP. The number of reported events per 100 miles of pipe per year will be tracked.

9.3.2 New Capital Investment

New capital investments improve or expand the existing wastewater and stormwater collection systems by constructing new infrastructure to eliminate hydraulic deficiencies, provide service for new developments, and meet regulatory mandates. **Table 9.2** identifies the combined capital investment metrics that can be used to measure success.

Similar to capital reinvestments, new capital investment metrics will be measured over time to demonstrate trends in performance. Data for each of these metrics will be tracked in the following ways:

Capacity Sewer Overflow Rate

Overflows are reported to EPA and MassDEP. The number of reported events per year per 100 miles of pipe will be tracked.

Street Flooding Within Green Island Area and Street Flooding Outside Green Island Area

Street flooding events will be tracked using the Customer Service Request System database and the Computerized Maintenance Management System.

9.3.3 Study and Assessment

Studies and assessments are a necessary component of this Integrated Plan. The success of studies and assessments is based on their completion, as they will inform baseline performance.

Once studies and assessments are completed, baseline performance will be updated where applicable, and the performance gaps will be better defined based on the more accurate baseline conditions. Two examples of studies that may result in plan modifications are:

Drainage System Improvements

The City's drainage infrastructure is a complex, inter-dependent system. Flooding is a common occurrence even during minor rain storms. Currently the City tracks and responds to flooding incidents as they occur. The recommended Drainage System Master Plan will evaluate key drainage components, such as culverts and structures, and address localized flooding through a phased approach by subcatchment areas. This study is scheduled to begin in 2022.

Infiltration and Inflow (I/I)

Extraneous flow entering the wastewater system in the form of infiltration and inflow reduces the capacity of City sewers to convey peak flows. Although the gap analysis in **Chapter 3** shows the City meeting the established benchmark for infiltration and inflow on a system-wide basis, certain areas of the system are known to have high rates of infiltration and inflow. The first infiltration and inflow study recommended in the plan, Northern Tributary of Lake Avenue Pump Station Infiltration and Inflow Study, is scheduled to begin in 2024. This study will quantify and provide recommendations to reduce infiltration and inflow within the study area and flow to the pump station.

TABLE 9.1: CAPITAL REINVESTMENT PERFORMANCE METRICS

Key Performance Indicator	Baseline Performance	Performance Target	Performance Gap
Wastewater Pipe Age *(% of system exceeding service life)*	34.7	0	34.7
Stormwater Pipe Age *(% of system exceeding service life)*	18.4	0	18.4
Loss-of-Service Complaints *(per year)*	234	176	58
Unplanned Maintenance *(hours per 100 miles of pipe per year)*	3,303	1,257	2,046
Non-Capacity Sewer Overflow Rate *(events/100 miles of pipe per year)*	3.92	1.31	2.61

TABLE 9.2: NEW CAPITAL INVESTMENT PERFORMANCE METRICS

Key Performance Indicator	Baseline Performance	Performance Target	Performance Gap
Capacity (Wet Weather) Sewer Overflow Rate *(events per 100 miles of pipe per year)*	0	0.7	No gap
Street Flooding Rate Within Green Island Area *(days with Customer Service Request System complaints per year)*	9.5	6	3.5
Street Flooding Rate Outside Green Island Area *(days with Customer Service Request System complaints per year)*	51	39	12

Studies will also inform the City's risk model, as discussed in **Chapter 5**. The risk model is used to grade renewal of high-risk wastewater and stormwater collection system assets. As additional condition information is gathered through system inspections, the risk model will be updated to more accurately depict existing conditions, and the plan for system renewal will be modified. The risk model development and findings are summarized in **Appendix 5.2**.

9.3.4 Post-Construction Monitoring

While performance metrics can be used to measure long-term trends, individual project successes can be tracked through post-construction monitoring. Post-construction monitoring is a short-term assessment of the progress of ongoing projects before long-term trends are available.

Post-construction tracking will be used to compile information on a regular basis, such as:

- Wastewater pipe installed (linear feet)
- Wastewater pipe replaced (linear feet)
- Wastewater pipe rehabilitated (lined, spot repair, etc.) (linear feet)
- Wastewater pipe cleaned/inspected (linear feet)
- Stormwater pipe installed (linear feet)
- Stormwater pipe replaced (linear feet)
- Stormwater pipe rehabilitated (lined, spot repair, etc.) (linear feet)
- Stormwater pipe cleaned/inspected (linear feet)
- Twin invert manholes separated (number)
- Catch basins installed (number)
- Green infrastructure installed (square feet or number)

Other metrics may be tracked as needed.

9.3.5 Financial Performance

Measuring financial performance is an important step to evaluate adjustments to water and sewer rates.

The City reviews the financial performance of its water and sewer enterprise funds annually as part of its regular budgeting and rate setting process. This review begins by comparing actual revenue and costs from the prior fiscal year to its budgeted revenue and costs. The majority of enterprise fund revenue is rate revenue based on water consumption, so a decrease in consumption means less revenue, which is a continuing trend in the City. For the sewer account, the single largest cost is the City's annual assessment from the Upper Blackstone Treatment Facility for wastewater treatment. The City pays approximately 85% of the Upper Blackstone Treatment Facility costs. Most of the remaining sewer account costs are fixed. In addition, the City reviews costs from unanticipated events and emergencies. Past revenue and costs are used to establish trends to guide budget assumptions for the future.

The City's Comprehensive Annual Financial Report is the key resource used to obtain the data needed for its annual financial review. The Comprehensive Annual Financial Report is prepared by the City's Auditing Department, independently audited by a third party, and published annually for the City Council. The Comprehensive Annual Financial Report summarizes the budgeted and actual schedule of revenues, expenditures, and changes in fund balance for the Water and Sewer Enterprise Funds using the City's financial statements. **Appendix 7.2** contains the FY18 Comprehensive Annual Financial Report.

If the City's annual financial performance review indicates significant changes to anticipated revenue and costs for the next fiscal year, the City will assess potential impacts to the water and sewer rates. **Table 9.3** lists the financial metrics that may be considered.

These financial metrics support the City's preliminary assessment by:

- Recognizing whether past and current rate adjustments align with the plan's recommendations.
- Accounting for tax levies as another financial burden ratepayers are facing.

- Considering whether the current account balance is adequate for unanticipated or emergency events.
- Identifying whether too much budget is dedicated to debt service.
- Reviewing the City's bond rating, which affects its ability to finance Integrated Plan projects at favorable interest rates.

9.4 Adaptive Management

The foregoing forms the basis of adaptive management, discussed in **Chapter 10**.

TABLE 9.3: POTENTIAL FINANCIAL PERFORMANCE METRICS

Measurement	Description
User Fee Rate Change	The percent increase in water and sewer rates in the prior year or past several years.
Tax Levy Status	The percent increase in the tax rate in the prior year or past several years.
Account Balance	The available cash on hand in the enterprise funds to cover unanticipated costs.
Debt Service Coverage Ratio	The percent of the annual account budget dedicated to debt service.
Bond Rating	An indication of the issuer's financial strength. The ratings affect the interest rate that government agencies pay on their issued bonds.

CHAPTER 10.
Adaptive Management Process

10.1 Overview

This Integrated Plan will require review and periodic adjustments to ensure it is meeting the stated goals. As such, this Integrated Plan incorporates an adaptive management approach, which is a method to modify and update the plan as needed to respond to changes in economic, social, environmental and infrastructure conditions.

The adaptive management approach consists of plan assessments at various times throughout the 50-year planning period. These plan assessments, which include affordability reviews, allow the City to make modifications based on changing circumstances or project outcomes.

Financial planning beyond a 10-year horizon is not valuable. The economic climate can change significantly, and it is not practical or accurate to project affordability beyond the initial 10-year financial planning period. Periodic reviews will keep the plan at an appropriate level of affordability.

10.2 Adaptive Management

Adaptive management provides opportunities to check on key aspects of the plan — benefits and affordability — and to adjust the implementation schedule. This approach assesses completed infrastructure investments and progress toward closing performance gaps, as detailed in **Chapter 9**. Plan assessments scheduled at set times throughout the 50-year period are referred to as program milestones.

Reviewing the plan during program milestones or after unforeseen events, including financial reviews, will not always result in changes. The review process is an opportunity to determine if infrastructure investment needs are being met and, if not, adjusted.

Adaptive management of the Integrated Plan may include:

Adding New Projects Based on the Results of Completed Studies

If a completed study identifies infrastructure improvements that can effectively contribute to closing performance gaps.

Rerunning the Benefits Model

If new infrastructure improvements are identified, the City will use the benefits model to assess their benefits and understand priority.

Reprioritizing Recommended Projects

If future benefits modeling alters the priority of the recommended projects or trends from the post-construction monitoring plan alter the implementation schedule.

Assessing Affordability

To ensure the plan remains within the established affordability parameters set herein.

Changing the Adaptive Management Schedule

As needed to match changes in the plan's implementation schedule and reprioritization.

Modifying the Implementation Schedule

If specific rate increases are not approved by City Council.

10.2.1 Program Milestones

The adaptive management approach identifies milestones based on the completion of major portions of the implementation schedule and in five-year increments. **Table 10.1** and **Figure 10.1** summarize the plan and schedule for program milestones.

10.2.2 Unforeseen Events

Unforeseen events may cause plan assessments. Unexpected events have the potential to impact the priorities and affordability of the plan. Future changes to drinking water regulations will impact the City's ability to implement this Integrated Plan, and therefore may require a plan reassessment. It may be necessary to replace the biosolids handling system, including the incinerator, at the Upper Blackstone Treatment Facility. Future air quality requirements and continued acceptance of incineration of organic matter are uncertain. The timing and magnitude of this investment is currently unknown, as discussed in **Section 8.5.4**, and will be considered as part of future plan reassessments.

Figure 10.2 shows other examples of these potential events.

10.2.3 Affordability

Changing economic conditions will require a detailed reassessment of financial capability as part of the adaptive management approach. The long-term financial plan acts as a guide in scheduling Capital Reinvestments, New Capital Investments, and Studies and Assessments. Scheduling of Upper Blackstone Treatment Facility Asset Investments will generally remain unchanged as these investments are critical to maintain discharge water quality. This reassessment strategy aims to balance financial impacts to ratepayers with an appropriate annual investment needed to implement the plan as financial conditions change.

This Integrated Plan is a long-term commitment to improve the community and benefit the region.

Reassessment may occur:

- Annually as part of the budgeting process for enterprise funds
- Concurrent with a milestone-based program assessment

- Initiated separately, as needed, based on unforeseen events

The key steps in a reassessment of financial capability include the following:

- Adjusting annual fixed cost inputs for the enterprise funds and for the recommended implementation schedule based on any changes that occurred, such as changes to investment needs, faster or slower project implementation, changes in project costs.
- Running the City's financial rate model and projecting rate increases for the future 10 years to understand impacts and select an appropriate and balanced financial plan.

This Integrated Plan is a long-term commitment to improve the community and benefit the region. The adaptive management approach ensures that the City is effectively managing its infrastructure, protecting public health, and addressing regulatory needs as conditions change, in a way that is consistent with the Integrated Plan goals.

TABLE 10.1: PROGRAM MILESTONES SUMMARY

Milestone	Plan Year	Anticipated Status
M1	2026	• Completion of Major Studies: ◦ Drainage System Master Plan ◦ CSO Long Term Control Plan Update ◦ Pump Stations Inspections & Evaluations • Draper Pipe Replacement Program: 28% complete • Completion of seven I/I rehabilitation and removal projects
M2	2031	• Completion of the Asset Management Program Implementation • Draper Pipe Replacement Program: 56% complete • Completion of five rehabilitation and I/I removal projects • Hamill Route Relief Interceptor Construction underway
M3	2036	• Completion of New Capital Investments: ◦ Hamill Route Relief Interceptor Construction ◦ Mill Street and Main Street Pipe Replacement ◦ Green Island Flooding Reduction Improvements ◦ Quinsigamond Avenue CSO Treatment Facility Pump Upgrades • Upper Blackstone Treatment Plant Nutrient Removal Upgrade Phase B underway
M4	2041	• Completion of the Draper Pipe Replacement Program • Completion of the Upper Blackstone Treatment Plant Nutrient Removal Upgrade - Phase B
M5	2046	• Completion of the Upper Blackstone Treatment Plant Nutrient Removal Upgrade - Phase C
M6-M10	2051-2071	• See **Figure 10.1**

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FIGURE 10.1: PROGRAM MILESTONES SCHEDULE

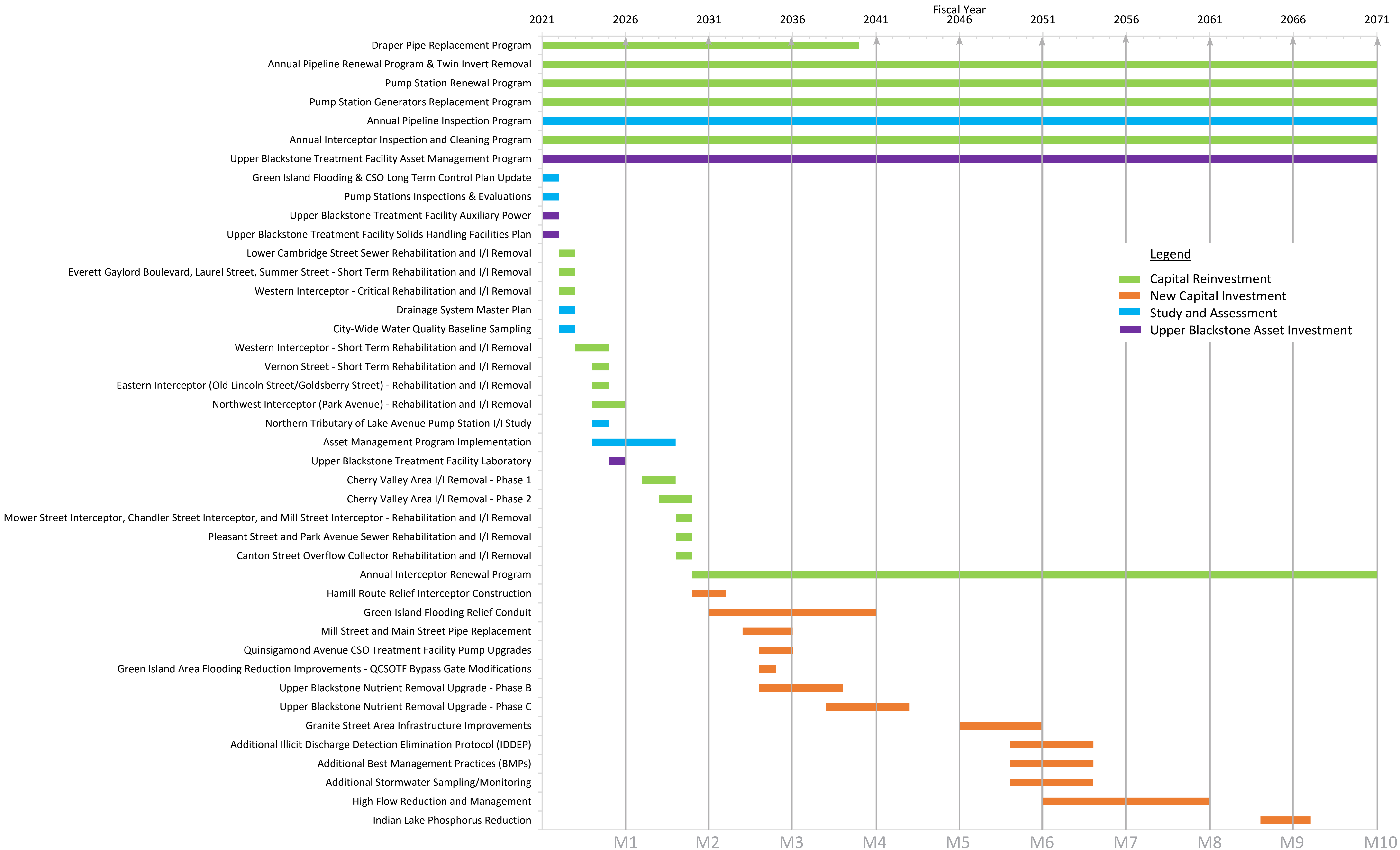

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FIGURE 10.2: POTENTIAL EVENTS RESULTING IN PLAN REASSESSMENT

Economic/Financial

- Recession
- Decrease in City revenue
- Increase in City revenue
- Regulatory fines
- Key ratepayers enter or depart the City
- Changes in interest rates

Regulatory/City Government

- New permits
- Adoption of Total Maximum Daily Loads (TMDLs)
- New regulated pollutants
- City Council actions
- Safe Drinking Water Act obligations

Climate/Environmental

- New climate change findings and recommendations
- Natural disasters
- Drought
- City population changes

Unanticipated Events

- Significant failure of assets
- Unanticipated findings from studies
- Major Key Performance Indicator changes
- Unforeseen conditions during construction