

FINAL REPORT

DECEMBER 2024

Phase 3 Candidate Area Sewer Separation Preliminary Design Report

Volume 1 of 2



Lowell Regional Wastewater Utility





December 20, 2024

Mr. Aaron Fox
Executive Director
Lowell Regional Wastewater Utility
451 First St Blvd.
Lowell, Massachusetts 01850

RE: Phase 3 Candidate Area Sewer Separation Preliminary Design Report (Phase 3 PDR)
Consent Decree Executed May 17, 2024: Paragraph 11 Requirement

Dear Mr. Fox:

In accordance with the subject Consent Decree (CD), the Lowell Regional Wastewater Utility (the Utility) is submitting this Phase 3 Candidate Area Sewer Separation Preliminary Design Report (Phase 3 PDR). This report builds upon the system information developed by the City of Lowell (City) in past long-term combined sewer overflow (CSO) control plans and PDRs, assesses full and/or partial sewer separation in the subject CSO subareas, and prioritizes successive phases of sewer separation in these basins based on CSO control benefits, cost, construction challenges, and resolution of incidents of sewer surcharge events and street flooding. Additionally, in accordance with specific CD requirements, this Phase 3 Candidate Area Sewer Separation PDR provides the following:

- Recommended plan and implementation schedule, extending through 2034, which includes a design and construction schedule for further sewer separation work in the Phase 3 Candidate Areas based on the assessment of the CSO control benefits, costs, and construction challenges
- Details of the engineering approach to carry out sewer separation and infiltration/inflow reduction (including private sources) in recommended subareas, including identification of major technical and permitting issues
- Overflow mitigation plan for the Wentworth-Douglas and Pevey Street Areas that includes:
 - Detailed description and map of the tributary sewer and storm drain system contributing to surcharge conditions in the sewers and combined sewers at these locations
 - Summary of surcharge/overflow events at these locations dating back to January 1, 2010, identifying the cause of the surcharge/overflow events and, if an overflow occurred, the volume discharged, as well as any properties and receiving waters affected
 - Assessment of the range of operational measures and capital improvements that are feasible to mitigate the risk and impacts of surcharge/overflow events at these locations
 - Recommended plan and schedule for actions to mitigate the risk and impacts of surcharge/overflow events at these locations



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The PDR addresses these items in detail both in the report sections and in the conceptual design drawings included as Appendix E.

As you know, the Utility is currently undertaking several major projects to achieve compliance with the CD and the Duck Island National Pollutant Discharge Elimination System (NPDES) Permit, including:

- Centralville Area Sewer Separation projects that provide for the installation of more than 40,000 feet (8 miles) of new drains, sewers, and water mains, and two new large-diameter drain outfalls to the Merrimack River. These projects will be completed in phases, with CD deadlines for each phase of work. The total cost of these projects is estimated to be approximately \$158 million, with the final phase of construction to be completed by December 31, 2031.
- Improvements to the Duck Island Clean Water Facility to address nutrients limits and revitalize existing infrastructure, which will help to maximize wet-weather treatment capabilities at the facility. The construction cost of these improvements is approximately \$27 million, with project construction scheduled for completion in 2027.
- Construction of the Douglas Road Wet Weather Storage Tank. The construction cost of this project is approximately \$17 million, with project construction scheduled for completion by the end of 2026.
- Compliance with CD-derived initiatives for the Utility's Capacity Management, Operation and Maintenance (CMOM) program, infiltration /inflow (I/I) reduction program, Municipal Separate Storm Sewer System (MS4) Stormwater compliance, and preparation of a Long-Term Control Plan (LTCP). These programs are estimated to cost approximately \$36 million.

In total, these projects commit the Utility to an expenditure of approximately \$238 million over a 10-year period. While these projects will provide considerable benefit in terms of reduced volume and frequency of CSO discharges and improved collection system performance under wet-weather conditions, these benefits will come at a substantial cost to the Utility and its rate payers.

Against this background, the Utility has undertaken this Phase 3 Candidate Area Sewer Separation PDR with the goal of meeting the CD requirements while demonstrating benefit to the residents of Lowell in terms of CSO mitigation and the reduction or elimination of overflow and flooding events in areas that historically have been impacted by such events. Based on these goals, the following projects have been identified and prioritized as part of the Phase 3 recommended plan:

1. **Phase 3A – The Grand Separation Project (including School Street Drain Separation and Inland Street Drain).** The Grand Separation Project provides for the separation of 44 acres of combined sewer area with the installation of approximately 7,000 linear feet (LF) of proposed drainpipe (ranging from a 12-inch diameter to a 60-inch diameter) and a new proposed outfall discharge to the Pawtucket Canal, near the Boys & Girls Club. School Street Separation includes an additional 500 LF of drainpipe and the redirection of 15 catch basins from the existing sewer to either an existing or a new drainpipe. Inland Street Drain includes an additional 630 LF of drain and the replacement of four catch basins. The total cost of this project is estimated to be approximately \$29.5 million.



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2. **Phase 3B – The Lower Saunders Separation Project** provides for the separation of 12 acres of combined sewer area with the installation of approximately 2,000 LF of proposed drainpipe (ranging from 12 inches in diameter to 30 inches in diameter). The total cost of this project is estimated to be approximately \$11.6 million.
3. **Phase 3C – The Pevey Separation Project** provides for the separation of 31 acres of combined sewer area with the installation of approximately 5,100 LF of proposed drainpipe (ranging from a 12-inch-diameter to 3-foot high by 4-foot-wide box culvert). The total cost of this project is estimated to be approximately \$17.1 million.

These projects will serve to resolve surcharges in the Marginal Interceptor resulting from excess wet-weather flow, thereby eliminating overflow events along the interceptor. Additionally, these projects will provide an annual CSO volume reduction of approximately 18 million gallons at the West CSO Diversion Station, thereby achieving the Utility's goals of both providing CSO mitigation and reducing or eliminating surcharge and flooding events in areas that historically have been impacted by such events.

The total cost of these three recommended Phase 3 Sewer Separation projects is \$58.2 million. In combination with the Centralville Sewer Separation projects, this represents a total commitment of approximately \$216 million on sewer separation projects over a 10-year period; these projects will separate approximately 480 acres of combined sewer area in the City, providing about a 16 percent reduction in the area served by a combined sewer system in the City. Additionally, it is estimated that these Phase 3 Sewer Separation projects, in combination with the Centralville Sewer Separation projects, will reduce the total average annual volume of CSO discharges from approximately 385 million gallons to approximately 278 million gallons, a reduction of 28 percent. It is proposed that these Phase 3 Sewer Separation projects be implemented concurrently with the Centralville Sewer Separation projects, with the recommended Phase 3 work completed by the end of 2032, approximately one year after completion of the Centralville Sewer Separation projects.

The combined implementation of the Centralville Sewer Separation and Phase 3 Sewer Separation projects over a 10-year period represents an extraordinary commitment by the City to meeting both the requirements of the CD and to providing tangible water quality and public health benefits to residents. Additionally, these proposed projects represent the practical limit of what can be designed and constructed in a 10-year period given traffic, noise, and other construction impacts on the local community; the capacity of the Utility and the engineering and construction industry to plan, design, and implement projects of this scale within the required time frame; and the financial impacts of this level of expenditure on rate payers. In short, this recommended plan represents the maximum amount of combined sewer separation that can be achieved in a 10-year period given the nature of this work and the limits of financial and physical burden that can be placed on the City and its residents.

We believe that the recommendations of the Phase 3 Candidate Area Sewer Separation PDR represent an important next step in implementing a cost-effective, technically sound approach to combined sewer separation in the City. CDM Smith appreciates the opportunity to support the Utility on this important



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project. Should you have any questions or require additional information, please contact me at 617.452.6535 or WalshMJ@cdmsmith.com.

Sincerely,

A handwritten signature in blue ink, appearing to read "Michael J. Walsh".

Michael J. Walsh, PE, CEng, ENV SP
Senior Vice President

cc: Evan Walsh, Lowell Regional Wastewater Utility
Jim Drake, CDM Smith
David Tanzi, CDM Smith



**PHASE 3 CANDIDATE AREA SEWER SEPARATION
PRELIMINARY DESIGN REPORT**

CERTIFICATION STATEMENT

I certify under penalty of perjury that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I have no personal knowledge that the information submitted is other than true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Aaron Fox
Executive Director
Lowell Regional Wastewater Utility

12/20/2024

Date



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Appendix B	CSO Discharge Station Schematics
Appendix C	Lowell Sewer and Street Flooding Issues Survey
Appendix D	Lowell Collection System Model Calibration and Validation Documentation (CDM Smith, 12/19/2024)
Appendix E	Conceptual Drainpipe Plans and Profiles for Phase 3 Candidate Areas Prioritized Projects



Acronyms and Abbreviations

ACP	Asbestos Cement Pipe
ADR	Automated Defect Recognition
ADS	ADS Environmental Services
AI	Artificial Intelligence
ARPA	American Rescue Plan Act
ARI	Average Recurrence Intervals
AUL	Activity and Use Limitations
BVW	Bordering Vegetated Wetland
CAP	Corrective Action Plan
CB	Catch Basin
CCTV	Closed-Circuit Television
CD	Consent Decree
CFR	Code of Federal Regulations
CIP	Cast Iron Pipe
CIPP	Cured-in-Place-Pipe Lining
City	City of Lowell, Massachusetts
CMOM	Capacity Management, Operations, and Maintenance
CMR	Code of Massachusetts Regulations
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DCR	Department of Recreation and Conservation
DIP	Ductile Iron Pipe
Duck Island	Duck Island Wastewater Treatment Facility
EEA	Executive Office of Energy and Environmental Affairs
EIR	Environmental Impact Report
EENF	Expanded Environmental Notification Form

EPA	U.S. Environmental Protection Agency
ENR	Engineering News Record
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GMPS	Inland Water/Green Mountain Pipeline Services
gpd/in-mile	Gallons per Day per Inch-Mile
GP	General Permit
HFMP	High Flow Management Plan
I/I	Infiltration /Inflow
IP	Integrated Plan
km	Kilometer
LF	Linear Feet
LoF	Likelihood of Failure
LRWWU	Lowell Regional Wastewater Utility
LSP	Licensed Site Professional
LTCP	Long-Term Control Plan
LUW	Land Under Water
MACP	Manhole Assessment Certification Program
MassDEP	Massachusetts Department of Environmental Protection
MassDOT	Massachusetts Department of Transportation
MassGIS	Bureau of Geographic Information
MBTA	Massachusetts Bay Transportation Authority
MCP	Massachusetts Contingency Plan
MEPA	Massachusetts Environmental Policy Act
MG	Million Gallons
MGD	Million Gallons per Day
M.G.L.	Massachusetts General Law
MHC	Massachusetts Historical Commission
MS4	Municipal Separate Storm Sewer System
MWPA	Massachusetts Wetlands Protection Act

NAD	North American Datum
NASSCO	National Association of Sewer Service Companies
NAVD88	North American Vertical Datum of 1988
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System
NRDIS	National Registry
OOC	Order of Conditions
OPCC	Opinion of Probable Construction Cost
PACP	Pipeline Assessment Certification Program
PCN	Pre-Construction Notification
PCSWMM	Personal Computer Storm Water Management Model
PDR	Preliminary Design Report
PLPA	Public Land Preservation Act
PM	Particulate Matter
PNF	Project Notification Form
PVC	Polyvinyl Chloride
QPE	Multi-Radar Multi-Sensor Quantitative Precipitation Estimation
RC	Reinforced Concrete Pipe
RMB	River Meadow Brook
RTN	Release Tracking Number
SCADA	Supervisory Control and Data Acquisition
SDS	Sewer Discharge Stations
SHPO	State Historic Preservation Office
SSES	Sewer System Evaluation Survey
SRF	State Revolving Fund
SSO	Sanitary Sewer Overflow
SWMM	Stormwater Management Model
USACE	United States Army Corps of Engineers

USGS	U.S. Geological Survey
UNK	Unknown
Utility	Lowell Regional Wastewater Utility
VCP	Vitrified Clay Pipe
WP	Wright-Pierce
WQC	Water Quality Certification
WWTF	Wastewater Treatment Facility
yr	Year



1.0 Introduction

1.1 Background

The City of Lowell, Massachusetts (City), like many older cities in the northeastern United States, has a combined sewer system (CSS). The CSS was originally designed to convey both sanitary wastewater (residential, commercial, and industrial flow) and stormwater within a single pipe in the street. The Duck Island Wastewater Treatment Facility (Duck Island) treats both dry-weather sanitary weather flow and most wet-weather flow collected by the CSS. During wet weather, stormwater entering the CSS (via catch basins, surface inflow, and private connections) can exceed the hydraulic capacity of the combined sewer and interceptor piping system, resulting in the discharge of untreated combined sewer overflow (CSO) to receiving waters. The Lowell Regional Wastewater Utility (LRWWU or Utility) operates Duck Island and sewage and drainage collection system facilities in the City.

The Utility has nine permitted outfalls (National Pollutant Discharge Elimination Permit System [NPDES] Number MA-100633) to receiving waters where untreated CSOs discharge from the CSS during rainstorms. The permit refers to the station/outfalls as the Sewer Discharge Stations (SDS). The CSOs discharge to the following receiving waters:

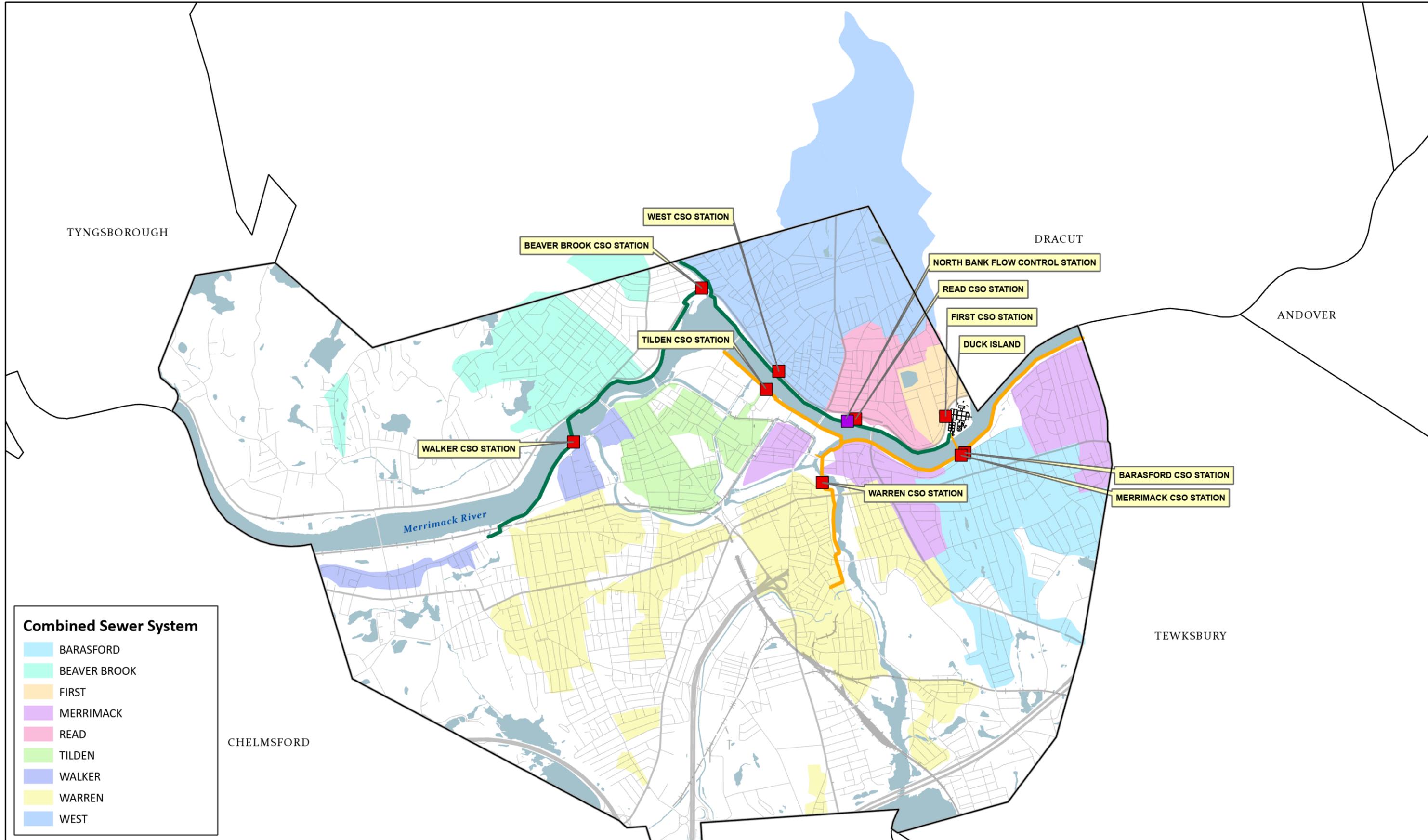
- Beaver Brook (Beaver Brook Station #007-SDS#2)
- Concord River (Warren Station #020-SDS#6)
- Merrimack River (Walker Station #002-SDS#1, West Station #008-SDS#3, Read Station #011-SDS#4, First Station #012-SDS#5, Tilden Station #027-SDS#7, Barasford Station #030[1]-SDS#8-1, and Merrimack Station #030[2])

Figure 1.1 shows the City's combined sewer system areas.

In 2023, the regulatory agencies (the U.S. Environmental Protection Agency [USEPA] and the Massachusetts Department of Environmental Protection [MassDEP]), along with the U.S. Department of Justice and the Commonwealth of Massachusetts Department of Justice, and the City and the Utility completed negotiations to develop a new Consent Decree (CD) with remedial measures to address violation findings (NPDES permit, Section 301[a] of the Clean Water Act [CWA]), and provisions of the 2003 Small Municipal Separate Storm Sewer System [MS4] General Permit). The CD was fully executed and filed with the U.S. District Court on May 17, 2024 (Case: 1:24-cv-10290-DJC, Document 13).

This Phase 3 Candidate Area Sewer Separation Preliminary Design Report (referred to in the CD as "Phase 3 PDR") is a requirement of this CD, specifically, under Section VI. According to Remedial Measure (Paragraph 11), the City must:

On or before December 31, 2024, the City shall submit to EPA and MassDEP for review and approval, a Phase 3 Preliminary Design Report and Sewer Separation Implementation Schedule ("Phase 3 PDR") for the Warren, Tilden, Merrimack, and Barrasford CSO subareas. The Phase 3 PDR shall build upon the system information developed by the City in past long-term CSO control plans and preliminary design reports, assess full and/or partial sewer separation in these CSO subareas, and prioritize successive phases of sewer separation in these basins based on CSO control benefits,



Combined Sewer System

- BARASFORD
- BEAVER BROOK
- FIRST
- MERRIMACK
- READ
- TILDEN
- WALKER
- WARREN
- WEST

Legend

- North Bank Interceptor
- South Bank Interceptor
- Diversion Station and CSO Outfall
- North Bank Flow Control Station



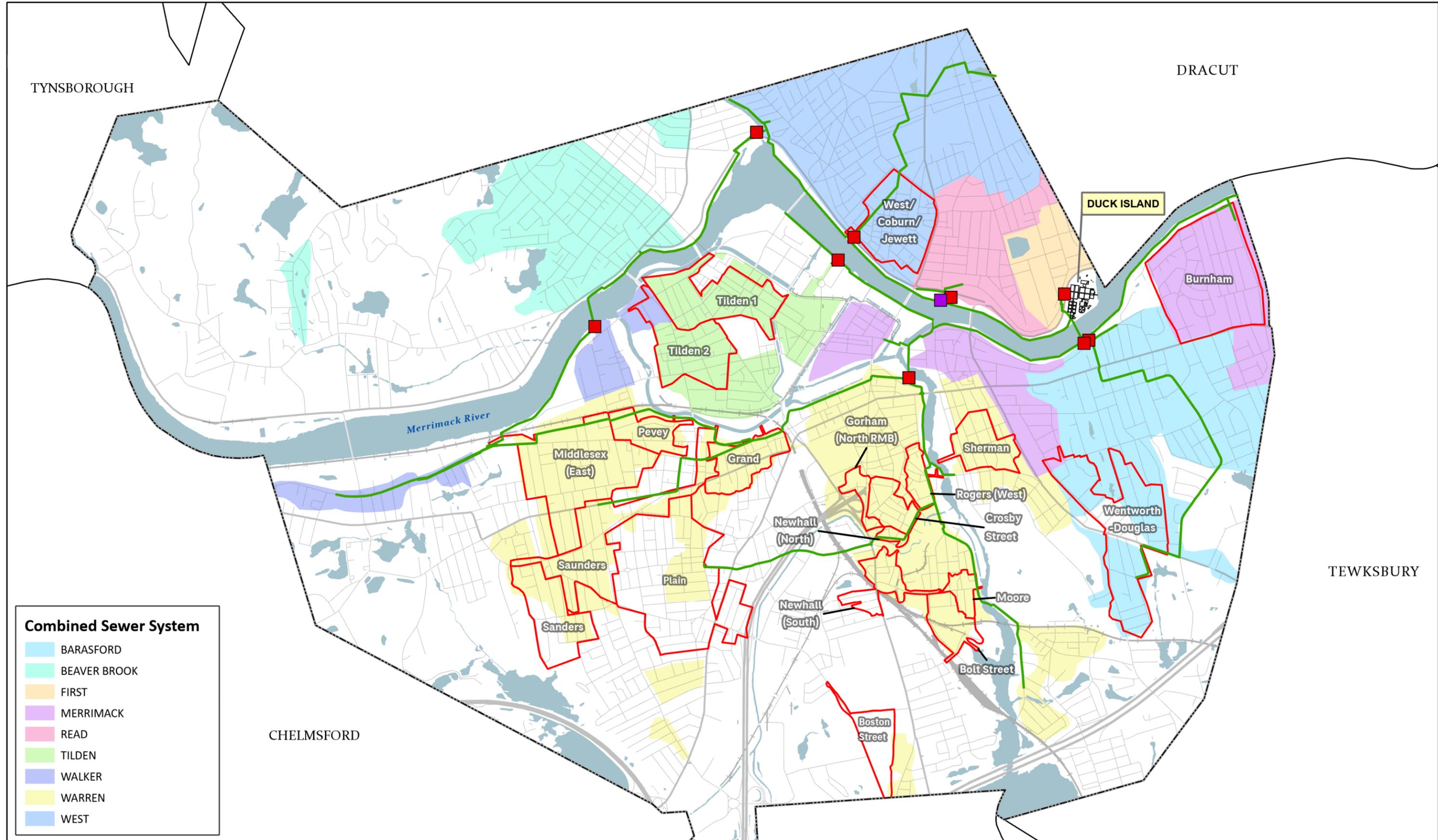
Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 1.1
Existing Combined Sewer System

cost, construction challenges and resolutions of City property backups and street flooding. The Phase 3 PDR shall specifically include:

- a. A recommended plan and implementation schedule, extending through 2034, which includes a design and construction schedule for further sewer separation work in the Phase 3 subareas, based on the assessment of the CSO control benefits, costs, and construction challenges.*
- b. For the subareas identified for sewer separation work, the PDR will detail the engineering approach to: carry out sewer separation in these areas; address Infiltration and Inflow into the collection system in these areas, including, private sources; prioritize sewer separation based on CSO control benefits, cost, and construction challenges; and identify major technical and permitting issues.*
- c. For the Wentworth/Douglas and Pevey Street Areas an overflow mitigation plan which shall include, at a minimum:*
 - i. A detailed description and map of the tributary sewer and storm drain system contributing to surcharge conditions in the sewers and combined sewers at these locations.*
 - ii. A summary of surcharge/overflow events at these locations dating back to January 1, 2010, identifying the cause of the surcharge/overflow events, and if an overflow occurred, the volume discharged, and any properties and receiving waters affected. Where a surcharge/overflow event was caused by a wet weather event, the data on the event (rainfall depth, duration, intensity) shall be provided, along with an estimate of the recurrence interval of the storm event.*
 - iii. An assessment of the range of operational measures and capital improvements which are feasible to mitigate the risk and impacts of surcharge/overflow events at these locations.*
 - iv. A recommended plan and schedule for actions to mitigate the risk and impacts of surcharge/overflow events at these locations.*

During the CD negotiations with the regulatory agencies, the Utility identified 18 subareas in the Warren, Tilden, Merrimack, and Barasford CSO basins that would be considered in the Phase 3 Candidate Area Sewer Separation PDR. The information was communicated to the agencies in a memorandum (**Appendix A**), via email, on January 24, 2023, from the City's CD negotiations legal counsel.

Some of these potential separation areas were included in the 2004 Warren Street CSO Basin Sewer Separation Program Preliminary Design Report. A nineteenth area, West/Coburn/Jewett, was added to the scope of the Phase 3 PDR based on discussions with the regulatory agencies for the Centralville Area Sewer Separation Revised Preliminary Design Report (CDM Smith, July 2024). Saunders, a twentieth area was also added to the list of the Phase 3 Candidate Areas, because it fell between the Grand and Pevey Areas, along Marginal Interceptor, near the sanitary sewer overflow (SSO) at the Boys & Girls Club of Lowell (Eagle Court). **Figure 1.2** shows these 20 areas and the respective Combined Sewer System Area in which they are located.



Combined Sewer System

- BARASFORD
- BEAVER BROOK
- FIRST
- MERRIMACK
- READ
- TILDEN
- WALKER
- WARREN
- WEST

Legend

- Diversion Station and CSO Outfall
- Interceptor/Trunk Sewer
- North Bank Flow Control Station
- Potential Phase 3 Candidate Areas



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 1.2
Potential Phase 3 Candidate Areas

The Boston Street Area has since been eliminated as a Candidate Area. It is a cemetery with no sewer or sewer connections; however, the area does include a drain network of drainpipe and catch basins. Pipe extending from Chelmsford on the southwest edge of the Boston Street Area is not connected to the existing sewer. The drainpipe exists to the north connecting to existing separated drainpipe at Court Street per the Utility's Lincoln Street construction project of 2008.

The Plain Area was to be separated with an outfall pipe along Plain Street. However, during final design it became apparent that the mainline trunk drain could not be feasibly installed in the center of the basin because of a high number of utility conflicts and constructability issues related to traffic in a highly congested five-point intersection, among other issues. The solution was to separate significant portions of the Plain Area via adjacent separation projects, i.e., the Lincoln West separation project. Today, the Plain Area is primarily separated.

For this study, the remaining 18 Candidate Areas were evaluated for sewer separation projects.

1.2 Project History

Under the CWA, municipalities nationwide must take steps to reduce or eliminate CSO discharges to receiving streams to improve water quality. In response, USEPA issued a series of interim CSO control policies and adopted a National CSO Control Policy in 1994. This Policy established a comprehensive national strategy to ensure that municipalities, permitting authorities, water quality standards authorities, and the public engage in a coordinated planning effort to develop and implement cost-effective CSO controls that meet appropriate environmental and health objectives. MassDEP established its own CSO Policy (1997) reflecting the minimum requirements of the USEPA CSO Policy and compliance/maintenance of state water quality standards.

To address the federal and state CSO regulations and policies, communities with a CSS were required to submit a Long-Term Control Plan (LTCP) that identifies a program to abate CSO discharges.

In 1988, USEPA alleged that the City was discharging pollutants from CSO outfalls and certain unauthorized discharge points in its wastewater collection system in violation of the NPDES permit and Section 301 (a) of the CWA. Accordingly, the United States, the Commonwealth of Massachusetts, and the City entered into a CD (Civil Action No. 87-0688) that required the City to take specific actions to address its NPDES permit.

To address the NPDES mandate, the Utility developed several CSO planning document updates after the original 1988 CD, including the 1990 CSO Facilities Plan and the 1998 Revised Draft Long-Term CSO Control Plan (adopted in a 2002 Administrative Order). These planning documents were developed to address changing federal and state CSO control regulations and policies, update the existing Stormwater Management Model (SWMM) hydraulic model of the CSS for system evaluations, identify and quantify progress on implementation of past CSO abatement measures, and update and revise the LTCP to reflect new costs and strategies to continue CSO control in Lowell.

Each report included a phased set of recommendations to control CSO discharges from the Utility's CSS, and the Utility has implemented these recommendations. Capital improvements included Duck Island improvements to maximize and provide reliable treatment of wet-weather flows reaching Duck Island, sewer separation of key areas of the system including portions of the Warren and Beaver Brook CSO

basins, implementation of real-time instrumentation and control to facilitate the use of inline interceptor pipeline storage (including the construction of the North Bank Interceptor Flow Control Station), and a sewer system rehabilitation program.

1.3 Purpose

In addition to the CD requirement to complete a Phase 3 PDR to assess sewer separation of the Candidate Areas, the City updated its Capacity Management, Operation and Maintenance (CMOM) Program under Paragraph 14 under CD Section VI. Remedial Measures. This document included a CMOM Program Self-Assessment Checklist intended to evaluate system improvements or operational measures to reduce the risk of surcharge/overflow events, as well as resultant health risks at/near areas with recurring backup events, including, at a minimum, the following locations:

- Raven Road/River Road
- Eagle Court (Boys & Girls Club of Lowell)
- Windward Road
- Marginal Street
- Bishop Street
- Merrimack Street
- Chelmsford Street Pump Station

The CMOM Self-Assessment Checklist identified completion of this evaluation as a deficiency and the Utility subsequently submitted a CMOM Corrective Action Plan (CMOM CAP) on December 19, 2024 (under Paragraph 15 under CD Section VI. Remedial Measures) with a plan to correct this deficiency. This CMOM CAP plan was integrated with the requirement to develop an overflow mitigation plan for the Wentworth-Douglas and Pevey Street areas in accordance with the CD Paragraph 11c (as noted in Section 1.1).

Accordingly, the purpose of this report is to assess the CSO/SSO reduction potential achieved by sewer separation of the individual Phase 3 Candidate Areas and to identify a prioritized program for sewer separation (or other system improvements). Key objectives are as follows:

- Address the chronic sewer surcharge locations.
- Consider updated SWMM simulations of the CSS to evaluate CSO and SSO mitigation effectiveness.
- Incorporate public input regarding current system problems.
- Identify feasible separation plans and new outfall locations.
- Summarize cost estimates and construction challenges to address Utility priorities.

As part of the CD negotiations, the Utility committed to updating and recalibrating the Collection System SWMM model of the CSS using flow metering information collected during a Spring 2023 flow metering program (required to update the 2023 Infiltration/Inflow [I/I] Analysis Report [Kleinfelder, January

2024]). The updated model was used to identify the relative priority of each Phase 3 Candidate Area based on an assessment of CSO and SSO mitigation benefits.

1.4 Study Area

Figure 1.2 shows the Phase 3 Candidate Areas. The total combined sewer acreage considered for potential separation is 1,400 acres. New drainage outfalls will be required to separate these areas, which will potentially discharge to the Merrimack River, Concord Rivers, River Meadow Brook, Black Brook, and the Lowell Locks and Canals system.

All these areas have a wide variety of uses, ranging from one- and two-family homes and small multifamily properties to more densely developed areas with multistory apartment buildings and small commercial businesses, which increases the complexity of sewer separation based on the density of existing development and existing underground utilities serving these areas. As discussed herein, the discharge locations, especially into Black Brook and the Lowell Locks and Canals, represent hydraulic challenges for successful drainage discharge.

1.5 Approach

The preliminary design is intended to identify the most feasible and cost-effective alternatives for separation of the Phase 3 Candidate Areas to reduce CSO/SSO discharges. This report summarizes the field investigations, preliminary design drawing development, SWMM hydraulic evaluations, including updates and calibration of the Collection System SWMM and development of separate SWMM drain models, and alternatives analyses conducted to complete and enhance the preliminary design for sewer separation of these areas.

Preliminary engineering for the project consisted of the following activities:

- Collection of available information, mapping, and reports in support of the assessment and conceptual design of the separation work for the Phase 3 Candidate Areas
- Completion of limited field investigations to evaluate potential pipeline routes, existing utilities and conflicts, actual site conditions, public inflow sources, construction issues, etc.
- Assessment of the existing sewer system conditions and development of recommendations to rehabilitate the system, as necessary, using existing information, client discussions, closed circuit television (CCTV) inspection, manhole inspections, smoke testing, etc.
- Consideration of the potential reuse of existing combined sewer pipes to convey wastewater or stormwater as an alternative to larger drainpipes
- Update and calibration of the existing Collection System SWMM to simulate CSO benefits that may be achieved through separation
- Development and use of SWMM models for new drain systems in each Phase 3 Candidate Area, using flow data, to develop pipe networks optimized for hydraulic conditions and pipe slopes
- Identification of permitting issues and environmental impacts applicable to the implementation of the Phase 3 Candidate Area separation projects

- Estimation of most probable construction and projects costs for the conceptual separation plans
- Identification of priority sewer separation projects based on CSO reduction benefits, corrective actions to eliminate SSOs, constructability, and implementation costs
- Development of a preliminary design report to summarize the findings and provide recommendations along with an implementation schedule.



2.0 Existing System

2.1 Overview

The Utility owns and operates the wastewater collection and stormwater drainage systems within the City. The wastewater collection systems comprises approximately 220 miles of gravity sewers and 14 sewer pumping stations. The Utility also collects and provides treatment of sewer flow from four neighboring communities (Chelmsford, Dracut, Tewksbury, and Tyngsboro).

Lowell's wastewater collection system dates back to the 1800s and is composed primarily of a combined sewer system that conveys sanitary sewage, surface water runoff collected by the City's catch basins, and other sources of public and private infiltration and inflow (I/I) to a system of large-diameter interceptor pipes that run along the banks of the Merrimack and Concord Rivers. Ten miles of large-diameter interceptors convey flow to the regional wastewater treatment facility at Duck Island, which is a 32-million-gallon-per-day (MGD) facility, with a peak hourly flow of 112 MGD, that provides secondary wastewater treatment before discharging to the Merrimack River. Excess wet-weather flow collected by the combined sewer system is discharged to the Merrimack and Concord Rivers, and to Beaver Brook as CSO discharges. There are nine CSO Diversion Stations with outfalls in Lowell's CSS. Figure 1.1 provides an overview of the wastewater collection system, including the CSO Diversion and Flow Control Stations, interceptor pipes, and Duck Island.

The Utility has made substantial improvements to its CSS since 2005, including Duck Island's capacity and process improvements, rehabilitation of the sewer system, installation of new drains for separation of the combined system, and capital and operational improvements to the CSO Diversion Stations to enhance control of the system during wet-weather conditions.

Section 2.2 provides a description of the existing combined collection system. The system includes 12 interceptors and nine CSO Diversion Stations that receive flow from the nine contributory CSO Basins. This system serves as the basis for the citywide Collection System Model presented in Section 4. The model has been used to assess potential sewer separation in the 18 Phase 3 Candidate Areas evaluated in this study. Section 2.3 documents the selection of these Phase 3 Candidate Areas evaluated and provides a description of each area, including location and extent of the existing pipe network. Section 2.4 reviews the history of surcharging and street flooding in the Pevey and Wentworth-Douglas Areas, in accordance with the CD, as the basis of determining appropriate corrective actions that could eliminate SSOs in these areas.

2.2 Existing Combined Collection System

Lowell's wastewater collection system serves nearly 100 percent of the population and developed land area within the City, covering approximately 90 percent (7,600 acres) of the City's total land area. Lowell's wastewater collection system and regional wastewater treatment facility also serve the adjacent communities of Chelmsford, Dracut, Tewksbury, and Tyngsboro. These communities operate and maintain separate sanitary wastewater collection systems. Sewer flow from these outside communities enter Lowell through metering stations located along the corporate boundaries, with the flow then conveyed by the Utility's interceptor and collection system to Duck Island.

The collection system conveys combined sewage to a series of interceptors shown in **Figure 2.1**. Generally, combined sewer flow is from the northern and the southern portions of Lowell to the interceptor networks along the banks of the Merrimack River. The primary interceptors are referred to as the North Bank Interceptor and the South Bank Interceptor, located respectively along the northern and southern edge of the Merrimack River. Each comprises a network of interceptors which generally convey flow west to east to Duck Island. The North Bank Interceptor includes five interceptors (Walker, Beaver Brook, West, Read, and Duck Island). The South Bank Interceptor includes seven interceptors (Upper Tilden, Lower Tilden, Marginal, Warren, Merrimack West, Merrimack East, and Barasford). Section 2.2.2 provides further details of the interceptor system, including a description of each interceptor.

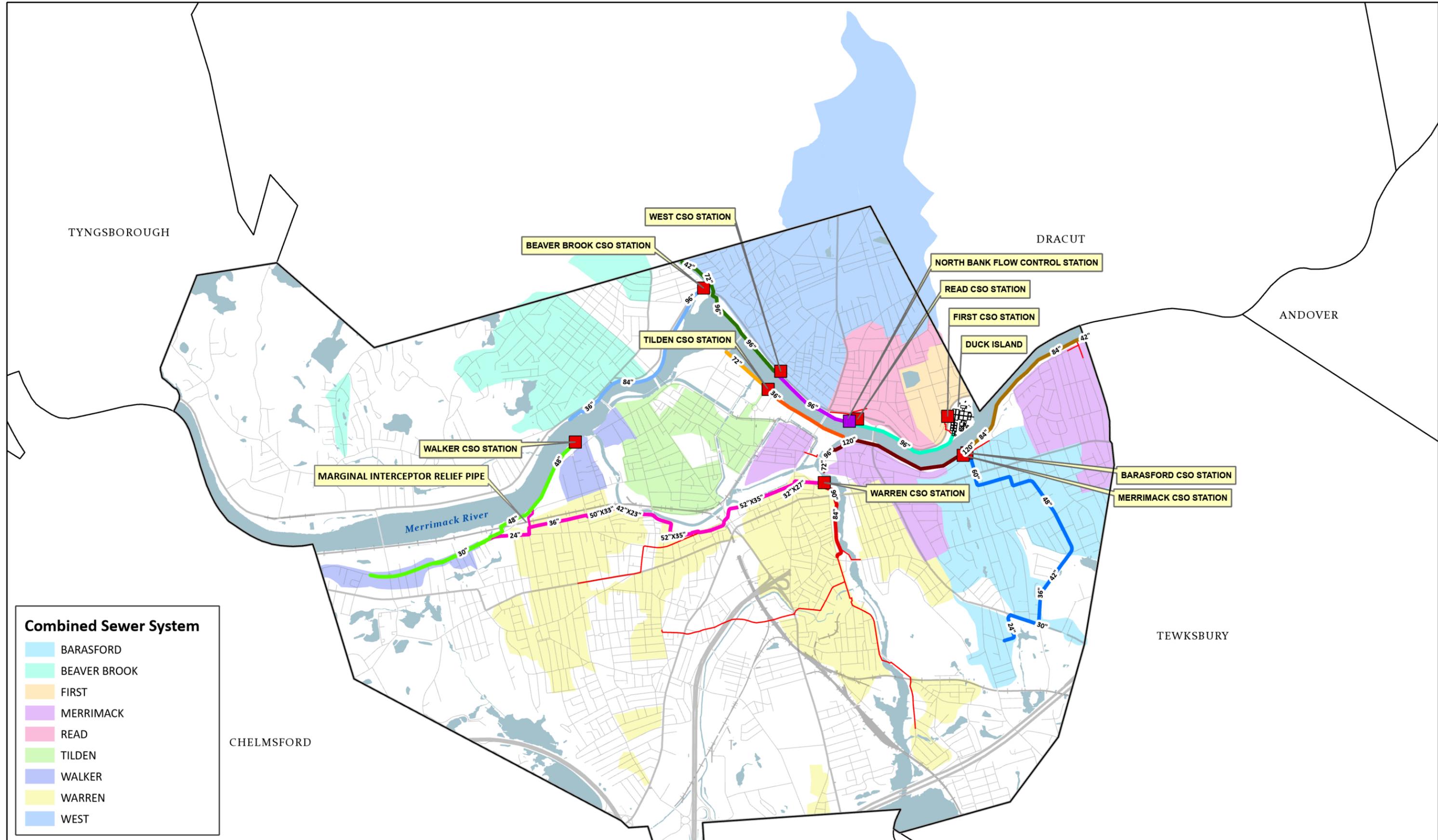
The combined system includes nine CSO Diversion Stations as shown in Figure 2.1. Six of those CSO Diversion Stations (Walker, Beaver Brook, West, Warren, Tilden, Merrimack) regulate flow along the interceptor. The remaining three CSO Diversion Stations (Read, Barasford, First) regulate the CSO Basin before the interceptor system. Under normal operating conditions, flow is directed through each station to Duck Island for treatment. However, when the CSS is overwhelmed with excess wet-weather flow, some flow is discharged directly from the CSO Diversion Station to an adjacent water body. Combined sewer tributary areas to each CSO Diversion Station have been mapped to identify that portion of the combined system contributing to each CSO Diversion Station and outfall (Figure 2.1). Section 2.2.3 provides a description of each of the CSO Diversion Stations and the Flow Control Station.

2.2.1 Combined Sewer Overflow Basins

Approximately 56 percent of the land area served by the wastewater collection system (3,600 acres) is served by the combined sewers. The combined sewer area represents areas in the City where the wastewater collection system does not have separated sewer and drainpipes. Figure 2.1 shows the combined sewer area tributary to each CSO Diversion Station and outfall in relation to the major interceptor/collection system facilities. There are nine combined sewer tributary areas, also referred to as CSO Basins. The areas include Walker, Beaver Brook, West, Read, First, Tilden, Warren, Merrimack, and Barasford. **Table 2.1** summarizes the piping and sewer area characteristics of each CSO Basin.

Table 2.1 Characteristics of Combined Sewer Overflow Basins

CSO Basin	Combined Sewer Area (acre)	Separated Sewer Area (acre)	Total System Area (acre)	Combined Sewer Pipe (linear feet)	Separated Sewer Pipe (linear feet)	Total System Pipe (linear feet)
Walker	109	333	442	18,700	22,000	40,700
Beaver Brook	343	1,198	1,541	66,900	127,200	194,100
West	533	5	538	97,500	5,200	102,700
Read	173	13	186	34,500	3,500	38,000
First	50	49	99	11,000	4,800	15,800
Tilden	234	166	400	63,400	17,600	81,000
Warren	1,242	1,904	3,146	230,700	257,400	488,100
Merrimack	365	56	421	70,800	12,300	83,100
Barasford	543	243	786	89,400	16,000	105,400
TOTAL	3,592	3,967	7,559	682,900	466,000	1,148,900



Combined Sewer System

- BARASFORD
- BEAVER BROOK
- FIRST
- MERRIMACK
- READ
- TILDEN
- WALKER
- WARREN
- WEST

Legend

North Bank Interceptors	Beaver Brook	South Bank Interceptors	Warren	Trunk Sewer
Duck Island	Walker	Merrimack East	Marginal	Diversion Station and CSO Outfall
Read		Merrimack West	Upper Tilden	North Bank Flow Control Station
West		Barasford	Lower Tilden	

0 1,000 2,000 4,000 Feet

Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.1
Existing Combined Sewer System Interceptors

2.2.2 Interceptors

Although the combined sewer system dates back to the 1800s, most of the interceptor system was constructed in the 1970s to intercept and convey flow to Duck Island. The interceptors were all designed to convey dry-weather flow and a portion of the wet-weather flow to Duck Island.

There are 12 main interceptors (see Figure 2.1 and **Table 2.2**). The interceptors are grouped based on whether they are a part of the North Bank Interceptor System or the South Bank Interceptor System. The interceptors are generally referenced based on the name of the adjacent CSO Diversion Station or facility, except for the Marginal Interceptor, which contributes flow to the Warren CSO Diversion Station. In addition, there are several trunk sewers that convey flow to some of the interceptors as shown on Figure 2.1. These trunk sewers are larger-diameter pipes, typically ranging in diameter from 24 to 120 inches, which collect the combined wastewater from smaller branch sewers and transport it to the interceptors.

Table 2.2 Summary of Interceptor Piping Network

Interceptor	Length of Pipe (linear feet)	Range of Diameters (inches)
North Bank Interceptor System		
Walker	9,900	30–48
Beaver Brook	6,800	36–96
West	5,100	42–96
Read	3,300	96
Duck Island	3,500	96
South Bank Interceptor System		
Upper Tilden	2,800	72
Lower Tilden	2,900	36
Marginal	12,200	24–52 x 35, egg shaped
Warren	2,700	84–90
Merrimack West	5,400	72–120
Merrimack East	5,500	42–120
Barasford	10,300	24–60

A further description of the interceptor piping system and routes follows. Section 2.2.3 discusses the CSO Diversion Stations and the Flow Control Station.

2.2.2.1 North Bank Interceptor System

In general, north of the Merrimack River, the wastewater collection piping system flows north to south toward the Merrimack River where it is collected by the North Bank Interceptor System along the riverbank and conveyed to Duck Island. South of the Merrimack River, there is an area of the wastewater collection system that flows northeast toward the Merrimack River and into the North Bank Interceptor (via the Walker CSO Diversion Station and a siphon across the Merrimack River). The North Bank Interceptor System consists of five interceptors (Walker, Beaver Brook, West, Read, and Duck Island), and the North Bank Flow Control Station, all described in the following sections.

Walker Interceptor

The Walker Interceptor begins at the Lowell/North Chelmsford boundary and runs east along the south bank of the Merrimack River to the Walker Street CSO Diversion Station. The Walker Interceptor collects combined wastewater flow from several small branches of the collection system in the southwest area of Lowell and sanitary flow from the North Chelmsford regional connection. Wastewater flow from the Walker Interceptor is conveyed to the Beaver Brook Interceptor, under the Merrimack River, via three siphons (14, 16, and 20 inches in diameter, with a total capacity of approximately 8 MGD) located within the Walker CSO Diversion Station. Although the Walker Interceptor is located on the south bank of the Merrimack River, it is connected to the North Bank Interceptor System via siphons to the Beaver Brook Interceptor.

Beaver Brook Interceptor

The Beaver Brook Interceptor begins at the siphon outlet structure across the Merrimack River from the Walker CSO Diversion Station and runs east along the north bank of the Merrimack River to the Beaver Brook CSO Diversion Station. The Beaver Brook Interceptor collects combined wastewater flow from the northwest portions of the Lowell collection system in areas north of the Merrimack River, flow from Tyngsboro and Dracut, and flow conveyed by the Walker Interceptor. The Beaver Brook CSO Diversion Station regulates the wastewater flow conveyed by this interceptor. Flow passing through the Beaver Brook CSO Diversion Station is conveyed by a set of siphons (16, 20, and 24 inches in diameter, with a total capacity of approximately 25 MGD) across Beaver Brook to the West Interceptor.

West Interceptor

The West Interceptor begins at the Dracut town line and runs south along Beaver Brook and east along the north bank of the Merrimack River to the West CSO Diversion Station along VFW Highway near West Street. The interceptor collects sanitary flow from the Centralville area north of the Merrimack River and one of the major regional sewer connections from Dracut. The West Interceptor also receives flow from the Beaver Brook CSO Diversion Station via the siphons under Beaver Brook.

Read Interceptor

The Read Interceptor begins downstream of West CSO Diversion Station and runs east along the north bank of the Merrimack River to a point where the dry-weather flow from the Read CSO Diversion Station connects to the interceptor system.

The Read CSO Diversion Station is connected to the interceptor system by a 30-inch-diameter dry-weather connection pipe and regulates flow from a smaller combined area of Lowell near Bridge Street. The Duck Island Interceptor, which conveys flow from the north side of the system into the Duck Island wastewater treatment facility, starts at the point where the 30-inch pipe from the Read CSO Diversion Station connects to the interceptor system.

Duck Island Interceptor

The Duck Island Interceptor begins at approximately the Read CSO Diversion Station connection and runs east along the north bank of the Merrimack River to the Duck Island influent pump station. There is one area with a direct connection (Llewellyn Street) to this interceptor before Duck Island. All dry- and wet-weather flow from the Llewellyn Street area is conveyed to the Duck Island influent pump station.

2.2.2.2 South Bank Interceptor System

In most areas south of the Merrimack River, wastewater collection system flow is generally east toward the Concord River and north toward the Merrimack River where it is collected by the South Bank Interceptor System and conveyed to Duck Island. The South Bank Interceptor System consists of seven interceptors (Upper and Lower Tilden Interceptors, Marginal Interceptor, Warren Interceptor, Merrimack West Interceptor, Merrimack East Interceptor, and Barasford Interceptor), all described in the following subsections.

Upper and Lower Tilden Interceptors

The Upper Tilden Interceptor begins by the Aiken Street Bridge on the south bank of the Merrimack River and runs east along the Merrimack River to the Tilden CSO Diversion Station, after which it decreases in size and becomes the Lower Tilden Interceptor. The Lower Tilden Interceptor begins downstream of the Tilden CSO Diversion Station and runs east along the south bank of the Merrimack River to the Concord River. The Lower Tilden Interceptor flow is conveyed by a set of siphons (18 and 24 inches in diameter) across the Concord River to the Merrimack West Interceptor.

Marginal Interceptor

The Marginal Interceptor is located in south–central Lowell between the Walker Interceptor and Warren Interceptor, running along Marginal Street (near the south campus of University of Massachusetts [UMass] Lowell) and along Middlesex Street (adjacent to the Hamilton Canal). This interceptor conveys flow east toward the Warren CSO Diversion Station. The Marginal Interceptor Relief Pipe was built to transfer excess flow towards Walker CSO Diversion Station to reduce local surcharging during wet weather conditions; however, the weirboards within the regulator structure have been removed, thus creating a cross-connection allowing some dry weather flow towards the Walker CSO Diversion Station. There is also a high-level cross-connection at the upstream end of the Marginal Interceptor (at Middlesex Street between Pawtucket Street and Duren Avenue) that allows surcharged flow along the interceptor to be relieved to the Walker Interceptor and CSO Diversion Station under extreme storm event conditions.

Warren Interceptor

The Warren Interceptor is located along the west bank of the Concord River and runs north to the Warren CSO Diversion Station. This portion of the interceptor system collects combined wastewater flow from most of Lowell’s collection system in the southern and central areas of the City.

Figure 2.1 also shows the location of large-diameter trunk sewers in the Warren Basin. The trunk sewers are unnamed collector pipes that convey flow from south Lowell into the Warren Interceptor. These two larger collector pipes convey flow to the interceptor, one that has a west–east route from the Highlands neighborhood (including Chelmsford Street), and one that has a south–north route (parallel to the Concord River) that conveys flow from the South Lowell area.

Merrimack West Interceptor

The Merrimack West Interceptor begins at the siphon outlet structure from Warren CSO Diversion Station and runs north along the east bank of Concord River. From the confluence of the Concord River, the Merrimack West Interceptor runs east along the south bank of the Merrimack River to the Merrimack River CSO Diversion Station. The Merrimack West Interceptor accepts flow from the Warren

siphon outlet structure, a siphon outlet structure at East Merrimack Street, and the Lower Tilden Interceptor siphon outlet at the confluence of the Concord River.

Merrimack East Interceptor

The Merrimack East Interceptor begins at the Lowell/Tewksbury boundary and runs west along the south bank of the Merrimack River. This interceptor collects combined wastewater flow from several sewer tributary areas of the wastewater collection system adjacent to the southeastern bank of the Merrimack River and sanitary flow from the Tewksbury regional connection. The Barasford CSO Diversion Station discharges flow into this interceptor directly adjacent to the Merrimack CSO Diversion Station.

Barasford Interceptor

The Barasford Interceptor begins in southeast Lowell near the municipal boundary with Tewksbury, conveying flow from the Wentworth-Douglas Area to the Merrimack East Interceptor. The Barasford Interceptor extends along Wentworth Avenue, then runs east along Douglas Road before turning in a northerly direction. There are then several changes in direction as the interceptor makes its way north through the Belvidere neighborhood, ultimately conveying flow to the Barasford CSO Diversion Station. The Barasford CSO Diversion Station regulates wet-weather flows to the Merrimack East Interceptor.

2.2.3 Combined Sewer Overflow Diversion Stations and Flow Control Station

There are nine CSO Diversion Stations in Lowell along with the North Bank Flow Control Station that control wet-weather flow from either adjacent combined sewer areas and/or interceptor flow to downstream interceptors. Each CSO Diversion Station is associated with a combined sewer area, which is situated along the North and South Bank Interceptors. Figure 2.1 shows the locations of the stations and associated sewer areas and interceptors. **Table 2.3** provides a summary of each CSO Diversion Station.

During normal dry-weather operations, wastewater flow is directed through the stations for conveyance downstream to Duck Island for treatment before discharge to the Merrimack River. However, during a storm event, the flow can exceed system capacity and is discharged as a CSO. Of the nine CSO Diversion Stations, seven overflow to the Merrimack River, one overflows to the Concord River, and one overflows into Beaver Brook. A description of each CSO Diversion Station and Flow Control Station is presented as follows. **Appendix B** shows schematics of each CSO Diversion Station.

Table 2.3 Combined Sewer Overflow Diversion Stations

CSO Diversion Station	NPDES Outfall No.	Receiving Waters	Approx. Upstream Combined Acreage (acres)	Diversion Station Characteristics				Potential Flow Constraint (MGD)
				Station Influent		Station Effluent		
				Influent Pipe Size (inches)	Influent Capacity (MGD)	Effluent Pipe Size (inches)	Effluent Capacity (MGD)	
Walker CSO Diversion Station	002	Merrimack River	140	48	32	3 Siphons (14, 16, and 20)	8	24
Beaver Brook CSO Diversion Station	007	Beaver Brook	570	96	170	3 Siphons (16, 20, and 24)	25	145
West CSO Diversion Station	008	Merrimack River	1,100	96, 72, and 48	280	96	93	187
Read CSO Diversion Station	011	Merrimack River	175	60	53	30	16	37
First Street CSO Diversion Station	012	Merrimack River	90	48	37	18	3	34
Tilden CSO Diversion Station	027	Merrimack River	350	72	72	36	28	44
Warren CSO Diversion Station	020	Concord River	1,626	90 and 48	348	3 Siphons (30, 30, and 30)	45	303
Merrimack CSO Diversion Station	030(2)	Merrimack River	2,941	84 and 120	204	3 Siphons (30, 36, and 48)	63	141
Barasford CSO Diversion Station	030(1)	Merrimack River	600	84	277	48	21	256

2.2.3.1 Walker Street Combined Sewer Overflow Diversion Station

The Walker Street CSO Diversion Station (which is part of the North Bank Interceptor) is located just upstream of Black Brook and Pawtucket Dam and includes a building with below-ground levels. Combined flow to the Walker Street CSO Diversion Station is received from the Walker Interceptor, which takes flow from the southeast area of the City and the Chelmsford regional connection. As previously mentioned the Marginal Interceptor Relief Pipe currently acts as a cross connection sending some flow from the Warren Basin towards the Walker Interceptor. Note the acreage of combined areas tributary to the Marginal Interceptor Relief Pipe are assigned to the Warren CSO Basin (in case the weirboards are replaced).

These flows enter the CSO Diversion Station via a 48-inch influent pipe that splits into two parallel channels. The flow typically proceeds through the channel that contains the mechanically cleaned bar screens, enters the diversion channel where it continues through a Parshall flume for flow measurement

and level monitoring, and then exits to Beaver Brook CSO Diversion Station via three siphons that cross under the Merrimack River (14-, 16-, and 20-inches in diameter).

The Walker CSO Diversion Station discharges to the Merrimack River. During wet-weather flow, there is a 13-foot CSO discharge weir that diverts the flow to a wet well with an ultrasonic level element and three diversion pumps, which discharge to a 54-inch CSO discharge pipe. The discharge pumps are activated automatically based on wet well level. One pump will start pumping when the wet well reaches 8.5 feet; two pumps will run at 9.1 feet; and all three pumps will run at 11.1 feet. Pump operations will stop when the wet well reaches 1.8 feet. The CSO discharge pumps have a capacity of 66 MGD. There is no gravity diversion at this structure because the interceptor is below the typical river water level (which is controlled by the adjacent dam).

2.2.3.2 Beaver Brook Combined Sewer Overflow Diversion Station

The Beaver Brook CSO Diversion Station (which is part of the North Bank Interceptor) is located along Beaver Brook at Martin Street and includes a building and below-ground levels. Combined flow to the Beaver Brook CSO Diversion Station is received from the Beaver Brook Interceptor. Flow enters the station via a 96-inch influent pipe, which splits into two parallel channels and a third bypass channel, if required. The influent flow is automatically controlled by two 5-foot by 6-foot influent gates to allow flow storage in the upstream collection system. This influent flow then typically travels past an automated 4-foot by 4-foot flow control gate to the Parshall flume for flow measurement and monitoring and exits the station through three siphons (16-, 20-, and 24-inch siphons) to the West CSO Diversion Station. The maximum capacity of the siphons is reportedly about 25 MGD.

There is a 40-foot-long gravity flow CSO discharge weir. Diverted flow is automatically calculated using the height of the water passing over the diversion weir. When the depth in the station reaches 4.75 feet, flow can overtop the weir and discharge to Beaver Brook.

2.2.3.3 West Combined Sewer Overflow Diversion Station

The West CSO Diversion Station (which is part of the North Bank Interceptor) is located along the Merrimack River on the median of the VFW Highway in Centralville at West Street. The West CSO Diversion Station receives flow from the West Street Interceptor which carries combined flow from the Centralville area and combined flow from the Beaver Brook CSO Diversion Station. The West CSO Diversion Station conveys flow to the North Bank Interceptor via a 96-inch effluent line. The structure includes 96-, 48-, and 66-inch influent lines that converge upstream of a CSO diversion gate and effluent flow control gate. Flow normally passes through the below-ground control structure/vault and is conveyed downstream to the Read Interceptor and to Duck Island.

The West CSO Diversion Station is used as a backup flow control station for the interceptor, and the flow control gate only modulates if the North Bank Flow Control Station, located upstream of the Read Station site, has a failure. For CSO diversions to the Merrimack River, the start diversion set point is 9.00 feet. Once a diversion has started, the 8-foot by 7-foot gate will modulate to maintain a storage level of 7.5 feet. Diverted flow is automatically calculated using the equation for flow through an orifice based upon the gate position and water depth measurements on each side of the gate. The diversion gate will close when depth in the West Street structure is less than 6 feet.

In 2018, the station was rehabilitated to supplement Lowell's Flood Damage Reduction (FDR) system in the area. This included the rehabilitation of two pumps for when the river level is elevated above Action Level 3 (lower than 54.0 water service elevation based on U.S. Geological Survey [USGS] Gage 01100000 datum). This typically would be required in the event of a coincidental high river level and high wet-weather flow scenario. The pumps are engine driven and must be started locally but can be operated remotely via programmable logic controller (PLC) once started. Normal operation is for the pumps to be controlled automatically using the wet well level transducer or the pump back-up float control panel.

2.2.3.4 North Bank Flow Control Station

The North Bank Flow Control Station is located along the Read Interceptor, just upstream of the Read CSO Diversion Station interceptor connection. The North Bank Control Station maximizes wet-weather storage in the North Bank Interceptor. North Bank Interceptor flow control at this station is used in combination with the Merrimack CSO Diversion Station controls for the South Bank Interceptor to maximize flow to Duck Island while minimizing CSO discharges. An 8-foot gate is held at 15 percent open for dry-weather operations and modulates during wet-weather events. The gate modulates to maintain a maximum 112 MGD flow to Duck Island.

2.2.3.5 Read Combined Sewer Overflow Diversion Station

The Read CSO Diversion Station (which is part of the North Bank Interceptor) is a below-ground structure located along the Merrimack River near the rotary for the Hunts Halls Bridge and across the VWF Highway. Combined flow to the station is received from the Read Interceptor via a 60-inch influent pipe. The flow typically passes through an open flow control gate and 30-inch-diameter connection pipe to the North Bank Interceptor.

Diverted flow is automatically calculated using the height of the water passing over the diversion gate weir once flow depth in the influent channel exceeds 9.81 feet. The diverted flow discharges to the Merrimack River via a 60-inch-diameter outfall pipe. A tide-flex valve is installed at the end of the outfall to restrict river water from entering the system during high river levels.

There is no automatic or remote operation of this station during wet-weather conditions and there are no pumps to discharge flow when the river is high.

2.2.3.6 First Street Combined Sewer Overflow Diversion Station

The First Street CSO Diversion Station (which is part of the North Bank Interceptor) is located on First Street, directly across from Duck Island. Originally, this station was designed and constructed to receive flow from Dracut in addition to a small amount of combined flow from the subarea adjacent to Duck Island. However, flow from Dracut was subsequently connected to the Lowell system by another route. Accordingly, flow through the First Street Diversion Station is now reduced significantly such that the combined flow entering the station via a 48-inch influent pipe can all be conveyed through the 18-inch effluent pipe for treatment at Duck Island. While the structure's diversion gate remains closed, the CSO outfall to the Merrimack River remains.

2.2.3.7 Tilden Combined Sewer Overflow Diversion Station

The Tilden CSO Diversion Station (which is part of the South Bank Interceptor) is located adjacent to the Tsongas Arena, along the Merrimack River, and includes a building with below grade levels. Flow enters

the station via a 72-inch influent pipe (Upper Tilden Interceptor). Dry-weather flow continues through a Parshall flume and then exits the station to the Lower Tilden Interceptor (a 36-inch effluent pipe), which conveys flow to the South Bank Interceptor. Influent flow is automatically controlled via an influent gate just upstream of the station's Parshall flume to allow flow storage in the upstream collection system. The Parshall flume is used for non-diverted flow measurement and level monitoring.

The Tilden CSO Diversion Station includes a gravity diversion gate present along a 48-inch CSO discharge line extending from the 72-inch influent pipe to the Merrimack River outfall. The diversion gate opens when the influent channel level reaches 5.0 feet and will modulate at 4.5 feet. The diversion gate will close when the influent channel level reaches 4.0 feet. Flow through the station is measured by an ultrasonic device at the Parshall flume. There is also an ultrasonic depth device in the influent channel, which is used to modulate the flow control and diversion gates. Diverted flow is automatically calculated using the equation for flow through an orifice using the gate position and flow depth on each side of the gate.

2.2.3.8 Warren Combined Sewer Overflow Diversion Station

The Warren CSO Diversion Station (which is part of the South Bank Interceptor) is located along the Concord River in the downtown area, adjacent to the UMass Lowell Convention Center parking garage, and includes a building and below-ground levels. The Warren CSO Diversion Station receives combined flow from the Warren Interceptor and the Marginal Interceptor. Flow enters the Warren CSO Diversion Station via a 90-inch and a 48-inch influent pipe into an influent chamber, passes through a 4-foot by 3.5-foot influent control gate, followed by a mechanical cleaned bar screen, and exits to the South Bank Interceptor (Merrimack CSO Diversion Station) via three 30-inch siphons under the Concord River.

There are two overflow sluice gates at the Warren CSO Diversion Station within the influent structure, which are activated automatically by an ultrasonic sensor (located in the influent chamber) to control diverted flow to a 90-inch CSO diversion line that exits a 96-inch flap diversion gate to the Concord River. The diversion gates open, modulating at the same rate, when the influent level reaches 7.5 feet and will modulate to maintain a level of 6.5 feet. The diversion gates will close when the level reaches 4.0 feet. The diverted flow is automatically calculated using the height of the water passing over the diversion gate weirs using the gate position. There are no pumps at this station as high river depths do not typically restrict the gravity diversion capability of this station.

There are two depth monitoring devices in this station. An ultrasonic sensor is located within the influent channel (used to estimate diversion flow over the top of the gates and interceptor pipe storage depths) and another is located in the siphon channel before the bar screen to prevent overtopping of the interior conveyance channel in the station using the flow control gate.

2.2.3.9 Merrimack Combined Sewer Overflow Diversion Station

The Merrimack CSO Diversion Station (which is part of the South Bank Interceptor) includes both a building and below-ground levels and is located across the Merrimack River from Duck Island and adjacent to the Barasford Diversion Station. The Merrimack CSO Diversion Station collects combined flow from the Merrimack West Interceptor and Merrimack East Interceptor as well as controlled flow from Barasford CSO Diversion Station. The flow converges in the influent channel and proceeds through a flow control gate and into the three siphons (30-, 36-, and 48-inches) under the Merrimack River. This

facility is the primary point of control for flows entering Duck Island from the South Bank Interceptor System.

CSOs are discharged to the Merrimack River via gravity diversion or pumped flow diversion (400 MGD capacity). Gravity CSO diversion occurs through four diversion openings that are adjacent to the Merrimack Interceptor along the river wall. There are four, 48-inch diversion gates installed on each opening. The diversion gates will open when the interceptor reaches 9.2 feet and modulate to maintain 9.2 feet. All four diversion gates will modulate at the same rate. The diversion gates will close when the influent interceptor level reaches 8.5 feet. The diverted flow is automatically calculated using the equation for flow through an orifice based upon the gate position and flow depth on each side of the gates. There are no flap gates on the four gravity diversion openings; thus, when these gates are open, there is the potential for river water to enter the interceptor.

If the river elevation impacts gravity diversion flow, the river level exceeds the interceptor level, or the gravity diversion gates cannot maintain the modulation set points, there are two diversion pumps, which are controlled via an ultrasonic level element monitoring the wet well level. The lead pump will start when the wet well level reaches 15.0 feet and the lag pump will start at 15.5 feet; both pumps will stop running at 14.0 feet. The pumped flow discharges to a 48-inch pump diversion line and is measured off the pump maximum flow rate on the pump curve.

2.2.3.10 Barasford Combined Sewer Overflow Diversion Station

The Barasford CSO Diversion Station (which is part of the South Bank Interceptor) is located below ground adjacent to the Merrimack CSO Diversion Station. Combined flow to the Barasford CSO Diversion Station is received from the Barasford Avenue Interceptor from the Wentworth Avenue and Douglas Road areas along with the Belvidere neighborhood. Flow enters the station via an 84-inch influent pipe, passes through a Parshall flume that measures the flow, and exits to the South Bank Interceptor via a 48-inch effluent line to the Merrimack CSO Diversion Station.

Within the Barasford CSO Diversion Station, there is an automated diversion gate that diverts excess flow to the Merrimack River by gravity. The diverted flow is automatically calculated using the height of the water passing over the diversion gate weir. The diversion gate opens when the influent channel level reaches 4.5 feet and closes at 3.0 feet. The flow control gate will close when the influent channel level reaches 9.4 feet and opens back up at 8.8 feet. The flow control and diversion gates are modulated together to maximize flow into the interceptor. The station also includes an effluent flow control gate that is modulated based on the Merrimack Interceptor level to avoid diversion at the Merrimack CSO Diversion Station. The Barasford and Merrimack CSO Diversion Stations share a PLC and level instrumentation.

2.3 Phase 3 Candidate Areas

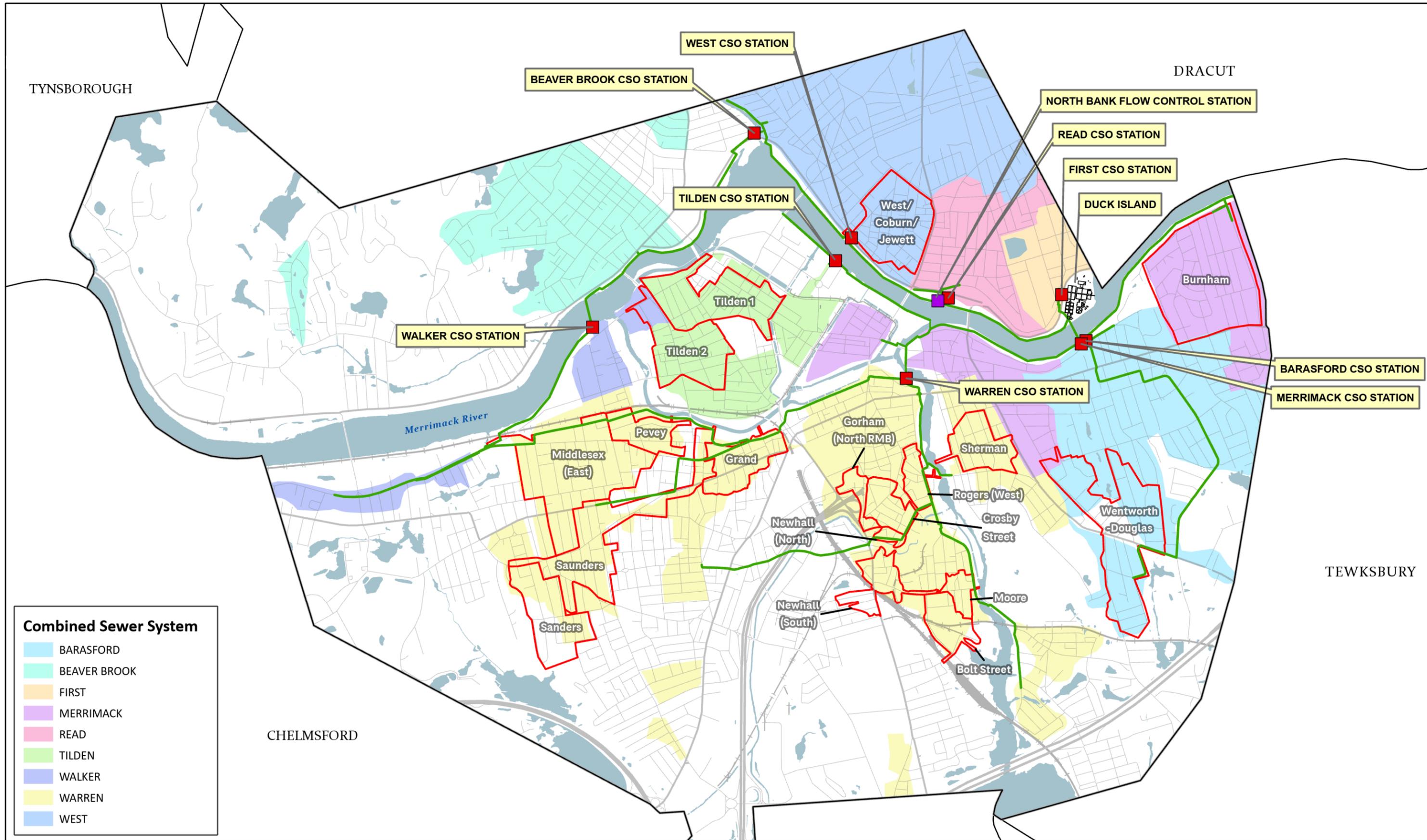
2.3.1 Listing of Phase 3 Candidate Areas for Evaluation

As discussed in Section 1, there are 18 Phase 3 Candidate Areas that are being evaluated for potential sewer separation projects. **Table 2.4** lists these areas which are shown on **Figure 2.2**. All Phase 3 Candidate Areas except for West/Coburn/Jewett are located south of the Merrimack River.

Table 2.4 Phase 3 Candidate Areas

Area Name	Phase 3 Candidate Area (Acres)
Warren CSO Basin	
Bolt Street	30
Crosby Street	27
Gorham (North River Meadow Brook [RMB])	13
Grand	44
Middlesex (East)	140
Moore	14
Newhall (North)	5
Newhall (South)	31
Pevey	31
Rogers (West)	18
Sanders	64
Saunders	100
Sherman	40
Tilden CSO Basin	
Tilden 1	79
Tilden 2 ¹	Tilden - 56 Warren - 13
Merrimack CSO Basin	
Burnham	152
Barasford CSO Basin	
Wentworth-Douglas	134
West CSO Basin	
West/Coburn/Jewett	77

(1) The northwest portion of Tilden 2 lies within the Warren CSO Basin.

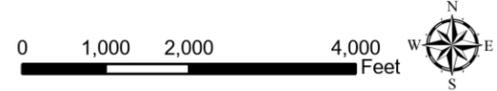


Combined Sewer System

- BARASFORD
- BEAVER BROOK
- FIRST
- MERRIMACK
- READ
- TILDEN
- WALKER
- WARREN
- WEST

Legend

- Diversion Station and CSO Outfall
- North Bank Flow Control Station
- Interceptor/Trunk Sewer
- Phase 3 Candidate Areas



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 2.2
Phase 3 Candidate Areas

2.3.2 Description of Phase 3 Candidate Areas

The following provides a description of each of the preferred Phase 3 Candidate Areas (presented by CSO Basin) listed in Table 2.4.

2.3.2.1 Warren Combined Sewer Overflow Basin

Bolt Street

Located within the Warren CSO Basin, the Bolt Street Area is approximately 30 acres and is situated west of the Concord River bordering other Phase 3 Candidate Areas, Moore, and Newhall (South) (**Figure 2.3**). **Table 2.5** presents the combined system pipe length, material, and diameter within the Bolt Street Area. The combined flow from the area is all conveyed to the Warren Interceptor and ultimately to the Warren CSO Diversion Station.

Table 2.5 Bolt Street Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
8 inches	1,681								1,681
12 inches	490								490
36 inches					1,370				1,370
Bolt Street Area Total									3,541

Crosby Street

Located within the Warren CSO Basin, the Crosby Street Area is situated between the Concord River to the east and River Meadow Brook to the west, south of the Marginal Interceptor (**Figure 2.4**). The area is approximately 27 acres and surrounded by other Phase 3 Candidate Areas, which include Gorham (North RMB) to the west, Newhall (North) to the south, and Rogers (West) to the east. **Table 2.6** presents the combined system pipe length, material, and diameter within the Crosby Street Area. The combined system takes flow to the Warren Interceptor where it is conveyed to the Warren CSO Diversion Station. There is a separated drainpipe located at the western edge of the Crosby Street Area.

Table 2.6 Crosby Street Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
10 inches	862							195	1,057
12 inches	1,554			596				349	2,499
15 inches								332	332
20 inches x 30 inches					482				482
36 inches					985				985
37 inches x 25 inches					481				481
84 inches					19				19
Crosby Street Area Total									5,855

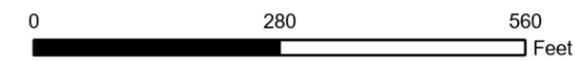


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Bolt Street Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



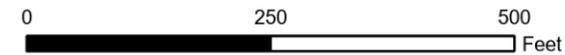


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Crosby Street Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.4
Existing Combined System
Phase 3 Candidate Area: Crosby Street

Gorham (North RMB)

Located within the Warren CSO Basin, the Gorham (North RMB) Area is approximately 13 acres and situated just west of the Crosby Street Area (**Figure 2.5**). Gorham includes only a small amount of combined sewer pipes. **Table 2.7** presents the combined system pipe length, material, and diameter within the Gorham (North RMB) Area. Combined flow from the area is collected and conveyed to the Warren Interceptor where it eventually flows to the Warren CSO Diversion Station. There is separated drainpipe in the southern portion of the Gorham (North RMB) Area.

Table 2.7 Gorham (North RMB) Area Combined System Pipe Material Summary

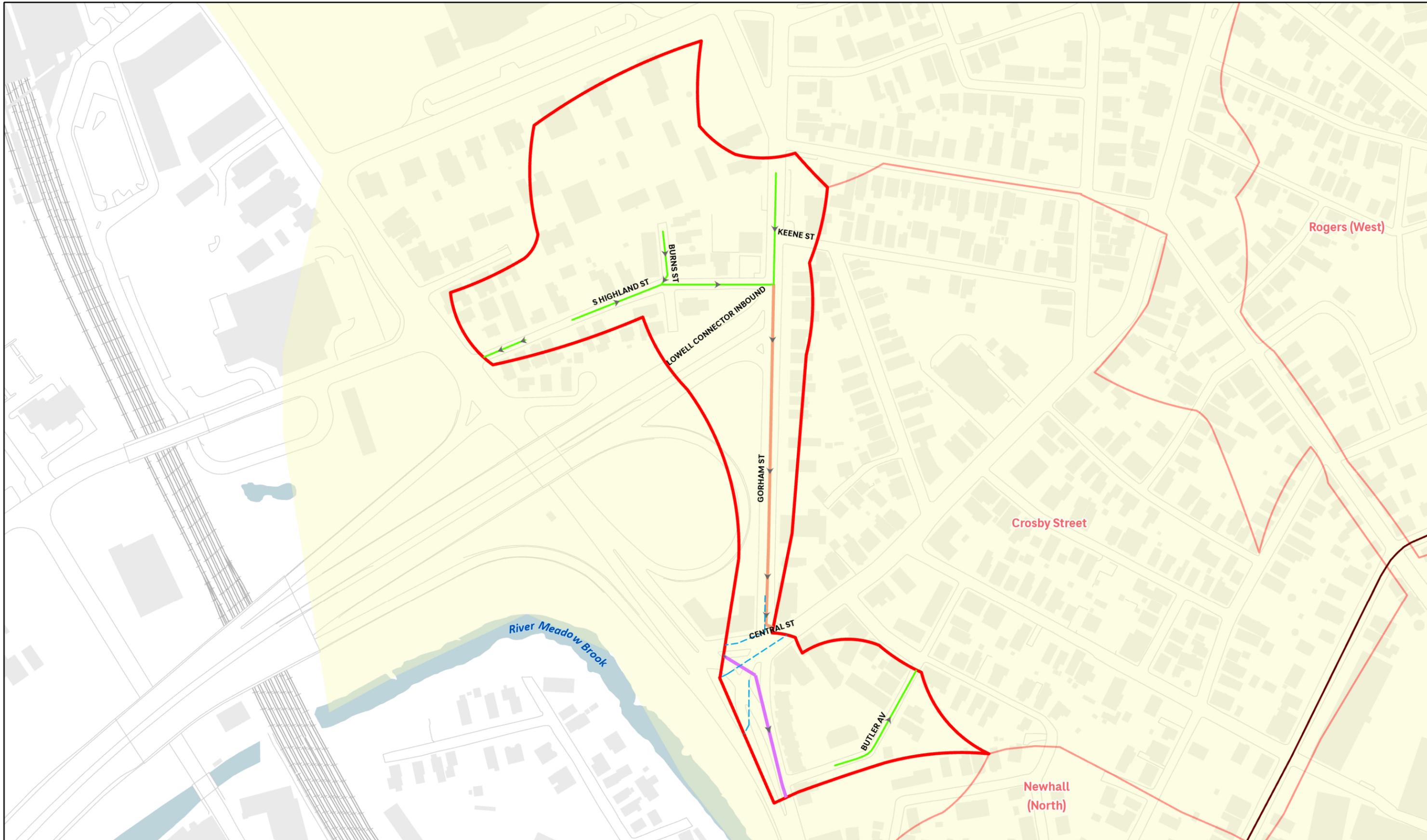
Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
8 inches								10	10
10 inches	117								117
12 inches	443								443
15 inches	237								237
20 inches					234				234
20 inches x 30 inches					489				489
45 inches x 30 inches					237				237
Gorham (North RMB) Area Total									1,767

Grand

Located within the Warren CSO Basin, the Grand Area is directly south of the Pawtucket Canal and spans 44 acres (**Figure 2.6**). To the north, the area is bound by the Marginal Interceptor with the Saunders Area located to the west. **Table 2.8** presents the combined system pipe length, material, and diameter within the Grand Area. All the flow from Grand is conveyed by the Marginal Interceptor to the Warren CSO Diversion Station.

Table 2.8 Grand Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
Unknown					179				179
10 inches	263								263
12 inches	3,348			704				463	4,515
14 inches by 16 inches					300				300
15 inches	1,078	145							1,223
18 inches	49							60	109
18 inches by 20 inches					404				404
35 inches by 23 inches					989				989
42 inches by 23 inches					102				102
52 inches by 35 inches					791				791
Grand Area Total									8,875

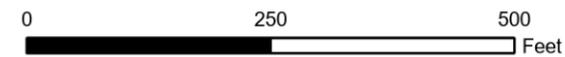


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

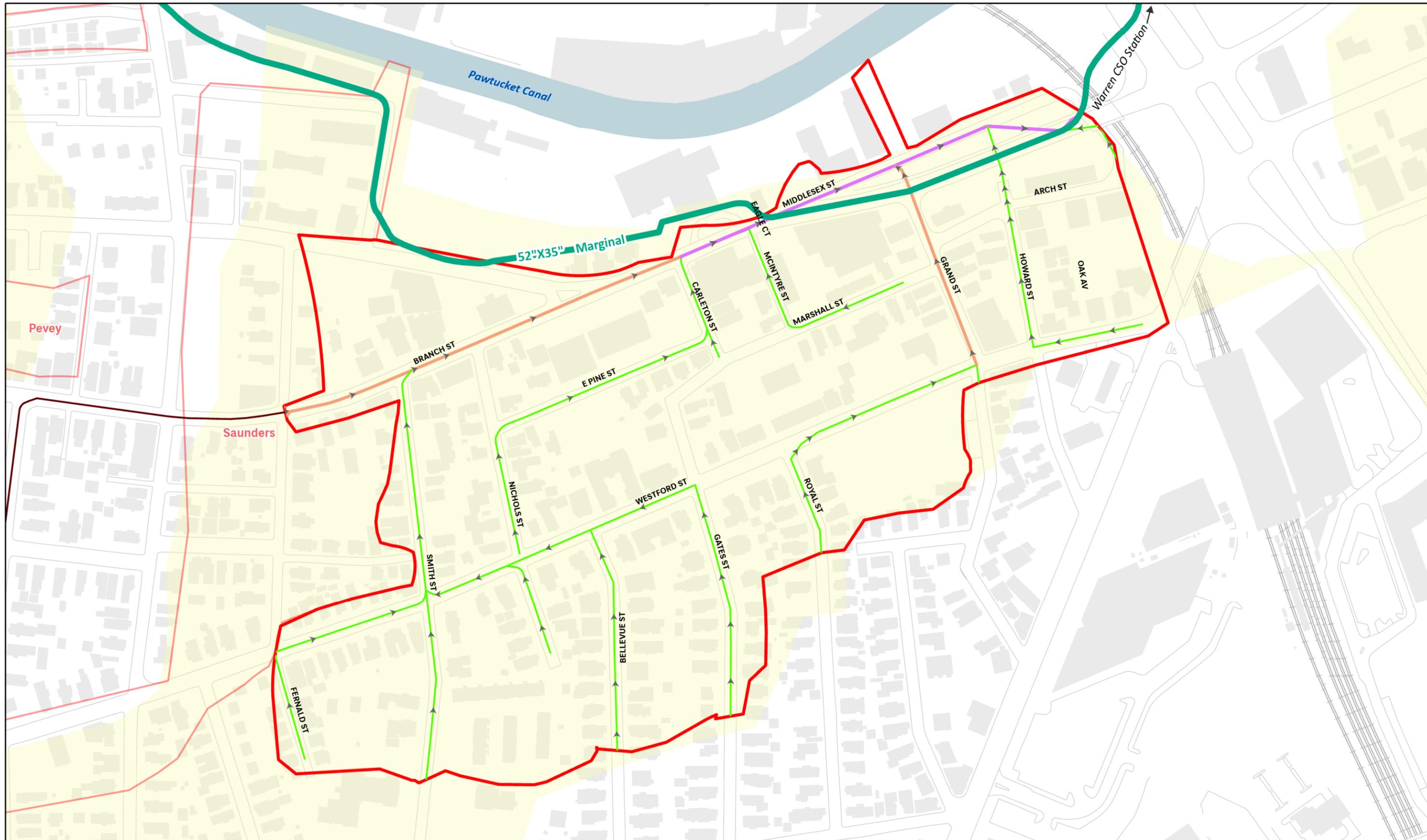
- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Gorham (North RMB) Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.5
Existing Combined System
Phase 3 Candidate Area: Gorham (North RMB)

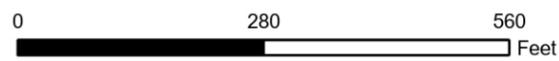


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- - - Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Grand Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
Warren



Middlesex (East)

Located within the Warren CSO Basin, the Middlesex (East) Area encompasses approximately 140 acres in the southwest portion of Lowell (**Figure 2.7**). The area is south of the Merrimack River with the Pawtucket Canal just to the northeast. It is adjacent to other Phase 3 Areas, Pevey to the northeast and Saunders to the south. **Table 2.9** presents the combined system pipe length, material, and diameter within the Middlesex (East) Area. Flow from the area is conveyed to the Warren CSO Diversion Station via the Marginal Interceptor. There is separated drainpipe at the northwest corner of the Middlesex (East) Area.

Table 2.9 Middlesex (East) Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
Unknown	267								267
8 inches	601		207	197					1,005
10 inches	2,775			238				396	3,409
12 inches	9,214			1,072	183			442	10,911
15 inches	2,004								2,004
18 inches	438			365					803
20 inches by 30 inches					379				379
24 inches					240				240
35 inches by 23 inches					679				679
35 inches by 33 inches					409				409
36 inches				5	414				419
48 inches				315					315
50 inches by 33 inches					356				356
50 inches by 33.5 inches					255				255
Middlesex (East) Area Total									21,451

Moore

Located within the Warren CSO Basin, the Moore Area encompasses approximately 14 acres and is situated west of the Concord River and adjacent to the Bolt Street Area to the west (**Figure 2.8**). **Table 2.10** presents the combined system pipe length, material, and diameter within the Moore Area. The combined flow meets at the Warren Interceptor and is conveyed to the Warren CSO Diversion Station.

Table 2.10 Moore Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
12 inches	1,005			1,529				650	3,184
36 inches				325					325
Moore Area Total									3,509

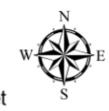


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- - - Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Middlesex (East) Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren





Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Moore Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Newhall (North)

Located within the Warren CSO Basin, the Newhall (North) Area is west of the Concord River and is surrounded by the Gorham (North RMB), Crosby Street, and Newhall (South) Areas (**Figure 2.9**). It is the smallest Phase 3 Area at just over 5 acres in size. **Table 2.11** presents the combined system pipe length, material, and diameter within the Newhall (North) Area. The combined flow is conveyed to the Warren Interceptor and flows to the Warren CSO Diversion Station.

Table 2.11 Newhall (North) Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
84 inches					651				651
Newhall (North) Area Total									651

Newhall (South)

Located within the Warren CSO Basin, the Newhall (South) Area is west of the Concord River and south of Newhall (North) bordering Bolt Street and Moore Areas (**Figure 2.10**). Newhall (South) spans 31 acres. **Table 2.12** presents the combined system pipe length, material, and diameter within the Newhall (South) Area. The combined flow collected within Newhall (South) exits the area and continues to the Warren Interceptor where it is conveyed to the Warren CSO Diversion Station. There is a length of separated drainpipe near the northwest edge of Newhall (South) (on Dix Street) that recombines with the combined sewer system.

Table 2.12 Newhall (South) Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
Unknown	252								252
6 inches								32	32
8 inches				376				125	501
10 inches	293							317	610
12 inches	1,422			909					2,331
15 inches	290								290
22 inches by 33 inches					368				368
24 inches							244		244
32 inches by 48 inches					538				538
36 inches					304				304
48 inches by 32 inches					824				824
50 inches by 75 inches					601				601
Newhall (South) Area Total									6,895



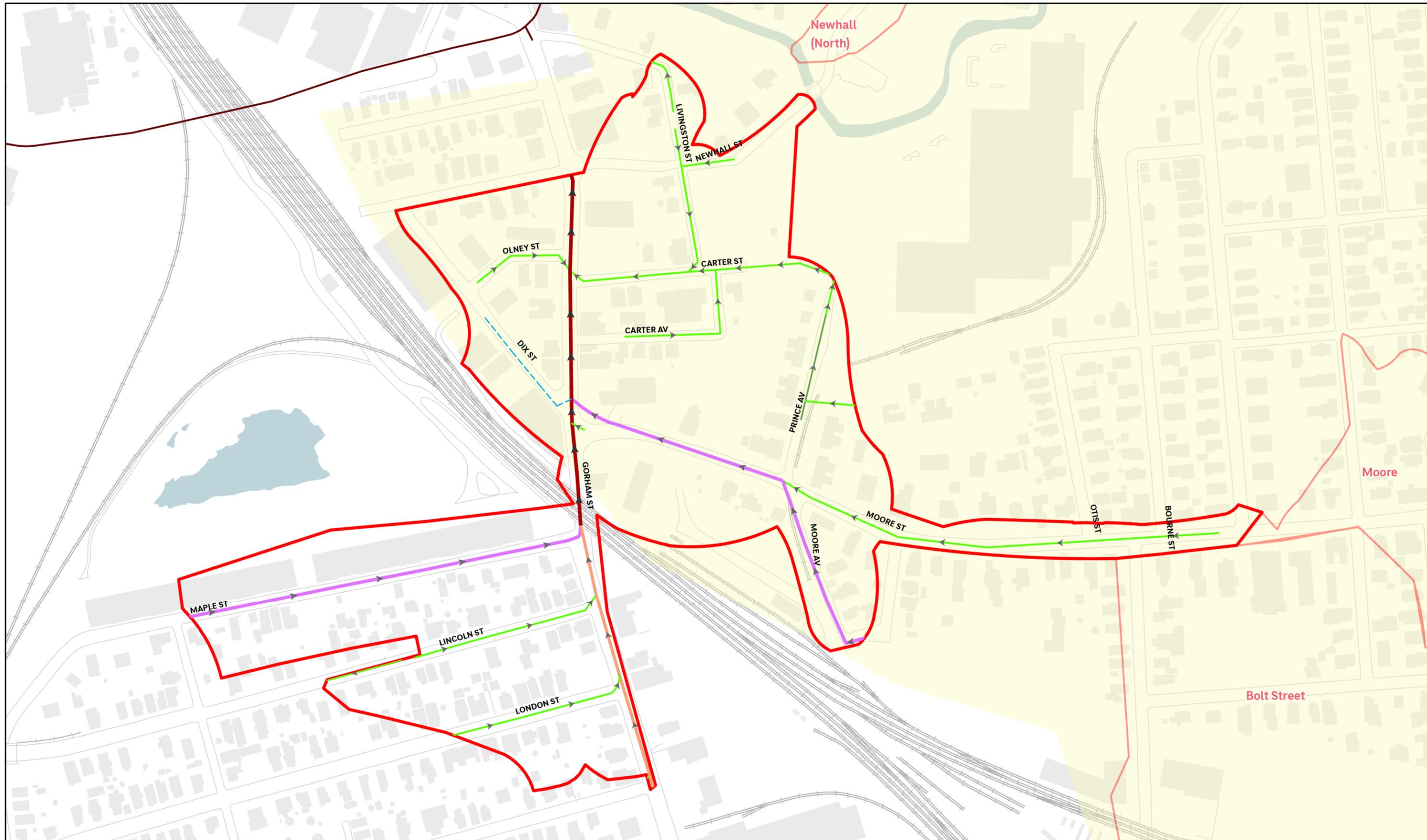
Legend

- Existing Gravity Main Pipe Diameter (In)**
- ▶ 6 - 15
 - ▶ 18 - 30
 - ▶ 32 - 60
 - ▶ 62 - 120

- Unknown
- - - Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Newhall (North) Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



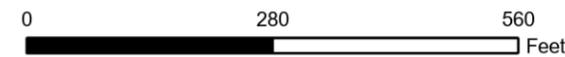


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- - - Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Newhall (South) Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Pevey

Located within the Warren CSO Basin, the Pevey Area is situated next to the Middlesex (East) Area and adjacent to the Pawtucket Canal to the north (**Figure 2.11**). The area is just under 31 acres. **Table 2.13** presents the combined system pipe length, material, and diameter within the Pevey Area. The combined flow within the area flows to the Marginal Interceptor and the Warren CSO Diversion Station.

Table 2.13 Pevey Area Combined System Pipe Material Summary

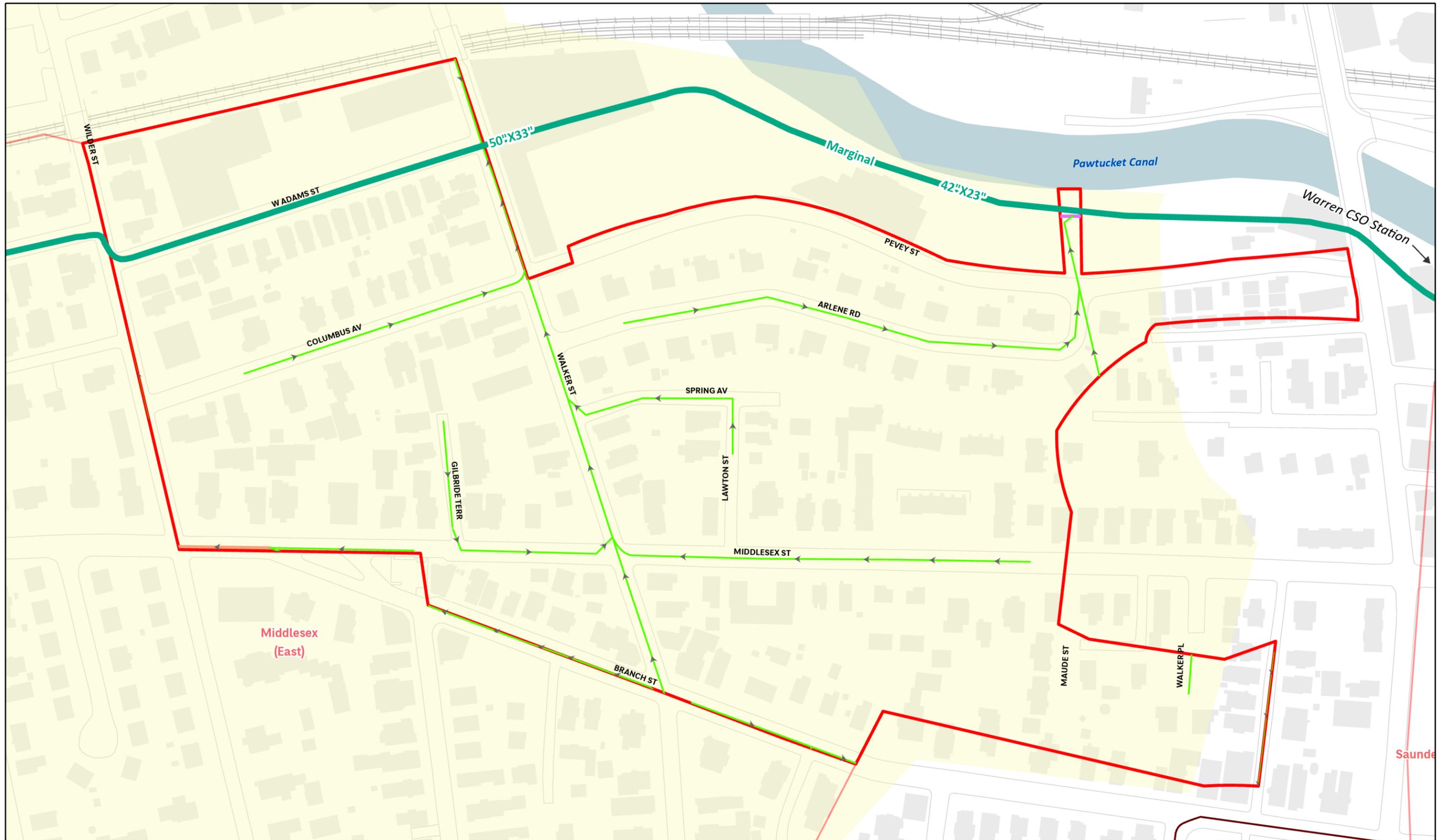
Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
8 inches	850								850
10 inches	213		92						305
12 inches	1,998		129	345				48	2,520
15 inches	571								571
50 inches by 33.5 inches					419				419
Pevey Area Total									4,665

Rogers (West)

Located within the Warren CSO Basin, the Rogers (West) Area is situated just west of the Concord River, bordering the Crosby Street Area to the west (**Figure 2.12**). The area is just under 18 acres in size. **Table 2.14** presents the combined system pipe length, material, and diameter within the Rogers (West) Area. The combined flow is conveyed to the Warren Interceptor from which it is released into the Warren CSO Diversion Station.

Table 2.14 Rogers (West) Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
10 inches				400					400
12 inches	1,142	32		868				991	3,033
24 inches					220				220
24 inches by 36 inches					163				163
84 inches					892				892
Rogers (West) Area Total									4,708



Legend

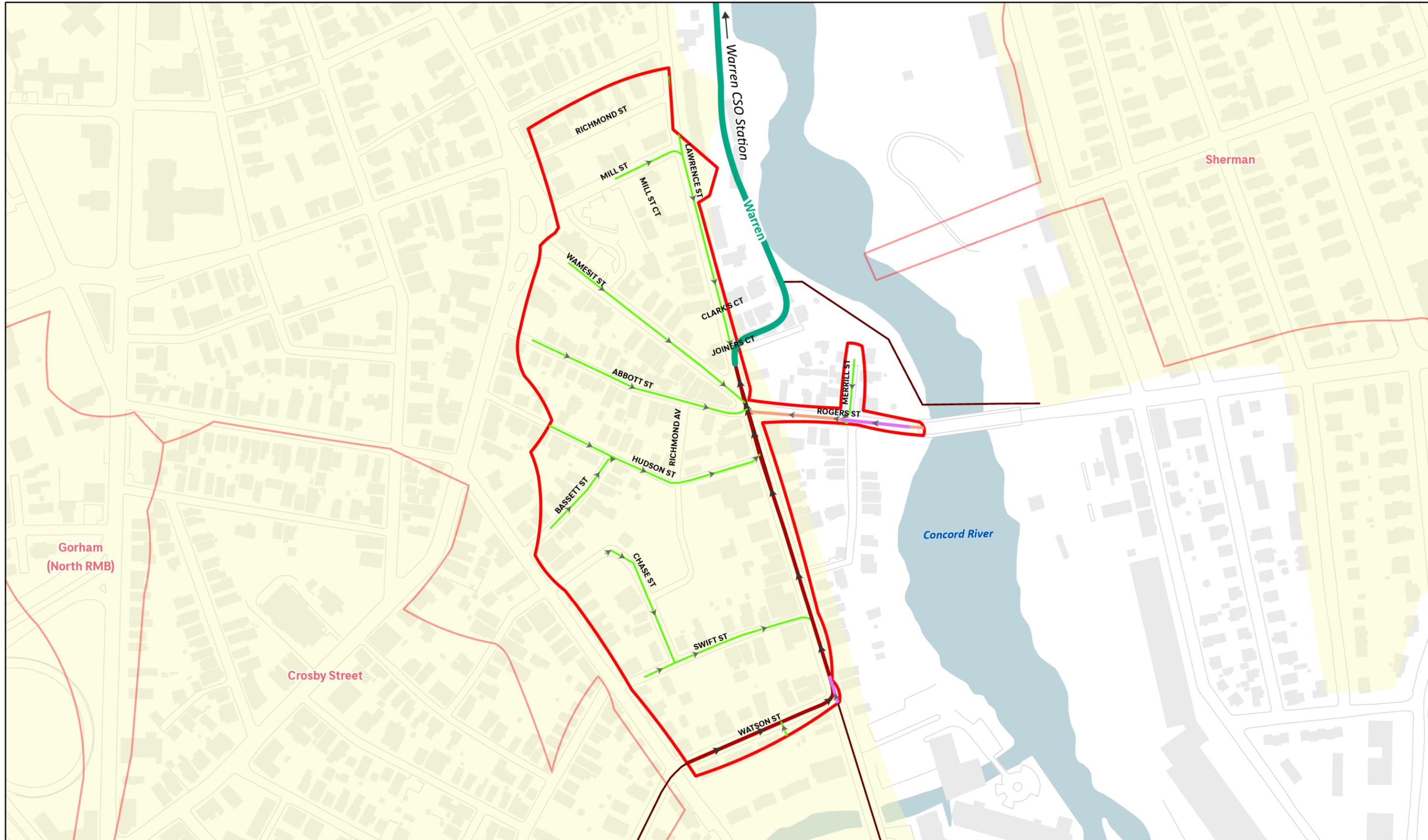
- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- - - Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Pevey Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 2.11
Existing Combined System
Phase 3 Candidate Area: Pevey

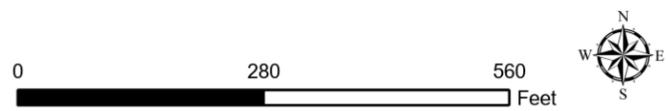


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Rogers (West) Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Sanders

Located in the Warren CSO Basin, the Sanders Area is situated in the southwest corner of Lowell and spans approximately 64 acres (**Figure 2.13**). **Table 2.15** presents the combined system pipe length, material, and diameter within the Sanders Area. The combined sewer flow from Sanders is conveyed to the Warren Interceptor and ultimately to the Warren CSO Diversion Station. There is separated drainpipe located in the west and southwestern corner of the Sanders Area.

Table 2.15 Sanders Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
Unknown	742	889							1,631
6 inches	325								325
8 inches	3,512			255		10			3,777
10 inches	1,715			2,605					4,320
12 inches	282								282
15 inches				1,363					1,363
Sanders Area Total									11,698

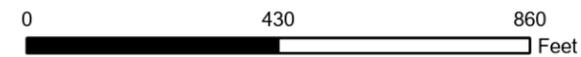


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Sanders Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

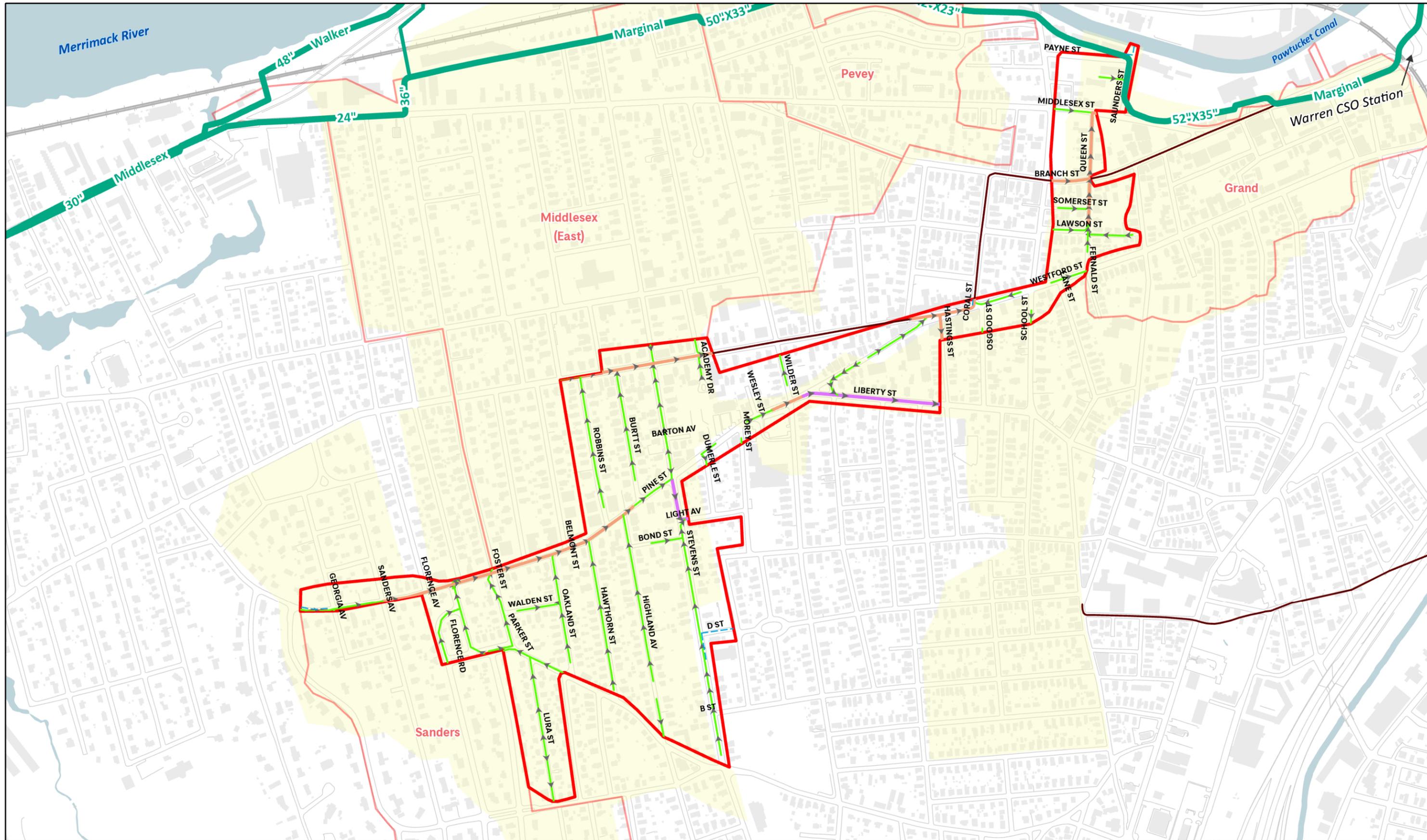
Figure 2.13
Existing Combined System
Phase 3 Candidate Area: Sanders

Saunders

Located within the Warren CSO Basin, the Saunders Area spans nearly 100 acres and is located south of the Merrimack River. The northern extent of the Saunders Area lies between the Pevey and Grand Areas, while the southern extent is south of the Middlesex (East) Area (**Figure 2.14**). **Table 2.16** presents the combined system pipe length, material, and diameter for Saunders. Saunders has multiple pipe networks where flow enters the Marginal Interceptor or the Warren Interceptor. These interceptors then convey flow to the Warren CSO Diversion Station. There is separated drainpipe along the southeast edge of the Saunders Area.

Table 2.16 Saunders Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
Unknown	447					20			467
8 inches		145						184	329
10 inches	2,423			925					3,348
12 inches	6,447	440		504					7,391
14 inches by 16 inches					205				205
15 inches	859								859
16 inches by 18 inches					201				201
18 inches	102			147					249
24 inches	1,666							30	1,696
27 inches by 18 inches					317				317
33 inches by 22 inches					861				861
35 inches					119				119
35 inches by 23 inches					822				822
42 inches by 23 inches					244				244
45 inches by 30 inches					278				278
Sanders Area Total									17,386

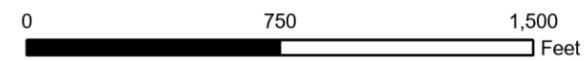


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Saunders Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



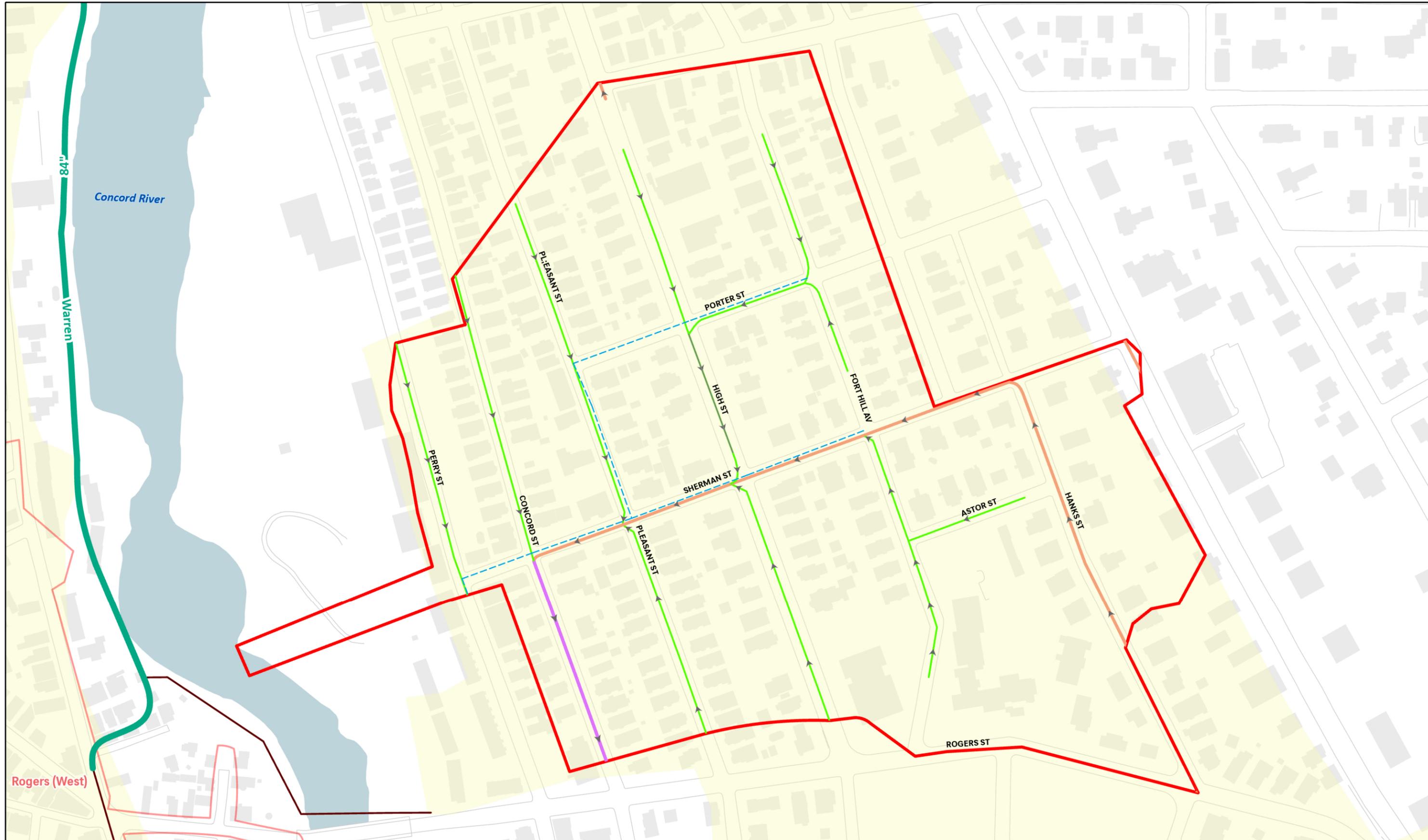
Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 2.14
Existing Combined System
Phase 3 Candidate Area: Saunders

Sherman

Located in the Warren CSO Basin, the Sherman Area is approximately 40 acres in area and located directly east of the Concord River (**Figure 2.15**). **Table 2.17** presents the combined system pipe length, material, and diameter within the Sherman Area. The combined flow from Sherman is conveyed to the Warren Interceptor to the Warren CSO Diversion Station. There is separated drainpipe located centrally within the Sherman Area.

Table 2.17 Sherman Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
Unknown		534							534
10 inches								468	468
12 inches	586			3,004				416	4,006
15 inches	342								342
15 inches by 18 inches					25				25
16.5 inches by 25 inches					330				330
18 inches by 27 inches					426				426
27 inches by 18 inches					301				301
33 inches by 22 inches					452				452
37 inches by 25 inches					263				263
Sherman Area Total									7,147



Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Sherman Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Warren



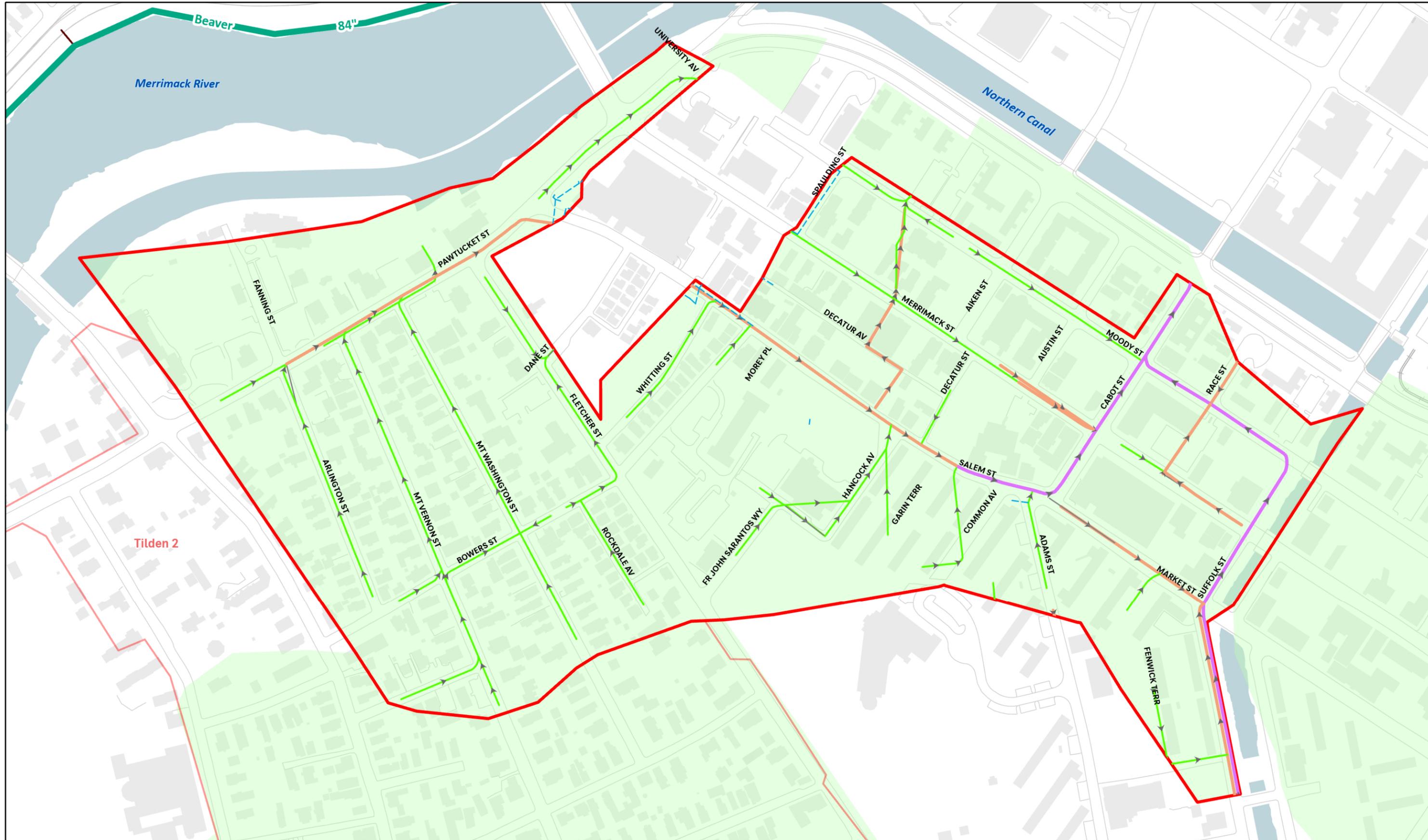
2.3.2.2 Tilden Combined Sewer Overflow Basin

Tilden 1

Located within the Tilden CSO Basin, Tilden 1 is situated within the canal system south of the Merrimack River. At approximately 79 acres, the Tilden 2 Area borders it to the south (**Figure 2.16**). **Table 2.18** presents the combined system pipe length, material, and diameter within the Tilden 1 Area. The combined sewer flow follows a northern direction from the area to the Upper Tilden Interceptor and then to the Tilden CSO Diversion Station.

Table 2.18 Tilden 1 Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
Unknown	8	338	108		743				1,197
8 inches								153	153
10 inches	798			440					1,238
12 inches	5,994	144	9	569				285	7,001
12 inches by 14 inches					472				472
14 inches by 15 inches					271				271
14 inches by 18 inches					504				504
15 inches	1,909								1,909
15 inches by 18 inches					251				251
15 inches by 20 inches					170				170
18 inches	252								252
18 inches by 22 inches					439				439
18 inches by 24 inches					321				321
19 inches by 22 inches			158		108				266
20 inches by 30 inches					196				196
22 inches by 33 inches					830				830
24 inches by 26 inches					240				240
24 inches by 28 inches	98								98
25 inches by 37 inches					757				757
30 inches by 20 inches					189				189
33 inches by 22 inches					478				478
38 inches by 52 inches					240				240
52 inches by 34 inches					1,179				1,179
Tilden 1 Area Total									18,651

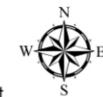


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Tilden 1 Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Tilden

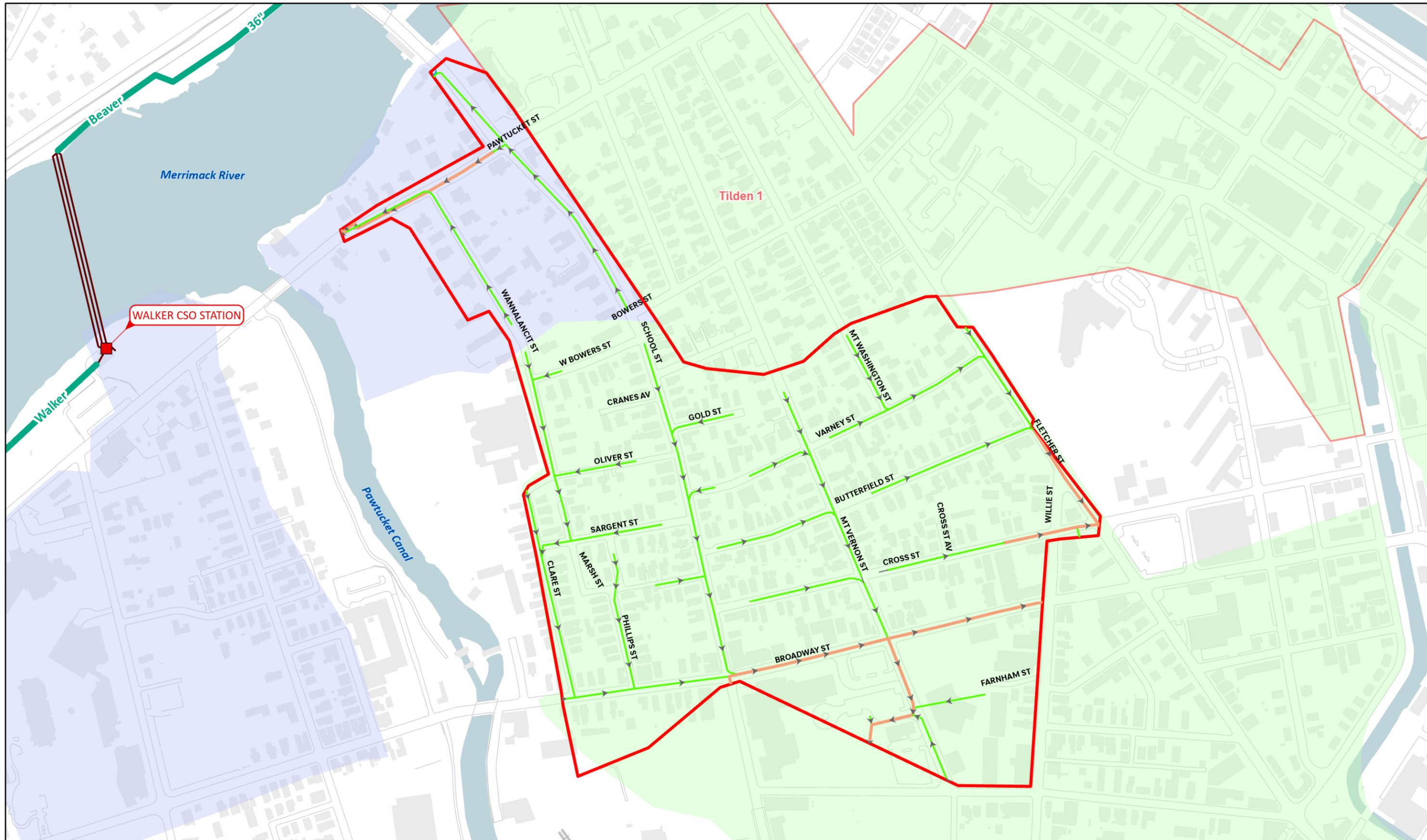


Tilden 2

Located within the Tilden CSO Basin, the Tilden 2 Area is situated within the canal system south of the Merrimack River. Spanning just over 69 acres, it is located adjacent to Tilden 1 to the north, the Western Canal to the east, the Pawtucket Canal to the south, and the Merrimack River to the west (**Figure 2.17**). **Table 2.19** presents the combined system pipe length, material, and diameter within the Tilden 2 Area. A majority of the combined flow is conveyed to the Upper Tilden Interceptor and ultimately to the Tilden CSO Diversion Station. In addition, there is a small portion of northwestern Tilden 2 that takes flow to the Walker CSO Diversion Station.

Table 2.19 Tilden 2 Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
Unknown	382			20				54	456
10 inches	979			108				942	2,029
12 inches	5,878							1,952	7,830
15 inches	864			474					1,338
16 inches by 24 inches					259				259
18 inches	203			1,160				321	1,684
20 inches	205								205
20 inches by 30 inches					394				394
24 inches					176				176
Tilden 2 Area Total									14,371

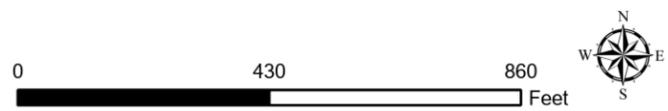


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Tilden 2 Area**
- Tilden 2 Area
 - Other Phase 3 Candidate Area
- Combined Sewer Area**
- Tilden
 - Walker



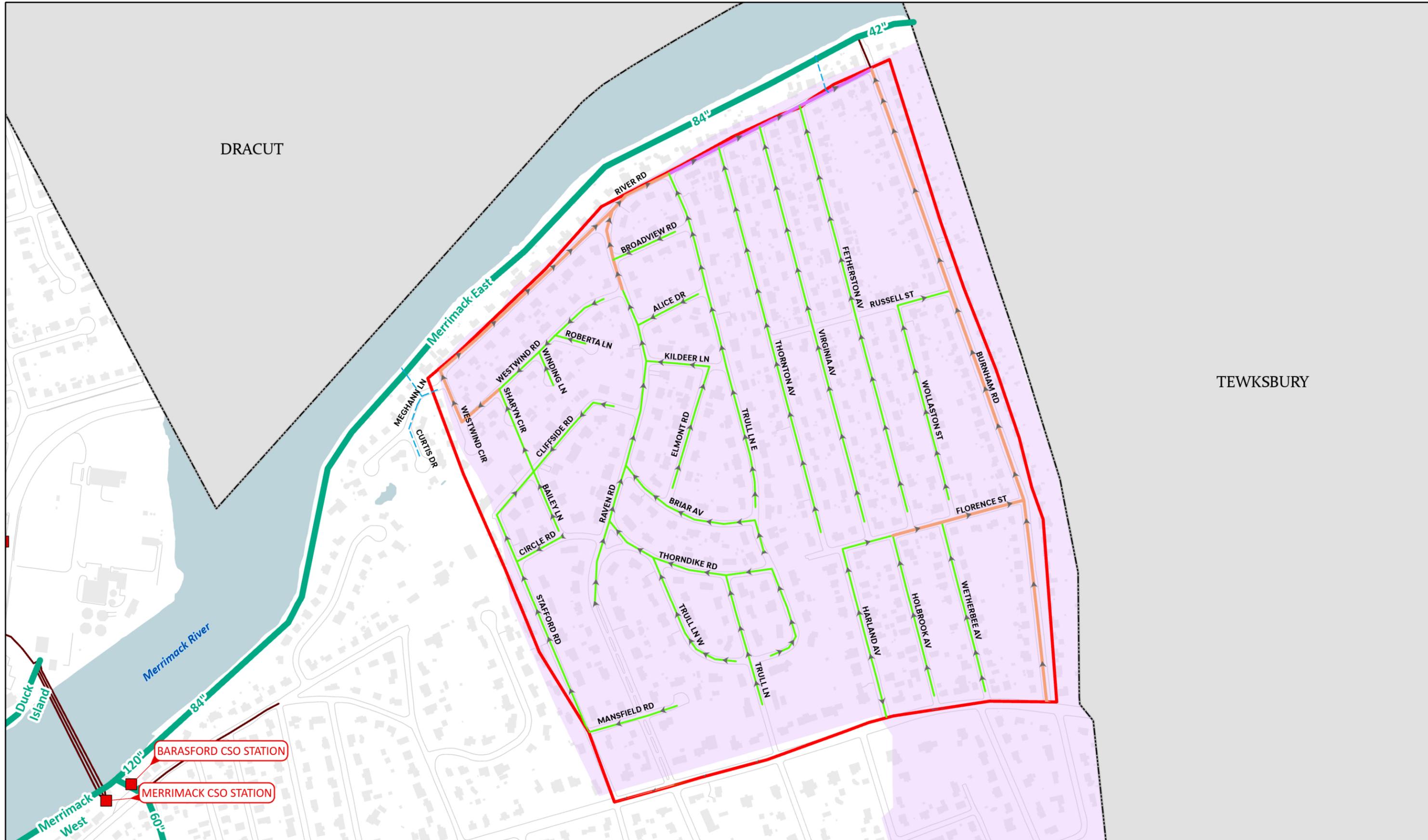
2.3.2.3 Merrimack Combined Sewer Overflow Basin

Burnham

Located within the Merrimack CSO Basin, the Burnham Area is directly south of the Merrimack River at the northeastern corner of Lowell and borders Tewksbury (**Figure 2.18**). Burnham is the largest area at 152 acres. **Table 2.20** presents the combined system pipe length, material, and diameter within the Burnham Area. Flow from Burnham is conveyed to the Merrimack East Interceptor and eventually to the Barasford CSO Diversion Station. There is separated drainpipe at the northeast and northwest corners of the Burnham Area.

Table 2.20 Burnham Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
6 inches	10								10
8 inches	8,530			1,903					10,433
10 inches	3,633			4,933					8,566
12 inches	1,382			246					1,628
15 inches				421					421
18 inches				1,523					1,523
24 inches				1,711					1,711
30 inches				2,479					2,479
36 inches				483					483
Burnham Area Total									27,254



DRACUT

TEWKSBURY

BARASFORD CSO STATION

MERRIMACK CSO STATION



Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Burnham Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Merrimack



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 2.18
Existing Combined System
Phase 3 Candidate Area: Burnham

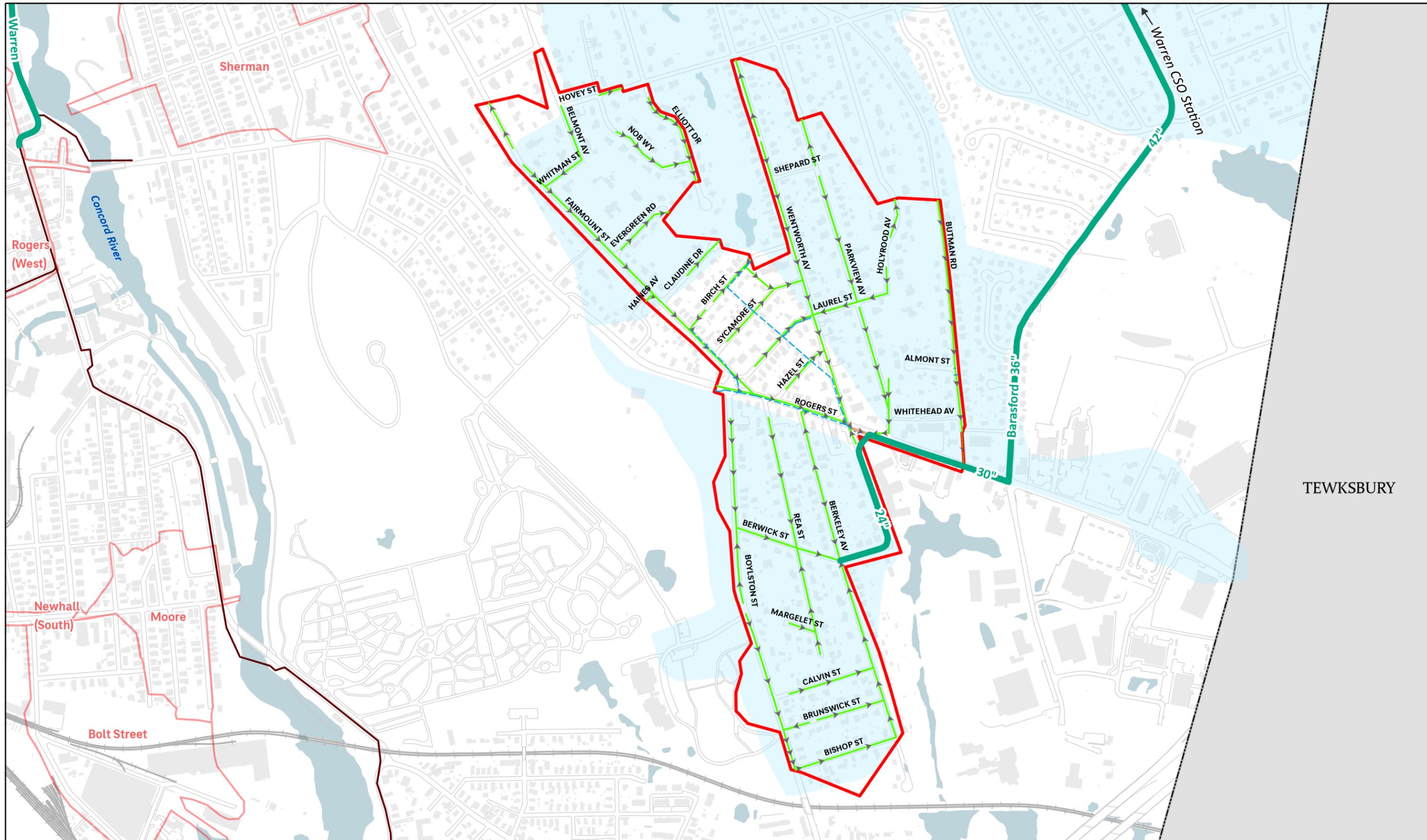
2.3.2.4 Barasford Combined Sewer Overflow Basin

Wentworth-Douglas

Located within the Barasford CSO Basin, the Wentworth-Douglas Area is one of the largest areas at approximately 134 acres. The Wentworth-Douglas Area is located to the northwest in Lowell next to the Tewksbury town border (**Figure 2.19**). **Table 2.21** presents the combined system pipe length, material, and diameter within the Wentworth-Douglas Area. Most of the combined flow is conveyed from the area to the Barasford Interceptor and ultimately flows to the Barasford CSO Diversion Station. There is separated drainpipe located centrally within the Wentworth-Douglas Area.

Table 2.21 Wentworth-Douglas Area Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (LF)							Total LF	
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP		UNK
Unknown	1,555			794				51	2,400
8 inches	1,082	1,271					50	527	2,930
10 inches	4,815			3,187				2,977	10,979
12 inches	4,271			859				139	5,269
15 inches	1,183			402					1,585
18 inches				162					162
24 inches				921					921
30 inches				572					572
Wentworth-Douglas Area Total									24,818



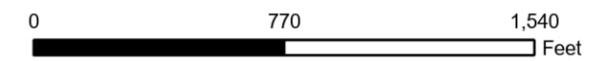
TEWKSBURY



Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
- 18 - 30
- 32 - 60
- 62 - 120
- Unknown
- Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Wentworth-Douglas Area
- Other Phase 3 Candidate Area
- Combined Sewer Area**
- Barasford



2.3.2.5 West Combined Sewer Overflow Basin

West/Coburn/Jewett

Located within the West CSO Basin, the West/Coburn/Jewett Area is the only Phase 3 Candidate Area north of the Merrimack River and spans approximately 77 acres (**Figure 2.20**). **Table 2.22** presents the combined system pipe length, material, and diameter within the West/Coburn/Jewett Area. The combined sewer system flows to the West CSO Diversion Station. There is existing drainage present on the western edge of the West/Coburn/Jewett Area associated with the MassDOT highway.

Table 2.22 West/Coburn/Jewett Area Combined System Pipe Material Summary

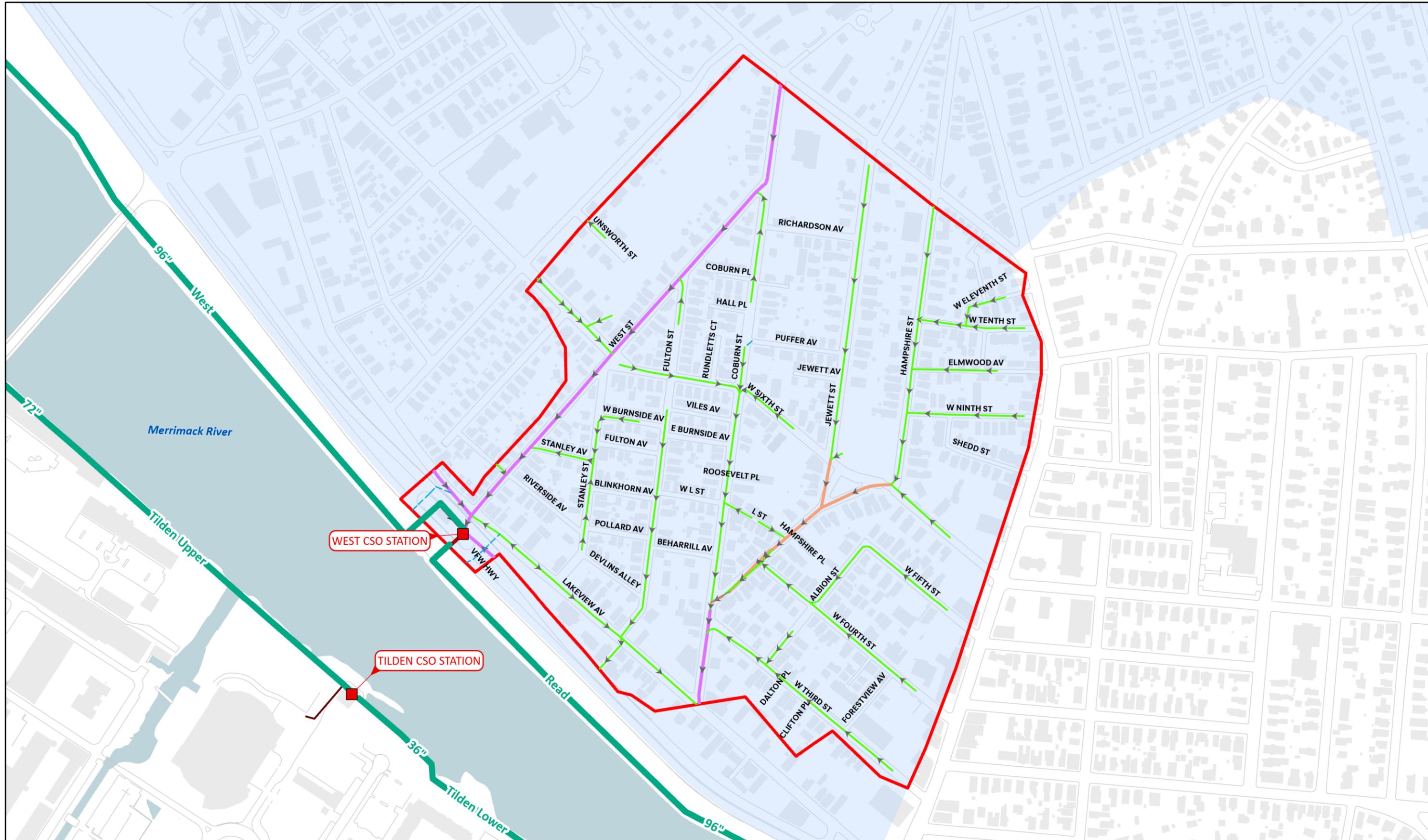
Pipe Diameter	Pipe Material (LF)								Total LF
	VCP	ACP	PVC	Concrete	Brick	CIP	DIP	UNK	
Unknown				10	83			120	213
8 inches	377			210				133	720
10 inches	187			169				932	1,288
12 inches	5,285			1,067				691	7,043
15 inches	1,306		201	472	46				2,025
18 inches								265	265
24 inches				214	403				617
36 inches				27					27
54 inches by 46 inches					173				173
60 inches					1,589				1,589
96 inches				131					131
West/Coburn/Jewett Area Total									14,091

2.4 System Surcharge and Street Flooding Conditions

2.4.1 Overview

It is important to understand the current level of known system surcharging and street flooding to identify potential system improvements that could be implemented to mitigate such conditions in the Phase 3 Candidate Areas. System surcharge in the CSS becomes problematic when it results in property backups and/or street flooding. Street flooding, meanwhile, may not be a result of combined sewer system surcharging, but it could be a result of inlet limitations to get the flow into the CSS.

Understanding these differences and occurrences are critical to developing an appropriate corrective action plan for surcharge mitigation. One objective of this Phase 3 PDR is to identify whether the separation of Phase 3 Candidate Areas will resolve known SSOs for the Pevey and Wentworth-Douglas areas, along with evaluating the reduction potential for mitigating CSO discharges in all Candidate Areas.

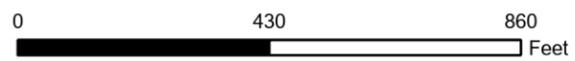


Legend

- Existing Gravity Main Pipe Diameter (In)**
- 6 - 15
 - 18 - 30
 - 32 - 60
 - 62 - 120

- Unknown
- - - Existing Drain
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- West/Coburn/Jewett Area
- Other Phase 3 Candidate Area
- Combined Sewer Area West



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.20
Existing Combined System
Phase 3 Candidate Area: West/Coburn/Jewett

2.4.2 System Surcharges

The City has a reported history of both system surcharge and street flooding events in the combined sewer portions of the system. Several sources of information were used to identify and document known areas of system surcharge and associated street flooding, including:

- Commonwealth of Massachusetts SSO/Bypass Notification Forms completed by the Utility and submitted to MassDEP following each SSO occurrence
- Reported street flooding conditions caused by historic and recent storm events (anecdotal reports, staff discussions, and photographs)
- Review of SSO/surcharge level metering data provided by the Utility
- The online Sewer Issues and Street Flooding Survey questionnaire available to residents and businesses in the City
- Property owners or residents reporting a discharge by phone and/or by Civic Plus (online reporting feature)

After notification of a surcharge condition, the Utility conducts a field inspection to assess the situation, clean up the affected area, and identify and assess corrective actions to mitigate the surcharge. Documentation of the SSO along with an assessment of the contributing conditions is submitted on a SSO Notification Form to MassDEP. The cause of the surcharge is easily identified sometimes (either a temporary blockage in the public sewer system or a private sewer lateral issue, which is not the Utility's responsibility) and then rectified. For other surcharge events, the City deploys temporary meters to monitor sewer depths for subsequent storms to identify whether there is a recurrent sewer surcharge issue or a localized street flooding issue related to catch basin (CB) inlet capacity. For this report, these temporary meters will be referred to as System Surcharge Meters.

Article VI.11.c.ii. of the CD requires documentation of surcharge/overflow events from January 1, 2010, to the present for Pevey, relative to the Boys & Girls Club area, and for Wentworth-Douglas, relative to the Windward Road/Douglas Road area. To accomplish this effort, SSO Notification Forms filed with MassDEP were reviewed and are summarized in **Table 2.23** and **Table 2.24** for the Pevey and Wentworth-Douglas Areas, respectively. SSO history information was only available from 2014 to present. As required by the CD, the cause of each surcharge/overflow event, occurrence of an overflow, volume, if known, properties impacted, and receiving waters affected are provided in these tables. Rainfall statistics presented in Tables 2.23 and 2.24 are drawn from several sources, since the principal long-term source of rainfall data for Lowell only reports daily totals, whereas the tables rely on hourly data. The following sources are referenced:

- Lowell Regional Water Utility records 24-hour rainfall totals for the National Weather Service COOP program. Rainfall for July 18, 2017 is reported from this site.
- Hourly data is collected by the National Weather Service at Lawrence Municipal Airport, 11 miles northeast of downtown Lowell. Lawrence data is used to report 2014 through 2017 events except July 18, 2017. On that date, only 0.18 inches of rain was measured at Lawrence, while 0.90 inches was observed at Lowell.

Table 2.23 Pevey Sanitary Sewer Overflow Data

Address of SSO ¹	Date(s) Occurred	Cause of Event(s)	SSO Discharge To	Estimated SSO Volume (gal) ²	Duration (hr)	Rain (inches)			Average Recurrence Interval		Rain Data Source ³
						1-hour	24-hour	Total	1-hour	24-hour	
Eagle Court (657 Middlesex St)	7/28/2014	Rain event	Pawtucket Canal - SMH to receiving water	15,000	12	0.74	1.07	1.07	8-mo	1-mo	Lawrence
Marginal St SMH 0997	7/28/2014	Rain event	SMH to Ground Surface	5,000	12	0.74	1.07	1.07	8-mo	1-mo	Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	6/1/2015	Rain event	SMH to Ground Surface	5,000	25	0.27	2.03	2.04	<1-mo	6-mo	Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	6/6/2015	Rain event	SMH to Ground Surface	50,000	<0.1" rain Lawrence and Lowell						Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	6/21/2015	Rain event	SMH to Ground Surface	15,000	14	0.49	1.60	1.60	3-mo	3-mo	Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	6/6/2016	Rain event	SMH to Ground Surface	50,000	14	0.26	1.09	1.09	<1-mo	1-mo	Lawrence
15 Sayles St	7/9/2016	Rain event	Backup in Property Basement to Ground Surface	3,300	13	0.43	0.63	0.63	2-mo	<1-mo	Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	7/9/2016	Rain event	SMH to Ground Surface	50,000	13	0.43	0.63	0.63	2-mo	<1-mo	Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	8/10/2016	Rain event	SMH to Ground Surface	5,000	4	0.65	1.06	1.06	6-mo	1-mo	Lawrence
Marginal St SMH 0996 (near 1371 Middlesex St)	6/27/2017	Rain event	SMH to Ground Surface	5,000	7	0.29	0.60	0.60	1-mo	<1-mo	Lawrence
Eagle Court SMH-3356	7/18/2017	Rain event	SMH to Ground Surface	6,000	2	0.17	0.18	0.18	<1-mo	<1-mo	Lawrence
Marginal St SMH 0995	7/18/2017	Rain event	SMH to Ground Surface	6,000	2	0.17	0.18	0.18	<1-mo	<1-mo	Lawrence
10 Sawtelle Pl	9/13/2017	Grease blockage	Backup into Property Basement	50	21	1.01	1.51	1.51	1-yr	2-mo	Lawrence
Eagle Court SMH-3356	7/22/2020	Rain event / insufficient capacity	SMH to Ground Surface	UNK	15	0.85	1.06	1.06	2-yr	1-mo	Rivers Edge
35 Eagle Ct (657 Middlesex St)	11/12/2021	Rain event / insufficient capacity	SMH to Ground Surface	UNK	21	1.13	1.62	1.62	2-yr	3-mo	Warren
67 Payne St	7/19/2022	Rain event / insufficient capacity	SMH to Ground Surface	<100	16	0.61	0.88	0.88	5-mo	<1-mo	Warren
67 Payne St	6/26/2023	Rain event	Pawtucket Canal - CB to receiving water	UNK	22	1.38	2.58	2.58	5-yr	1-yr	Warren
35 Eagle Ct	6/26/2023	Rain event	Pawtucket Canal - SMH to receiving water	UNK	22	1.38	2.58	2.58	5-yr	1-yr	Warren
67 Payne St	6/27/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	UNK	22	1.38	2.58	2.58	5-yr	1-yr	Warren
35 Eagle Ct	6/27/2023	Rain event	Pawtucket Canal - SMH to receiving water	UNK	22	1.38	2.58	2.58	5-yr	1-yr	Warren
67 Payne St	7/14/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	410	18	0.90	1.30	1.30	11-mo	2-mo	Warren
657 Middlesex St	7/14/2023	Rain event	Pawtucket Canal - SMH to receiving water	450	18	0.90	1.30	1.30	11-mo	2-mo	Warren

Address of SSO ¹	Date(s) Occurred	Cause of Event(s)	SSO Discharge To	Estimated SSO Volume (gal) ²	Duration (hr)	Rain (inches)			Average Recurrence Interval		Rain Data Source ³
						1-hour	24-hour	Total	1-hour	24-hour	
67 Payne St	7/16/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	10	18	0.43	1.38	1.38	2-mo	2-mo	Warren
67 Payne St	7/21/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	31	6	1.91	2.35	2.34	23-yr	10-mo	Warren
657 Middlesex St	7/21/2023	Rain event	Pawtucket Canal - SMH to receiving water	1,441	6	1.91	2.35	2.34	23-yr	10-mo	Warren
67 Payne St	7/29/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	1,807	7	1.18	2.21	2.21	3-yr	8-mo	Warren
657 Middlesex St	7/29/2023	Rain event	Pawtucket Canal - SMH to receiving water	1,367	7	1.18	2.21	2.21	3-yr	8-mo	Warren
67 Payne St	8/8/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	400	36	0.63	1.43	1.44	5-mo	2-mo	Warren
657 Middlesex St	8/8/2023	Rain event	Pawtucket Canal - SMH to receiving water	130	36	0.63	1.43	1.44	5-mo	2-mo	Warren
64 Foster St	8/8/2023	Rain event	Backup into Property Basement	UNK	36	0.63	1.43	1.44	5-mo	2-mo	Warren
67 Payne St	8/10/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	320	5	0.91	1.58	1.58	12-mo	3-mo	Warren
657 Middlesex St	8/10/2023	Rain event	Pawtucket Canal - SMH to receiving water	170	5	0.91	1.58	1.58	12-mo	3-mo	Warren
67 Payne St	8/18/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	826	9	0.79	1.78	1.78	9-mo	4-mo	Warren
657 Middlesex St	8/18/2023	Rain event	Pawtucket Canal - SMH to receiving water	883	9	0.79	1.78	1.78	9-mo	4-mo	Warren
67 Payne St	9/11/2023	Rain event	SMH to CB to Pawtucket Canal receiving water	828	14	0.25	1.50	0.51	7-mo	2-mo	Warren
35 Eagle Ct (657 Middlesex St)	9/11/2023	Rain event	Pawtucket Canal - SMH to receiving water	330	14	0.25	1.50	0.51	7-mo	2-mo	Warren
67 Payne St	8/15/2024	Rain event	SMH to CB to Pawtucket Canal receiving water	832	9	1.00	1.03	1.03	1-yr	1-mo	Warren
657 Middlesex St	8/15/2024	Rain event	Pawtucket Canal - SMH to receiving water	758	9	1.00	1.03	1.03	1-yr	1-mo	Warren
67 Payne St	8/19/2024	Rain event	SMH to CB to Pawtucket Canal receiving water	134	18	0.69	1.32	1.32	6-mo	2-mo	Warren
657 Middlesex St	8/19/2024	Rain event	Pawtucket Canal - SMH to receiving water	232	18	0.69	1.32	1.32	6-mo	2-mo	Warren

Notes:

- 1 All information as reported on SSO/Bypass Notification Forms to MassDEP.
- 2 SSO volume estimated using level sensor data.
- 3 Rain data sources:
 - Lawrence - NWS Lawrence Municipal Airport hourly data: <https://www.ncei.noaa.gov/data/global-hourly/access/2014/74490494723.csv>
 - Rivers Edge and Warren - 15-minute data collected by LRWWU

Table 2.24 Wentworth Sanitary Sewer Overflow Data

Address of SSO ¹	Date Occurred	Cause of Event	SSO Discharge To	Estimated SSO Volume (gal) ²	Duration (hr)	Rain (inches)			Average Recurrence Interval		Rain Data ³ Source
						1-hour	24-hour	Total	1-hour	24-hour	
Windward Rd (SMH 6783)	7/18/2017	Rain event	SMH to Ground Surface	5,000	6	NA	0.90	0.90	NA	<1-mo	Lowell COOP
174 Boylston St	7/18/2017	Rain event / Insufficient capacity	Backup into Property Basement	600	6	NA	0.90	0.90	NA	<1-mo	Lowell COOP
35 Windward Rd	8/19/2021	Rain event	SMH to CB to receiving water - unnamed wetland off of Windward Road	UNK	24	0.91	1.75	1.75	12-mo	3-mo	Warren
35 Windward Rd	9/2/2021	Rain event	SMH to CB to receiving water - unnamed wetland off of Windward Road	UNK	13	0.69	3.54	3.54	6-mo	3-yr	Warren
35 Windward Rd	6/27/2023	Rain event	SMH to CB to receiving water - unnamed wetland off of Windward Road	UNK	22	1.38	2.58	2.58	5-yr	1-yr	Warren
35 Windward Rd	6/28/2023	Rain event	SMH to CB to receiving water - unnamed wetland off of Windward Road	UNK	14	0.74	1.31	1.31	8-mo	2-mo	Warren
35 Windward Rd	7/3/2023	Rain event	SMH to CB to receiving water - unnamed wetland	1,600	26	0.53	2.43	2.48	3-mo	10-mo	Warren
Windward/Douglas Rd	7/21/2023	Rain event	SMH to CB to receiving water - unnamed wetland	13,416	6	1.91	2.35	2.34	23-yr	10-mo	Warren
47 Birch St	7/21/2023	Rain event	Backup into Property Basement	UNK	6	1.91	2.35	2.34	23-yr	10-mo	Warren
138 Rea St	7/21/2023	Rain event, sewer system blockage, root intrusion	Backup into Property Basement	UNK	6	1.91	2.35	2.34	23-yr	10-mo	Warren
150 Rea St	7/21/2023	Rain event, sewer system blockage, root intrusion	Backup into Property Basement	UNK	6	1.91	2.35	2.34	23-yr	10-mo	Warren
Windward/Douglas Rd	7/29/2023	Rain event	SMH to CB to receiving water - unnamed wetland	5,550	7	1.18	2.21	2.21	3-yr	8-mo	Warren
330 Douglas Rd	7/29/2023	Rain event	Backup into Property Basement	UNK	7	1.18	2.21	2.21	3-yr	8-mo	Warren
340 Douglas Rd	7/29/2023	Rain event	Backup into Property Basement	UNK	7	1.18	2.21	2.21	3-yr	8-mo	Warren
88 Elliott Dr	8/8/2023	Rain event	Backup into Property Basement	UNK	36	0.63	1.43	1.44	5-mo	2-mo	Warren
Windward/Douglas Rd	8/8/2023	Rain event	SMH to CB to receiving water - unnamed wetland	1,560	36	0.63	1.43	1.44	5-mo	2-mo	Warren
47 Birch St	8/8/2023	Rain event	Backup into Property Basement	UNK	36	0.63	1.43	1.44	5-mo	2-mo	Warren
Windward/Douglas Rd	8/10/2023	Rain event	SMH to CB to receiving water - unnamed wetland	1,230	5	0.91	1.58	1.58	12-mo	3-mo	Warren
Windward/Douglas Rd	8/18/2023	Rain event	SMH to CB to receiving water - unnamed wetland	1,480	9	0.79	1.78	1.78	9-mo	4-mo	Warren
15 Donald Terrace	8/23/2023	Grease blockage	SMH to Ground surface	UNK	1	0.95	0.95	0.95	1-yr	<1-mo	Warren
35 Windward Rd	1/10/2024	Rain event	SMH to CB to receiving water - unnamed wetland	3,582	18	0.63	3.09	3.09	5-mo	2-yr	Warren
35 Windward Rd	8/19/2024	Rain Event/Insufficient Capacity	SMH to CB to receiving water -unnamed wetland	UNK	18	0.69	1.32	1.32	6-mo	2-mo	Warren

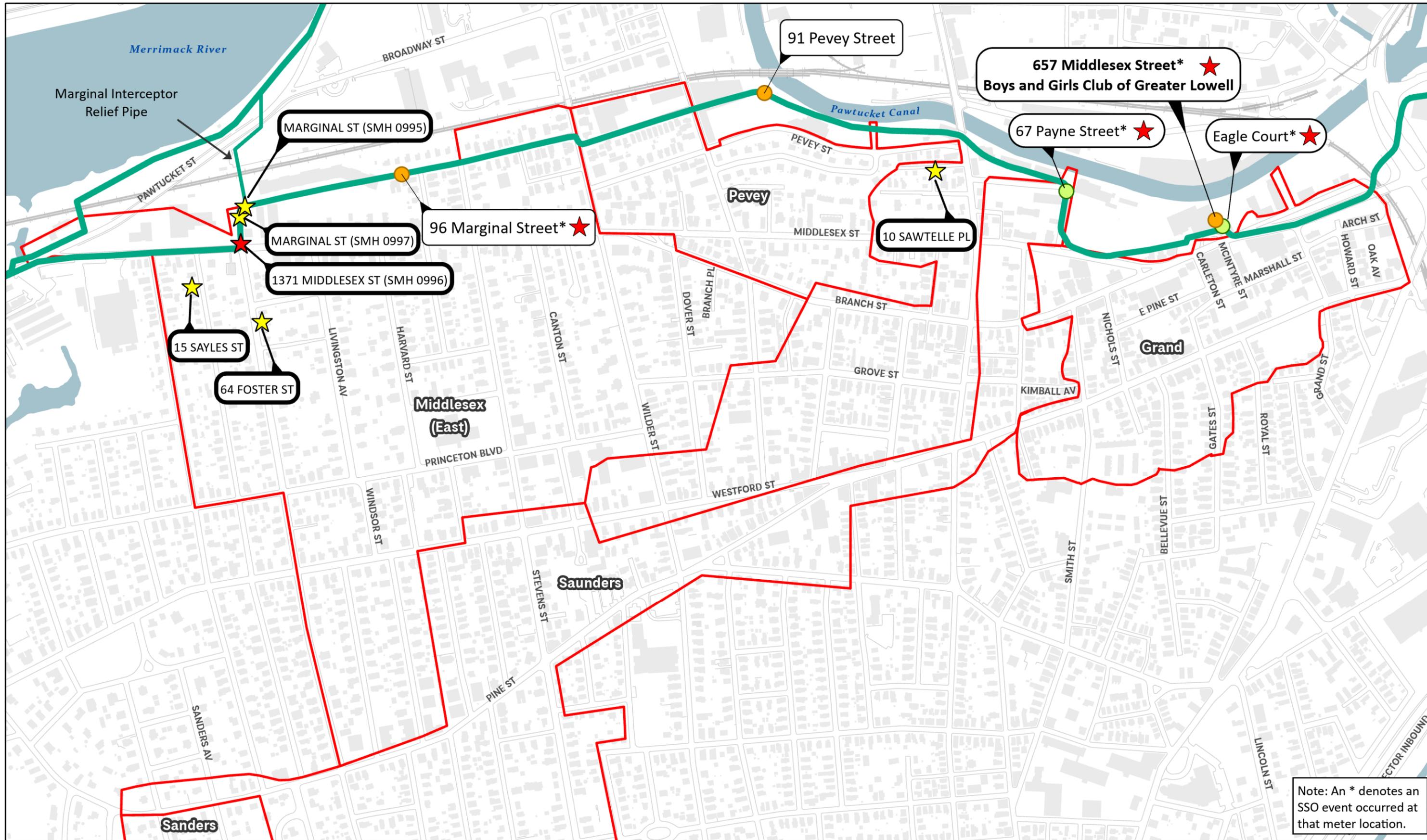
Notes:

- 1 All information as reported on SSO/Bypass Notification Forms to MassDEP.
- 2 SSO volume estimated using level sensor data.
- 3 Rain data sources:
 - Lawrence - NWS Lawrence Municipal Airport hourly data: <https://www.ncei.noaa.gov/data/global-hourly/access/2014/74490494723.csv>
 - Rivers Edge and Warren - 15-minute data collected by LRWWU

- The Utility records 15-minute rainfall at Duck Island, the Warren CSO Diversion Station, and River's Edge Road. For storms occurring from 2021 through 2024, rainfall for the Warren gage is shown in the tables. For the July 22, 2020 storm, the 1.06 inches reported for River's Edge is shown. On that date, Warren recorded no rainfall (likely issue with the gauge), while Duck Island measured 0.75 inches.

The tables show storm duration, storm total rainfall, 1-hour, and 24-hour maxima, and average recurrence intervals (ARI) for 1-hour and 24-hour durations. Precipitation frequency estimates for events exceeding a 1-year ARI are interpolated from NOAA Atlas 14 precipitation frequency estimates for Lowell. Frequency estimates for events smaller than a 1-year ARI are based on frequency statistics for Lawrence, as calculated using NetSTORM software.

Figure 2.21 and **Figure 2.22** show the locations of these surcharge/overflow events for each of the Pevey and Wentworth-Douglas Areas, respectively.



Note: An * denotes an SSO event occurred at that meter location.



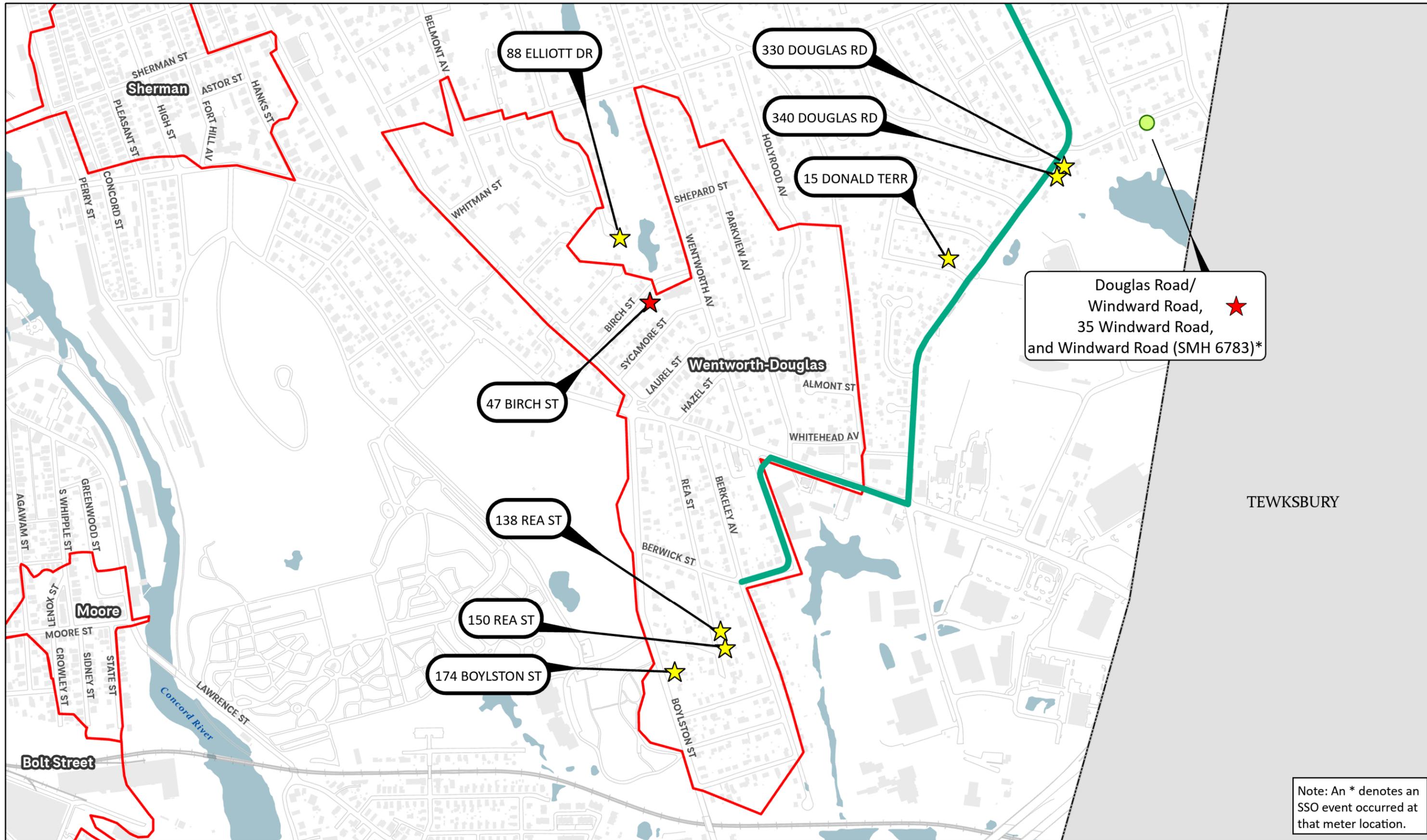
Legend

- Active SSO Level Meter
- Inactive SSO Level Meter
- ★ 1 SSO Occurrence
- ★ >1 SSO Occurrence
- Interceptor
- Phase 3 Candidate Areas



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.21
Pevey SSO Level Meters & Occurrences



Douglas Road/
Windward Road,
35 Windward Road,
and Windward Road (SMH 6783)*

Legend

- Active SSO Level Meter
- ★ 1 SSO Occurrence
- ★ >1 SSO Occurrence
- Interceptor
- Phase 3 Candidate Areas



Note: An * denotes an SSO event occurred at that meter location.

Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.22
Wentworth-Douglas SSO Level Meters & Occurrences

The Utility’s CMOM Program is used to track, report, and resolve system surcharge and identify collection system improvements or operational measures that will reduce the risk of surcharge/overflow events, and resultant public health risks at/near areas with recurring backup events. The documents for the program include the CMOM Program Self-Assessment (Lowell Regional Wastewater Utility, December 31, 2022) and the 2024 CMOM Corrective Action Plan (CAP) (Lowell Regional Wastewater Utility, December 19, 2024). The CMOM CAP includes a summary of the Utility’s action plan to address six recurring surcharges/overflows locations identified in Article VI.14 of the CD. **Table 2.25** summarizes the six CMOM documented surcharge/overflow locations, associated corrective actions, and whether or not the concern has been resolved. A review of Table 2.25 suggests that only the Pevey Area (i.e., near the Lowell Boys & Girls Club) and the Wentworth-Douglas Area (near Windward Road/Douglas Road) remain to be addressed. SSOs in the Windward Road/Douglas Road area are being resolved with construction of the Douglas Road Wet-Weather Storage Tank, as presented in Section 7.2.1. SSOs in the Pevey Area have been evaluated as part of this Phase 3 PDR, with a recommended corrective action summarized in Table 2.25

Table 2.25 Summary of Capacity Management, Operations and Maintenance Corrective Action Plan Surcharge/Overflow Events and Resolution Status

Area of Concern	Surcharge/Overflow History	Reported Cause	Corrective Action	Resolved (Yes/No)
River/Raven Road	September 2020–July 2023	Tree root growth in pipe causing hydraulic restriction	Removal of roots and cured-in-place-pipe lining (CIPP) lining	Yes
Eagle Court, Pevey Street, Payne Street, and Lowell Boys & Girls Club	July 2017–August 2024	Hydraulic capacity; steep pipe grade; tributary combined sewer catchments; rain events	Evaluation in the Phase 3 PDR	No (recommended solution provided in Section 7.2.2)
Windward/Douglas Road	July 2017–August 2024	Hydraulic capacity; tributary to a combined sewer catchment; rain events	Douglas Road Wet-Weather Storage Tank under construction	No (expected resolution 2026 – Section 7.2.1)
Marginal Street	June 2016–July 2017	Hydraulic capacity; tributary combined sewer; rain events	Addition of the Marginal Sewer Relief Pipe installed downstream of the surcharging manhole	Yes
Bishop Street	September 2020	Private sewer service backup; hydraulic capacity; rain event	Private issue	Yes
Chelmsford Pump Station	July 2017	Equipment failure; rain event	Installation of new pumps at Chelmsford Pump Station	Yes

Source: 2024 CMOM Corrective Action Plan, Lowell Regional Wastewater Utility (December 19, 2024)

2.4.3 Sanitary Sewer Overflow/Surcharge Level Metering

As identified in Tables 2.23 and 2.24, and documented in the CMOM CAP (Table 2.25), the history of surcharge/overflow events in the area of the Boys & Girls Club and Windward/Douglas Roads is well known. Photographs of flooding occurrences in these areas are shown in **Figure 2.23** through **Figure 2.25**.

To address these concerns, the Utility has conducted SSO/surcharge level metering in these areas. Figure 2.21 and Figure 2.22 show the locations of the SSO/surcharge level meters installed and monitored between 2020 and 2024 for each of the Pevey and Wentworth-Douglas Areas. **Table 2.26** provides a summary of the SSO/surcharge metering performed at these locations, inclusive of reported SSO/surcharge location, Phase 3 Candidate Area proximity, meter status, and metering dates. The requirement for assessment is also identified in Table 2.26, relative to CD compliance for the Phase 3 PDR and/or the CMOM Program. Utilizing the meter data through model efforts described in Section 4 has provided the basis for development of corrective actions to mitigate SSO and surcharge events in these areas as described in Section 7.



Figure 2.23 Street Flooding on Pevey Street Near the Bus Parking Lot During Summer 2023 Storm; Near the Boys & Girls Club



Figure 2.24 Flooding with Manhole Surcharging on Windward Road Near the Wentworth-Douglas Area



Figure 2.25 Flooding at 387 Douglas Road Near the Wentworth-Douglas Area After a 2023 Summer Storm

Table 2.26 SSO/Surcharge Level Meter Locations

Reported SSO/Surcharge Location	Phase 3 Candidate Area	Surcharge Level Meter Locations	Meter Status	Meter Installation Dates	Did SSO Occur During Meter Period?
35 Windward Road	Wentworth-Douglas	Douglas Road/Windward Road	Active	7/31/2020–Present	Yes–Multiple
Marginal Interceptor/ Lowell Boys and Girls Club	Grand/Pevey/ Saunders	96 Marginal Street	Inactive	8/4/2020–10/7/2021	Yes – 2x
		91 Pevey Street	Inactive	8/12/2020–3/31/2021	No
		657 Middlesex Street	Inactive	9/22/2020–2/2/2022	Yes–Multiple
		67 Payne Street	Active	9/7/2021–Present	Yes–Multiple
		Eagle Court	Active	3/20/2022–Present	Yes–Multiple

2.4.4 Public Sewer System Survey/City-Identified Problems

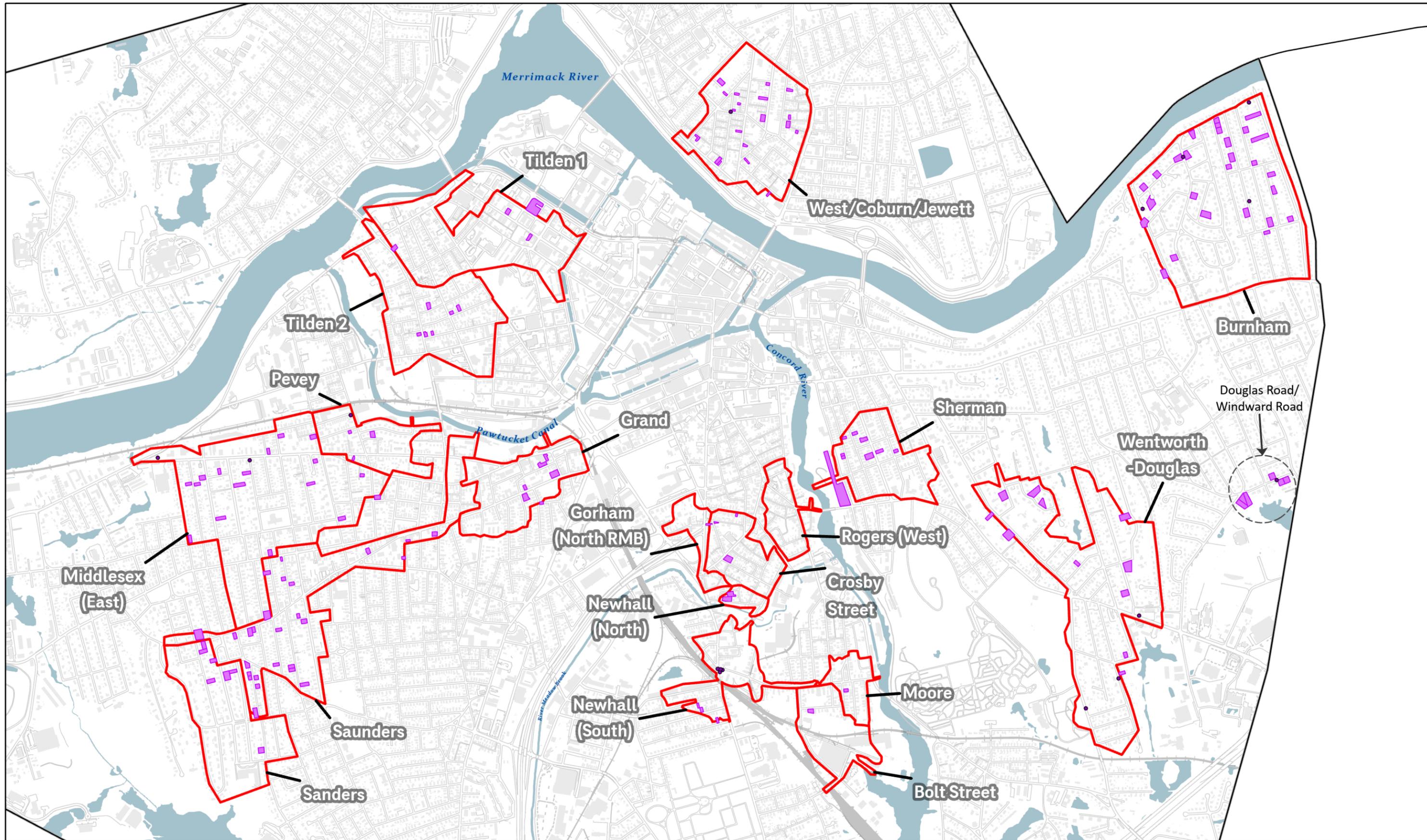
The Utility created an online Sewer and Street Flooding Issues Survey, available in English, Spanish, Portuguese, and Khmer, which was made available to residents from January 2024 to October 2024. Future sewer and street flooding issues are being reported through Civic Plus. The purpose of this survey was to actively solicit public input on adverse sewer system conditions within the City. Visitors and property owners in Lowell were notified of the availability of this survey via mailings, public notifications, newspaper articles, website notifications, and electronic media postings. **Figure 2.26** identifies submitted responses for the Phase 3 Candidate Areas. “Owner Responses” on Figure 2.26 reference responses by parcel owner or resident; “Other Responses” are in reference to issues identified by location provided by an individual other than the parcel owner.

The survey form (**Appendix C**) allowed the public to provide input on problems they experience and/or observe on their property or throughout the City relative to sewer and basement backups and/or surface flooding. The survey included questions about the presence of sump pumps in buildings, historical basement flooding, and adjacent street flooding. It was intended that data collected be used to help identify and/or confirm SSOs and potential sewer capacity issues.

Table 2.27 summarizes the survey responses from the Phase 3 Candidate Areas. The Utility and CDM Smith reviewed responses and comments received in each completed questionnaire. In general, review of responses and comments have shown that most of the sewer backup issues were related to private sewer lateral defects. In many cases, identified street flooding issues were a result of catch basin debris, which the City has mostly resolved. The City intends to follow up on remaining unresolved sources of sewer backup and street flooding. Questionnaire responses will be considered relative to future sewer separation planning and implementation as appropriate.

In general, review of the Sewer and Street Flooding Issues Survey responses show the following:

- Street flooding and basement backups are present in the Wentworth-Douglas Area (along Douglas Road and Windward Road) and Burnham Area (along Raven Road). Note that Wentworth-Douglas will be resolved with the Douglas Road Wet-Weather Storage Tank.
- Private sewer lateral defects are a frequent cause of sewer backup issues, confirming that sewer lateral rehabilitation could be considered as a component of the Phase 3 separation projects; though, this is private property work.
- The potential presence of sump pump connections to the CSS should continue to be evaluated, with intended efforts to disconnect whenever possible.



Legend

Sewer Survey Responses

- Owner Responses
- Other Responses

- Phase 3 Candidate Areas



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 2.26

Lowell Sewer Survey Responses in Phase 3 Candidate Areas

Table 2.27 Summary of Phase 3 Candidate Area Sewer Questionnaire Results

Phase 3 Candidate Areas	Questionnaire Responses	Response Results							Sump Pumps Reported		
		No Issue	Issues Reported					Street Flooding at Property ²	Street Flooding Observed ²	Sump Pump to Surface	Sump Pump to Sewer/UNK
			Water in Basement – Sewer Backup	Water in Basement – Leakage	Water in Basement – Both ¹	Water in Basement – Other					
Bolt Street	1	—	—	—	—	—	1	—	—	—	
Burnham	31	13	7	1	3	1	2	4	4	4	
Crosby Street	3	2		1	—		—	—	—	2	
Grand	7	4	1	—	—	2	—	—	—	—	
Gorham North (RMB)	1	1	—	—	—	—	—	—	—	—	
Middlesex (East)	21	14	2	1	2			2	1	4	
Moore	1	1	—	—	—	—	—	—	—	—	
Newhall (North)	2	2	—	—	—	—	—	—	—	—	
Newhall (South)	7	3	—	—	—	—	—	4	—	—	
Pevey	4	2	—	—	—	1	—	1	—	—	
Rogers (West)	0	—	—	—	—	—	—	—	—	—	
Sanders	7	5	—	1	—	—	1	—	5	—	
Saunders	25	18	2	3	—	1	1	—	4	3	
Sherman	12	7	2	—	—	—	3	—	—	—	
Tilden 1	4	3	—	1	—	—	—	—	—	—	
Tilden 2	6	5	—	—	1	—	—	—	—	2	
Wentworth-Douglas	14	9	2	—	—	—	—	3	2	1	
West/Coburn/Jewett	21	11	3	2	1	—	3	1	—	4	
Total	167	100	19	10	7	5	11	15	16	20	

Notes:

1 Source of water in basement was identified as both sewer backups and leakage.

2 Street flooding at property is defined as flooding at the property in which the respondent resides. Street flooding observed is when the respondent reported flooding elsewhere in the City and selected the location on a map.



3.0 Field Inspection Program

3.1 Introduction

Aging wastewater collection system infrastructure is a challenge for wastewater utilities. Historically, many municipalities operated with a run-to-failure management approach that caused assets to deteriorate faster, resulting in higher replacement and significant emergency response costs. Proactive operation and maintenance programs are the key to addressing this challenge, which includes taking an active approach to sewer system rehabilitation. Lowell has been a leader in proactive maintenance of collection system assets, with more than \$1.5 million annually spent on collection system maintenance and refurbishment programs. Activities under this program include regularly cleaning sewers, identifying and monitoring problem areas (through methods such as closed-circuit television (CCTV) inspections and SSO reporting), repairing failing sewers, inspecting pump stations, and implementing infiltration and inflow (I/I) studies and Sewer System Evaluation Survey (SSES) programs.

The need for collection system rehabilitation or upgrades arises from several factors, including:

- Deterioration of the structural integrity of an aging combined sewer system
- Excessive I/I due to defects in the systems
- Increasing regulatory control of wet weather overflows from sewer systems
- Additional hydraulic capacity needs for the combined sewer system
- New construction near aging combined sewer pipes.

Most of the collection system in Lowell was installed before 1950. Pipes of that age are reaching the end of their useful life, and the pipe materials used in these older installations are prone to settlement (causing joint issues), root intrusion, cracking/fracturing, and broken and collapsed pipe segments. The City also has a significant number of brick sewers. In general, brick sewers typically have issues, such as missing brick that can contribute to groundwater (and soil) infiltration. This can cause external pipe circumference voids, leading to sink holes and street collapses.

There are two primary purposes for the Utility to address this aging pipe issue—one is to rehabilitate or replace the aging pipes before they structurally fail, and the second is to eliminate sources of extraneous flow (i.e., flow not discharged by residents or businesses) that can enter through sewer defects. The CD requires the Utility to develop and implement an I/I reduction program to reduce this extraneous flow. Integration of a pipe rehabilitation plan into the sewer separation program for complete infrastructure renewal is a cost-effective approach.

Extraneous flow can enter a collection system as infiltration (indirect) or inflow (direct). Infiltration is groundwater that enters the sewer system from defects in mainline or property services pipes and joints. Sources of infiltration may also include rivers, brooks, and streams. Lowell continuously investigates its collection system for sources of extraneous flow because of the proximity of the interceptors to the river. Infiltration typically increases as pipes age and/or fall into disrepair.

Inflow is generally a factor of rainwater entering the system from public sources like catch basins and leaking manhole covers, or from private sources such as roof leader (gutters), yard/driveway drains, or foundation drains that are connected to the sewer system. Some buildings also may have sump pumps that take groundwater seeping into basements and discharge it to the sewer. Inflow can also include a continuous source of extraneous flow to a sewer such as a brook or stream. Removal of these extraneous flows can reduce the dry and wet weather capacity of the existing system substantially.

During a sewer separation project, attention should be given to identifying and reducing or eliminating all extraneous flows to the system. However, while a new drain system will readily eliminate catch basin flow to the sewer system, other sources of extraneous flow are more difficult (and costly) to identify and remove.

With sewer separation projects, new sewers and/or drains often must be installed in tight corridors where excavation could potentially damage or conflict with existing sewer pipes. Excavation near sewer pipes that are in poor condition can result in a structural failure because of vibration from machinery or pipes being unsupported near excavated trenches. Accordingly, the condition of the existing pipe, and its need for rehabilitation or replacement, should be assessed before construction begins.

A condition assessment provides the background to evaluate the existing system, characterize the defects and the severity of these defects, and identify other deficiencies. In support of these goals, field investigations were performed on the existing combined sewer system (CSS) in the Phase 3 Candidate Areas to develop a representation of overall system conditions. CDM Smith, with the support of Wright-Pierce, completed these investigations, which included windshield/desktop surveys, smoke testing, manhole inspections, and CCTV inspection. Review of the completed *2023 Infiltration and Inflow Analysis Report* prepared by Kleinfelder, dated January 2024, was also conducted to identify needed repairs and rehabilitation.

3.2 Field Investigations

This section summarizes the field investigations performed in the Phase 3 Candidate Areas as a representative sample to assess the condition of the existing CSS.

3.2.1 Television Inspections

During the spring and summer of 2023, Inland Water/Green Mountain Pipeline Services (GMPS), as a subcontractor to Wright-Pierce, performed CCTV of the CSS. Specific pipe sections were selected for inspection based on size, age, material, and location within the system. CCTV inspections were performed for over 75,300 linear feet of pipe in the Phase 3 Candidate Areas.

Inland Water/GMPS performed CCTV inspections of the sewer pipe according to National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP) standards. Pipe cleaning was performed before the inspection, as necessary, to maximize the value of the inspections. The CCTV camera traveled through the pipe to identify structural and maintenance defects, such as fractures, breaks, deformation, sedimentation/debris, infiltration, and lateral locations. Based on this inspection, a defect code was assigned to each pipe. The video from the inspection and defect codes were recorded and used to generate an inspection report for each pipe segment.

Once an inspection report was developed for the pipe, a likelihood of failure (LoF) rating was assigned to each defect according to NASSCO PACP standards. This is a numerical representation of the pipe's physical condition and probability of failure. NASSCO LoF ratings are more heavily weighted on structural defects compared to maintenance and operation defects, which focus on infiltration defects. Wright-Pierce used sewer asset rehabilitation software to generate preliminary recommendations for each pipe segment based on the LoF ratings and defect types. Program recommendations were then reviewed to confirm or revise the results and recommendations.

Historical CCTV inspections completed over the last five years were also reviewed. The videos did not have an inspection report or NASSCO coding, so Wright-Pierce engaged SewerAI to complete an automated defect recognition (ADR) technology pipe assessment. This is an emerging artificial intelligence (AI) process/approach that uses machine learning technology to identify defects from CCTV videos. The ADR process uses the NASSCO PACP standards as a guide for coding defects, but the software is not certified by NASSCO. Once PACP coding was complete, Wright-Pierce used this information in its software program to generate recommendations for the inspected subset of pipes.

In total, just under 40 percent of the total CSS piping in the Phase 3 Candidate Areas were inspected during this program. Section 3.4.1 presents results and preliminary rehabilitation/repair recommendations.

3.2.2 Manhole Inspections

During summer 2023, Wright-Pierce performed manhole inspections to assess the structural condition of the manholes and identify potential visible sources of I/I. Manhole inspections were completed on 632 manholes (54 percent of the total manholes) in the Phase 3 Candidate Areas to provide a representative indication of manhole condition. Inspections were performed using the NASSCO Manhole Assessment Certification Program (MACP) Level 1 inspection standards.

A Level 1 inspection involves the completion of an above-grade inspection using a form to record the location of the manhole and basic features, including the material and condition of each component of the manhole and pictures of the structure. The focus of this inspection is on the integrity of the manhole and not the confirmation of pipe inverts, materials, condition, and diameters.

Wright-Pierce also used a 360-degree high-definition pole-mounted video camera to record the conditions in each manhole and to examine the upstream and downstream pipes using the zoom camera capability. The zoom camera can be useful to assess pipe condition, but factors such as pipe size, material, and lighting can limit visibility (typically between 10 to 30 feet). However, the zoom camera was discontinued part way through the program because of visibility issues and time required for set-up/inspection. Based on the MACP Level 1 inspection, each manhole was given a condition rating of sound or defective. Manholes with a defective condition rating were then evaluated to determine whether rehabilitation is required.

Just over 65 percent of the manholes inspected were found to be in good overall condition, with no further action needed. Approximately 28 percent of manholes inspected were found to need rehabilitation by either lining or conducting point repairs. Nearly 6 percent of all manholes inspected are recommended for reinspection because of poor video quality of the inspection. Of the 632 manholes,

five manholes are recommended to be fully replaced. Section 3.4.2 summarizes all manhole recommendations.

3.2.3 Private Inflow Connections

A private inflow connection to a sewer system is any unauthorized pipe or structure that conveys water discharged from a commercial or residential property; such discharge is not comprised of sewage. These connections discharge stormwater into the sewer system and can cause the sewer conveyance system and/or treatment facilities to become overwhelmed. Therefore, it is important to identify and eliminate these private connections contributing inflow to the CSS throughout the City. Examples of inflow connections include, but are not limited to driveway drains, yard drains, and roof leaders. Smoke testing and a desktop/windshield survey were conducted as part of this project to identify these potential sources of inflow.

In-home sump pumps represent another source of private inflow because they commonly discharge directly to the local CSS through existing service connections. Sump pumps should instead be routed to a drainage system or, preferably, outside the home to a surface capable of receiving such discharge. Educating homeowners on the importance of removing these connections from the local sewer is a crucial element affecting the success of any disconnection program. Further investigations are required to determine the magnitude of sump pump connections in Phase 3 Candidate Areas. While not performed for this study, house to house surveys are typically the more effective way to assess the presence of sump pumps. The City's On-Line Sewer and Street Flooding Issues Survey questionnaire (described in Section 2) has been an alternative means of identifying sump pump presence based on responses from residents.

3.2.3.1 Smoke Testing

Smoke testing is typically used in a sanitary sewer system to identify potential sources of inflow into the sewer system. Smoke testing is not typically performed on a CSS because the primary source of inflow is from CBs, which are also the primary emitter of the testing smoke. However, smoke testing has been completed in other communities' CSSs successfully to identify other private sources of inflow (such as roof downspouts, floor drains, yard drains, and area drains). Accordingly, this field work was completed as a demonstration test with plywood covering CBs to minimize smoke leakage. However, during the program it became apparent that this effort was not sufficient to contain the smoke leakage. Because results were not as beneficial as envisioned, the program was halted and smoke testing was not performed on all Phase 3 Candidate Areas.

The smoke testing program was conducted in the fall of 2023 on approximately 100,000 linear feet of sanitary sewer in Phase 1 and 2B Centralville separation projects and Phase 3 Candidate Areas. **Table 3.1** summarizes the results of the smoke testing observations for the Phase 3 Candidate Areas, including all of Grand, Pevey, Middlesex (East), Wentworth-Douglas, and West/Coburn/Jewett, and certain streets within Moore, Newhall (South), Sanders, Sherman, and Tilden 2. In addition, the School Street area (which is between Pevey and Grand and has portions of separated sewer) was added to the smoke testing program at the Utility's request to evaluate the effectiveness of existing sewer separation. Because smoke was observed in certain CBs in the School Street area, it was concluded that sewer separation may not be complete. A recommendation is provided in Section 7 that further sewer

separation be conducted in the School Street Area to disconnect remaining CBs from the CSS and connect them to the drain network in the area.

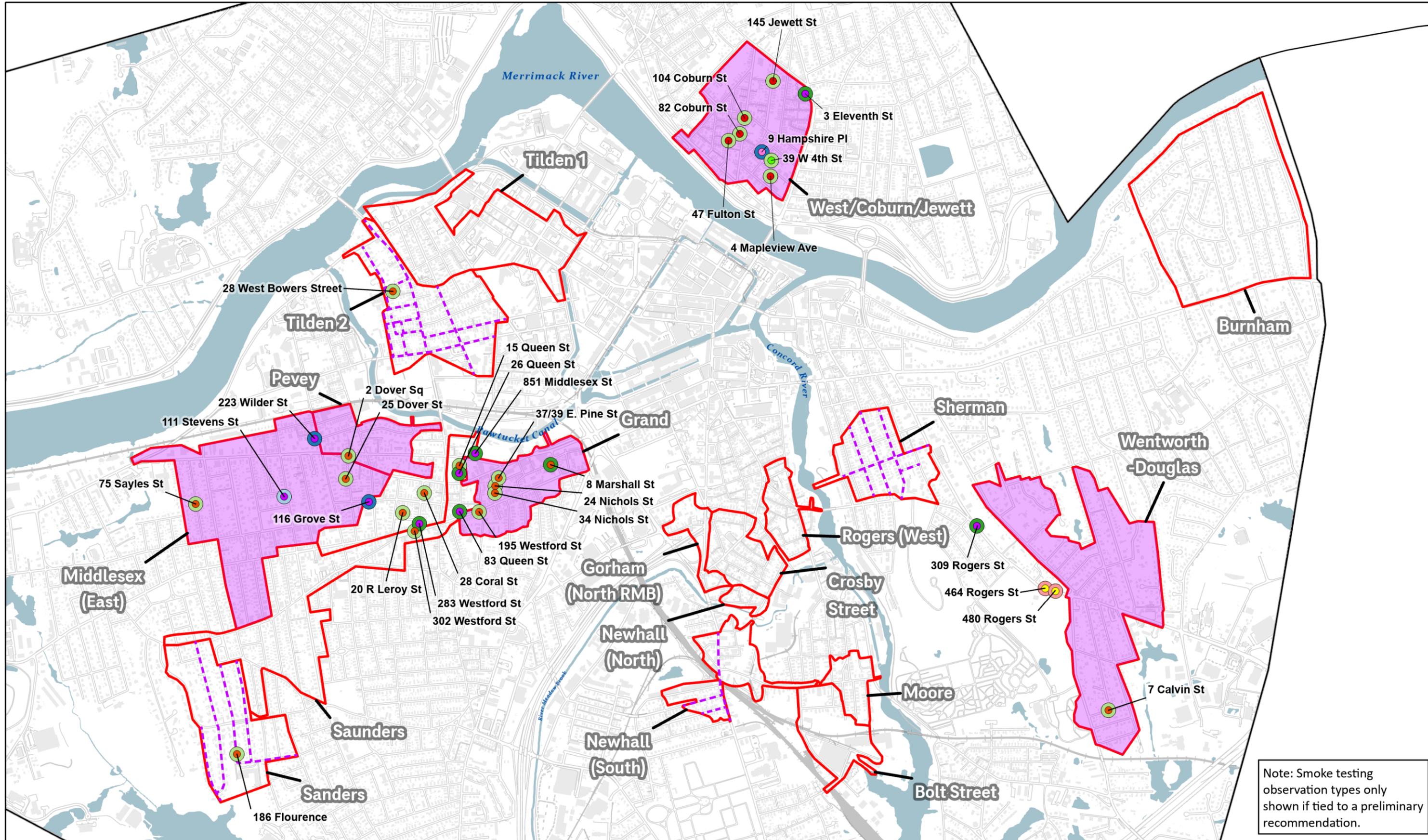
Table 3.1 Smoke Test Results

Source	Count
Sewer System Sources	
Catch Basin	347
Sewer Manhole Pick Hole	58
Sewer Manhole Vent Hole	377
Sewer Manhole Frame	19
Missing Cleanout	1
Drain Manhole	1
Private Sources	
Driveway Drain	3
Home/Structure/Building/Roof Leader	23
Ground	7
Other Undetermined Sources	
Other	4
Total	840

A relatively low number of potential private inflow connections were discovered as part of this investigation. Of the 840 sources of smoke identified, only 33 were identified as private sources. These sources included 23 from a home/structure/building/roof leader, three from a driveway drain, and seven from the ground. There are four remaining locations categorized as “other” that would require further investigation using dye testing or conducting building inspections to determine the sources. The Utility continues to investigate the one drain manhole where smoke was identified to confirm connectivity to the CSS. If it is determined there is a cross connection, it will need to be addressed under the MS4 requirements. The other smoke test results were associated with CBs, sewer, and cleanouts.

Figure 3.1 shows the results of the smoke testing program for private sources and the missing cleanout for the sewer system sources. Each circle indicates the source of the smoke in addition to a recommendation on how best to address the source of inflow at that location. Following is an explanation of each recommendation.

- Building Inspection – Further investigate internal plumbing and connections to identify the potential inflow source and how best to address it.
- CCTV Lateral Inspection – Determine whether a cleanout needs to be replaced or driveway drain needs to be rerouted to prevent further inflow. In addition, CCTV lateral inspection can help to identify cracks or breaks in the pipe from areas that emitted smoke from the ground.
- Redirect Source as Stormwater Flow – Direct stormwater runoff from a yard or driveway drain to areas where it can be absorbed into the ground or into the stormwater collection system.



Note: Smoke testing observation types only shown if tied to a preliminary recommendation.



Legend

- | | | |
|---|--|---|
| <p>Preliminary Recommendation</p> <ul style="list-style-type: none"> ● Building Inspection ● CCTV Lateral Inspection ● Redirect Source as Stormwater Flow ● No Action (Assumed Dry P-Trap) | <p>Observation Type</p> <ul style="list-style-type: none"> ● Smoke from Missing Cleanout (Public) ● Smoke from Driveway Drain (Private) ● Smoke from Home/Structure/Building/Roof Leader/etc. (Private) ● Smoke from Ground (Private) ● Other MH (electrical, etc) | <ul style="list-style-type: none"> ● Manhole Inspection ● Smoke Tested Streets (Approx. Extent) ● Smoke Tested Areas |
|---|--|---|



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 3.1
Smoke Testing Program

- Manhole Inspection – Identify and address potential infiltration and inflow into the sewer system.
- No Action – Applicable to those locations where no inflow source is identified.

These recommendations should be incorporated into the design of future sewer separation projects in the Phase 3 Candidate Areas. Smoke testing indicated a substantial source of inflow may be manholes with ventholes; therefore, during sewer separation, sanitary sewer manhole covers with vent holes should be replaced (with covers with no vent holes) along with any missing cleanout caps.

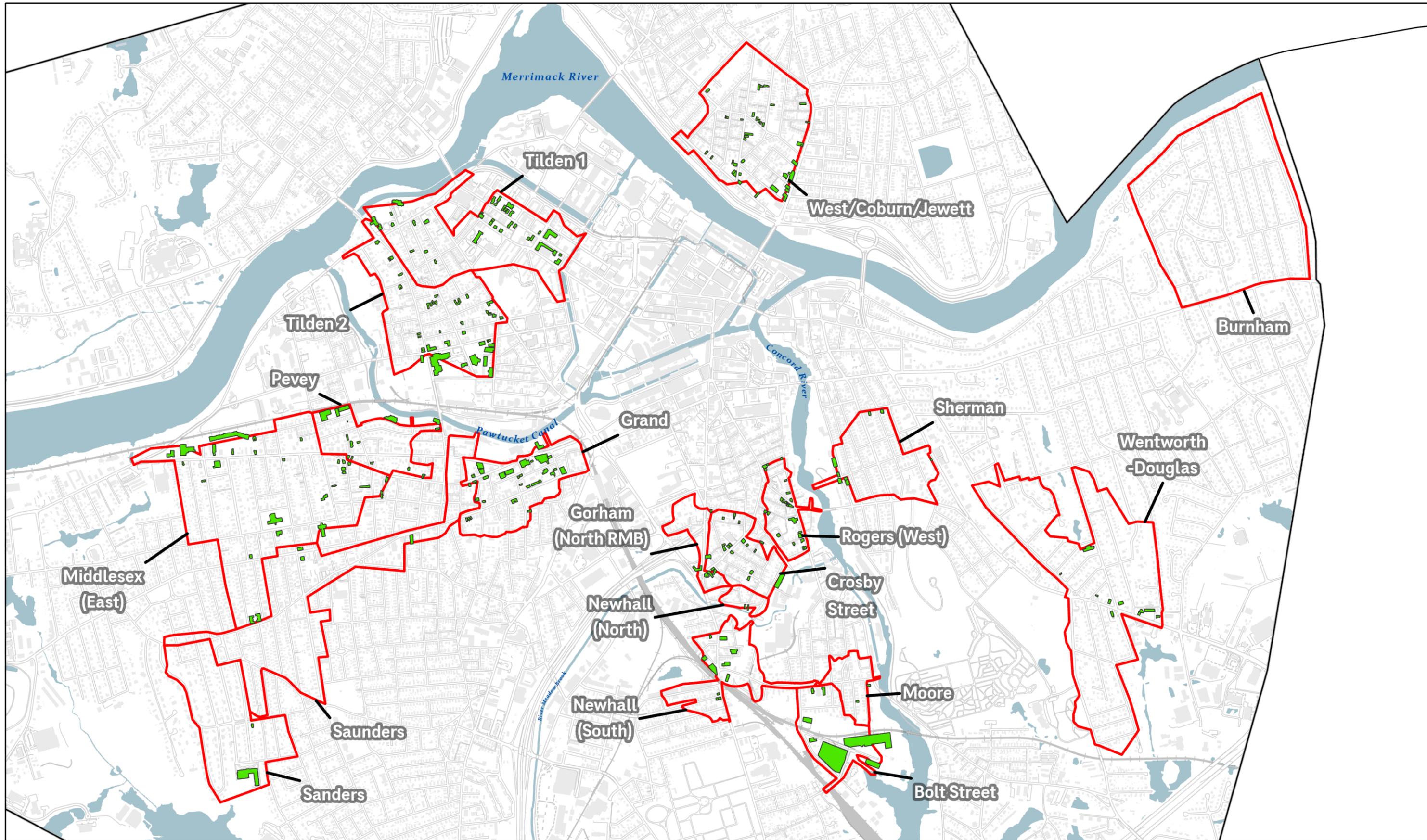
3.2.3.2 Desktop/Windshield Survey for Potential Inflow Sources

To complement the smoke testing program, a windshield survey/desktop analysis was completed. Initially, the City’s GIS and photogrammetry were used to identify flat building roofs. This was followed by a field review of these buildings during September and October 2023 to confirm the presence of flat roofs and to identify visible external roof drains or scuppers that direct roof runoff to the ground surface or via piped discharge into the ground. All Phase 3 Candidate Areas were investigated through photogrammetry and field visits. **Table 3.2** displays the counts for flat roofs in each area.

Table 3.2 Flat Roof Count

Phase 3 Candidate Area	Flat Roof Count
Bolt Street	7
Burnham	0
Crosby Street	20
Grand	29
Gorham (North RMB)	6
Middlesex (East)	28
Moore	2
Newhall (North)	2
Newhall (South)	10
Pevey	15
Rogers (West)	23
Sanders	2
Saunders	7
Sherman	8
Tilden 1	33
Tilden 2	36
Wentworth-Douglas	10
West/Coburn/Jewett	36
Total	274

Figure 3.2 shows the location of 274 buildings with flat roofs within the Phase 3 Candidate Areas. It is likely that these flat roofs have internal building drains that could be connected to the sewer service. During final design and/or construction of projects associated with Phase 3, building inspections and dye



Legend

- Flat Roof
- Phase 3 Candidate Areas



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR

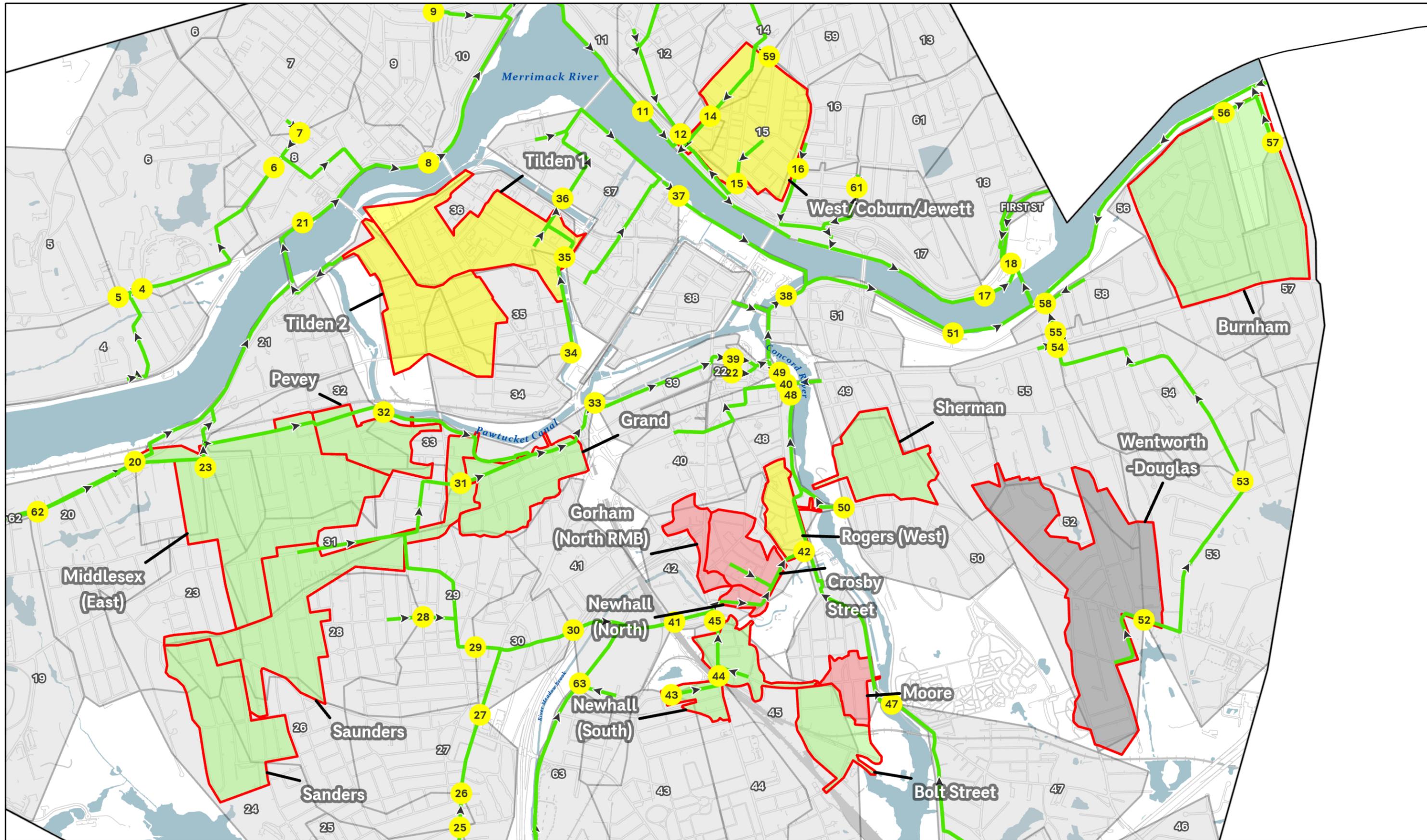
Figure 3.2
Potential Inflow Sources from Flat Roofs

Testing should be conducted to identify if extraneous flow connections to the sewer system can be disconnected in a cost-effective manner.

3.2.4 Infiltration/Inflow Analysis

The Utility is implementing an I/I and removal program in compliance with Massachusetts Department of Environmental Protection's (MassDEP's) regulation 314 Code of Massachusetts Regulation (CMR) 12.04(2). On behalf of the Utility, Kleinfelder prepared the 2023 Infiltration and Inflow Analysis Report, dated January 31, 2024, that provides a summary of the 2023 Citywide flow metering program. The 2023 flow metering program consisted of 63 temporary sewer flowmeters installed by ADS Environmental Services (ADS) for a period of 10 weeks, from March 24, 2023 to June 2, 2023. Three storm events were selected for inflow analysis and normalized to yield inflow volumes for MassDEP's 1 year, 6-hour design storm. CDM Smith used the meter data from this program to evaluate the relative amount of I/I in each of the Phase 3 Candidate Areas. The meters were associated with the Phase 3 Candidate Areas based on the proportion of the meter area that falls within each candidate area boundary. Then, all collective meters for an area were combined based on these proportions to establish a composite I/I rate for each area.

Generally, MassDEP considers extraneous flow rates greater than 4,000 gallons per day/inch diameter-mile (gpd/in-mi) excessive. Identifying and eliminating these excessive flows from the system through pipeline rehabilitation or replacement is considered cost-effective. **Figure 3.3** presents a map showing the infiltration rates for each Candidate Area and **Table 3.3** summarizes the infiltration rate by Phase 3 Candidate Area.



Legend

- 1 Meter Location/Number
- Hydraulic Model Conduit

- Composite Infiltration Rate Based on Area Meter (gpd/in-mi)
- < 4,000
 - 4,000 - 12,000
 - > 12,000
 - Data Not Available

- Meter Areas
- Phase 3 Candidate Areas



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 3.3
Infiltration Rates by Candidate Area

Table 3.3 Infiltration Rate by Phase 3 Candidate Area

Phase 3 Candidate Area	Meter #	Infiltration Rate per Meter # (gpd/in-mi)	Percentage of Candidate Area within Meter Area	Composite Infiltration Rate Based on Area Meter (gpd/in-mi)	Excessive I/I (>4,000 gpd/in-mi)
Bolt Street	44	3,190	100%	3,190	No
Burnham	56	4,899	50%	3,480	No
	57	2,067	50%		
Crosby Street	42	12,382	100%	12,382	Yes
Grand	33	1,077	100%	1,077	No
Gorham (North RMB)	42	12,832	100%	12,832	Yes
Middlesex (East)	21	6,116	10%	2,292	No
	23	3,378	30%		
	31	302	30%		
	32	1,922	30%		
Moore	42	12,832	100%	12,832	Yes
Newhall (North)	42	12,832	100%	12,832	No
Newhall (South)	44	3,190	50%	3,264	No
	45	3,338	50%		
Pevey	32	1,922	100%	1,922	No
Rogers (West)	48	6,631	100%	6,631	Yes
Sanders	23	3,378	40%	2,948	No
	24	3,321	20%		
	26	594	20%		
	28	4,071	20%		
Saunders	31	302	100%	302	No
Sherman	50	2,811	100%	2,811	No
Tilden 1	35	7,678	50%	6,250	Yes
	36	4,821	50%		
Tilden 2	21	6,116	100%	6,116	Yes
Wentworth-Douglas	52*	N/A	N/A	N/A	No
West/Coburn/Jewett	14	4,352	10%	6,303	Yes
	15	6,520	90%		

*Note: Meter area is not included in the I/I analysis because of the poor quality of data.

3.3 Repair and Rehabilitation Options

This section provides an overview of the different rehabilitation technologies available to reduce I/I and increase the useful life of the existing assets within the system. The field program described in Section 3.2 identifies representative pipe locations and manholes within the Phase 3 Candidate Areas that should be considered for either replacement or repair. Further assessment of the remaining Phase 3 Candidate Areas should be conducted before proceeding with future design and implementation of sewer separation to identify other system assets requiring rehabilitation.

3.3.1 Overview

While open-cut excavation and complete pipe segment replacement is an option, rehabilitation of existing sewer pipes, manholes, and service laterals can be accomplished with trenchless methods. Trenchless rehabilitation methods can be used to reduce I/I and extend the service life of the pipe, and these methods are typically structurally independent of the host pipe. Depending on project-specific situations, trenchless pipe rehabilitation techniques offer a variety of potential advantages over traditional open-cut pipeline replacement techniques, such as:

- More cost-effective than open cut
- Avoidance of many surface constraints
- Disruption of other services minimized
- Surface reinstatement needs minimized
- Surface disruption including traffic disruption kept to a minimum
- Reduced surface settlement
- Environmental disturbance minimized

Pipe and manhole inspections were evaluated based on NASSCO standards, which are focused on the structural condition and potential failure of the pipe. The Utility developed an I/I Analysis Report (Kleinfelder January 2024) using data obtained from a comprehensive flow metering program, conducted in 2023, to identify the sewer subareas with excessive I/I. Each of these pipe, manhole, and sewer lateral rehabilitation strategies should help mitigate extraneous flow entering the system through some of the defects noted in the NASSCO grading.

3.3.2 Sewer Pipe Rehabilitation

For this project, cured-in-place pipe (CIPP) will likely be the preferred method of pipe rehabilitation. CIPP liners can be used for both structural and nonstructural (for I/I reduction) rehabilitation of sewer lines. The CIPP liner consists of a tubular felt-like material saturated with an epoxy resin that, after curing, turns into a rigid liner for the pipe. Before the process is initiated, pipes must be thoroughly cleaned (and any roots removed) and dried.

A CCTV camera inspects the pipe to ensure the pipe wall is clean and ready for installation of the liner. In addition, the locations of service lines are documented during the CCTV operation. After the lining is installed and cured, a CCTV camera will be run through the pipe to inspect the condition of the liner and reinstate the lateral connections by a robotic machine.

Based on the extensive record of CIPP rehabilitation and the numerous trenchless contractors proficient at installing this technology, any recommended plan for rehabilitation of pipelines will typically use CIPP as its rehabilitation solution. Other methods such as sliplining, fold and form lining, spirally wound pipe, or segmental lining may be considered on a case-by-case basis during the design process.

3.3.3 Sewer Replacement and Point Repairs

Sewer replacement is generally considered when additional hydraulic capacity is required, or lining is not feasible because of significant pipe defects. If a pipe is generally in good condition except for a few short sections, then point repairs of the deficient sections can be used. Point repairs will not completely reduce I/I in that segment, but the use of trenchless methods may not be possible if the pipe has defects such as a collapsed or partially collapsed pipe segment(s), large holes, broken pipe with voids in the pipe bedding, missing brick, offset or separated pipe joints, or large obstructions exist. In these cases, the pipe segment could be repaired through a point repair and left alone, or full CIPP liner of the pipe from manhole to manhole could be completed.

3.3.4 Manhole Rehabilitation

Infiltration into manholes generally occurs because of cracks, loose/missing mortar at joints, or missing bricks. Deterioration due to corrosive sanitary sewer gases and microbiological growth can eat through the original cementitious walls and mortar causing leaks, erosion, and structural deterioration. Inflow into a manhole can occur during storm events because the rainwater from the surface may enter the manhole through the cover, frame, or frame seal. Following are typical defects associated with manholes:

- The cover may have open vent or pick holes, which are subject to ponding; the bearing surface may be worn or deteriorated; the cover may not fit properly; or the cover may be cracked, broken, or missing.
- The frame may be cracked, worn, or deteriorated.
- The frame may have separated from the manhole base on which it is sitting.
- The gasket may be missing, or the frame may be offset from the chimney causing leakage between the frame and chimney joint.

Rehabilitation of manholes, including cover replacement for those that have an excessive number of pick holes, provides for removal of I/I sources and reduces the potential for SSOs. The following methods can be used for manhole rehabilitation:

- **Chemical grouting.** Grouts give best results in cohesive soils and may be used to fill voids, stabilize soils behind manhole walls, or stop active infiltration before applying a coating system, but they are not warranted to improve the structural integrity of a manhole.
- **Coating systems.** Coating systems may be used as a corrosion protection barrier to enhance structural integrity of manholes and to reduce I/I. These may or may not include full coating of the manhole.
- **Structural lining.** Structural rehabilitation can be performed to restore the integrity of badly deteriorated manholes. Structural rehabilitation consists of a monolithic cementitious or epoxy

lining applied to the entire interior surface of the manhole. This is also an effective method to reduce I/I.

- **Frame, cover, invert, and chimney rehabilitation.** Rehabilitation under this category could include replacement of frame and covers due to defects or holes allowing I/I, point repairs to components of a manhole (chimney, wall, bench, etc.), or rebuilding an invert.

Manholes that are deteriorated to a point beyond rehabilitation would need to be fully replaced.

3.3.5 Service Lateral Rehabilitation

Service laterals can be a major source of private I/I into the collection system, with some estimates as high as 50 percent of total I/I contributed by service laterals. Wastewater utilities have found that an effective lateral rehabilitation program can significantly reduce the I/I in a system. The Utility only owns the sewer main, and private property owners own and are responsible for their lateral from the building to the connection point at the sewer main. This creates a challenge when navigating any rehabilitation work on private sewer laterals.

The following methods should be considered for sewer lateral rehabilitation:

- Removal and replacement
- CIPP lateral lining

Other methods include chemical grouting and pipe bursting; however, their selection is dependent on site-specific conditions. For this reason, such options should be considered as appropriate during future final design efforts. When CIPP lateral lining takes place, consideration also needs to be given to rehabilitation of the connection between the mainline sewer and sewer lateral.

3.3.5.1 Removal and Replacement

Open-cut removal and replacement of sewer laterals is a proven method for renewing sewer laterals. The old service line may either be abandoned in place or removed. This technique is cost-effective when dealing with relatively shallow services and where there is no elaborate landscaping or obstacles such as fences, paved driveways, or sidewalks. However, in many communities, private property owners are financially responsible for maintaining sewer laterals from the source to the mainline. Sewer lateral replacement is recommended when the structural condition of the pipe has failed or when structural defects allow excessive infiltration to enter the system. Pipe replacement is also recommended in areas where the pipe has not failed but is severely deformed or misaligned, so it is not possible to use trenchless techniques.

3.3.5.2 Cured-in-Place Pipe Lateral Lining

The most common type of liner used for lateral rehabilitation is CIPP. Access to the service lateral may be from either the sewer line or from the cleanout. If a cleanout is not available, a small entry point outside the building can be made to install one. Newer lining technologies can rehabilitate most of the service lateral from the mainline sewer.

The process of liner installation in the service lateral is very similar to the CIPP lining of sewer lines. The lateral should be cleaned of all debris and roots. The liner is saturated with resin and pulled through the

service lateral by either the inversion or winching method. The liner is then inflated and cured by either water or air. This method of rehabilitation is recommended when a sewer is structurally damaged or in danger of failure because the completed liner will fully restore the structural integrity of a damaged pipe.

3.3.5.3 Lateral/Mainline Sewer Connection Rehabilitation

Since the junction between the service lateral and the sewer line is the weakest point, special measures are taken after the liner is installed so the junction becomes watertight. Proprietary systems are available that rehabilitate the lateral/sewer line junctions while the lateral is rehabilitated. If both the sewer line and the lateral are to be rehabilitated, the mainline pipe should be rehabilitated first followed by rehabilitation of the lateral, because this will minimize any damage to the liner.

Service connection and lateral liners are CIPP liners used to seal the service connection between the sewer main and lateral as well as some portion of the lateral. The liner, installed by remote device, typically consists of felt fabric and polyester resin. A short portion of the liner is placed in the sewer main around the full diameter, and a second portion is located a defined distance up the lateral. The two pieces are attached during the hardening process to form a complete sleeve that encompasses both the lateral and the mainline sewer pipe.

There are different techniques that can be used to rehabilitate the connection between the mainline and lateral. In instances where the mainline has already been lined with a CIPP liner, one method to rehabilitate the connection is to use a brim-style liner, also known as a top hat liner (**Figure 3.4**). A brim (top hat) liner forms a ring around the penetration for the lateral that extends from 6 inches to 2 feet up the lateral.

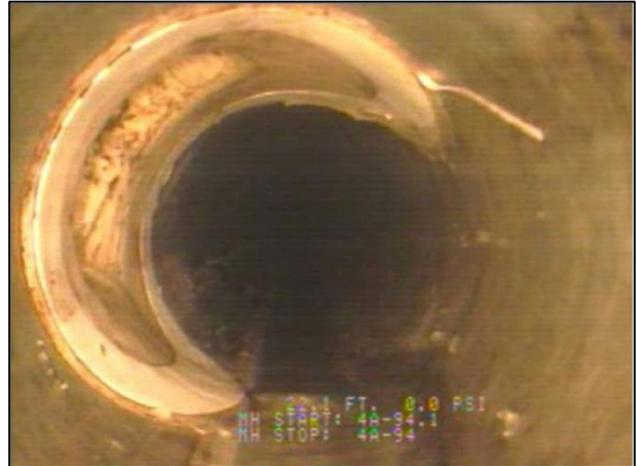


Figure 3.4 Brim-Style Liner

In situations where the mainline has not been lined, a technique known as a full wrap liner is typically used (**Figure 3.5**). A full wrap lines a short section of the mainline before and after a lateral and then extends up into the lateral, which is similar to a brim-style liner. This technique can also be used in situations where a mainline was previously lined and the service connection has been overcut or shifted to patch the liner (**Figure 3.6**).

Anytime a lateral connection is rehabilitated, it needs to be sealed. This is performed with either acrylamide or urethane chemical grout. The grout hardens in the annular space between the mainline and connection, as well as along the edges of a brim (top hat) or full wrap liner. The average expected life expectancy of a lateral connection seal is 5 to 20 years.



Figure 3.5 Full Wrap Liner



Figure 3.6 Shifted Service Connection/Lateral

3.4 Conclusions and Recommended Rehabilitation

This section provides recommendations for the rehabilitation of pipeline and manholes.

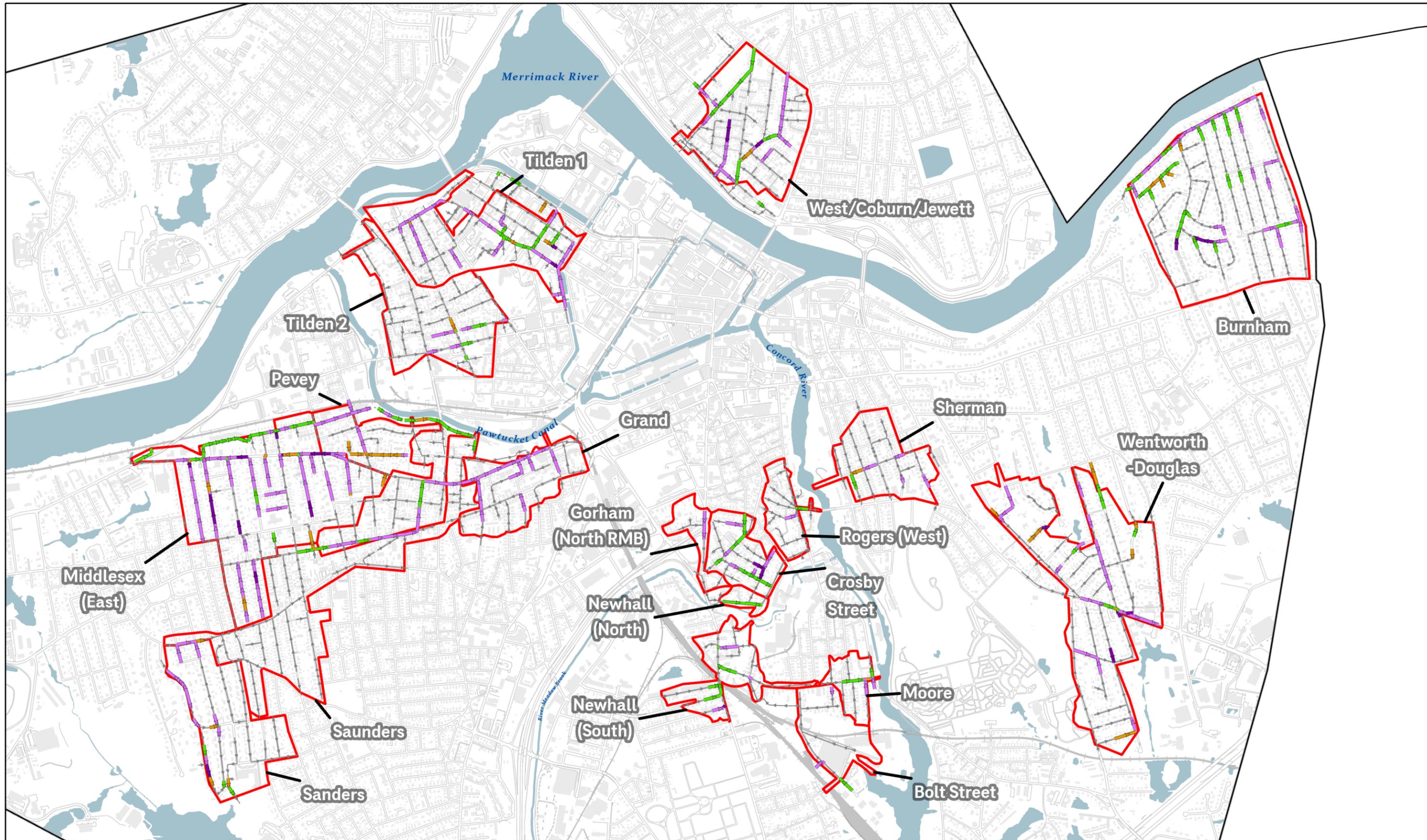
3.4.1 Pipeline Recommendations

Results of the CCTV inspection program discussed in Section 3.2.1 resulted in recommendations for approximately 75,300 linear feet of sewer pipe within the Phase 3 Candidate Areas. These results are presented in **Table 3.4** and **Figure 3.7**.

Table 3.4 Summary of Preliminary Rehabilitation Recommendations

Preliminary Rehabilitation Recommendation	Inspected Pipe Length (LF)	Percentage of Total LF of Pipe Inspected
No Action Required	20,243	27%
Lining Rehabilitation	43,679	58%
Point Repair	6,745 (42 pipes)	9%
Full Replacement	4,665	6%
Total	75,332	100%

These recommendations are based only on the pipes inspected as part of the field program and are meant to serve as a representative assessment of all Phase 3 Candidate Areas. Of the pipes inspected, approximately 58 percent were recommended for lining rehabilitation. The program also suggests that a smaller percentage of the system needs full replacement or point repairs. The recommendations from the CCTV inspection program could be projected over all pipes within the Phase 3 Candidate Areas to determine the recommended scope of rehabilitation that may be needed.



Legend

- | | | |
|----------------------------|-------------------------|---------------------------|
| Sewer Gravity Main | — Lining Rehabilitation | □ Phase 3 Candidate Areas |
| Preliminary Recommendation | — No Action | |
| — Full Replacement | — No CCTV Performed | |
| — Point Repair | | |

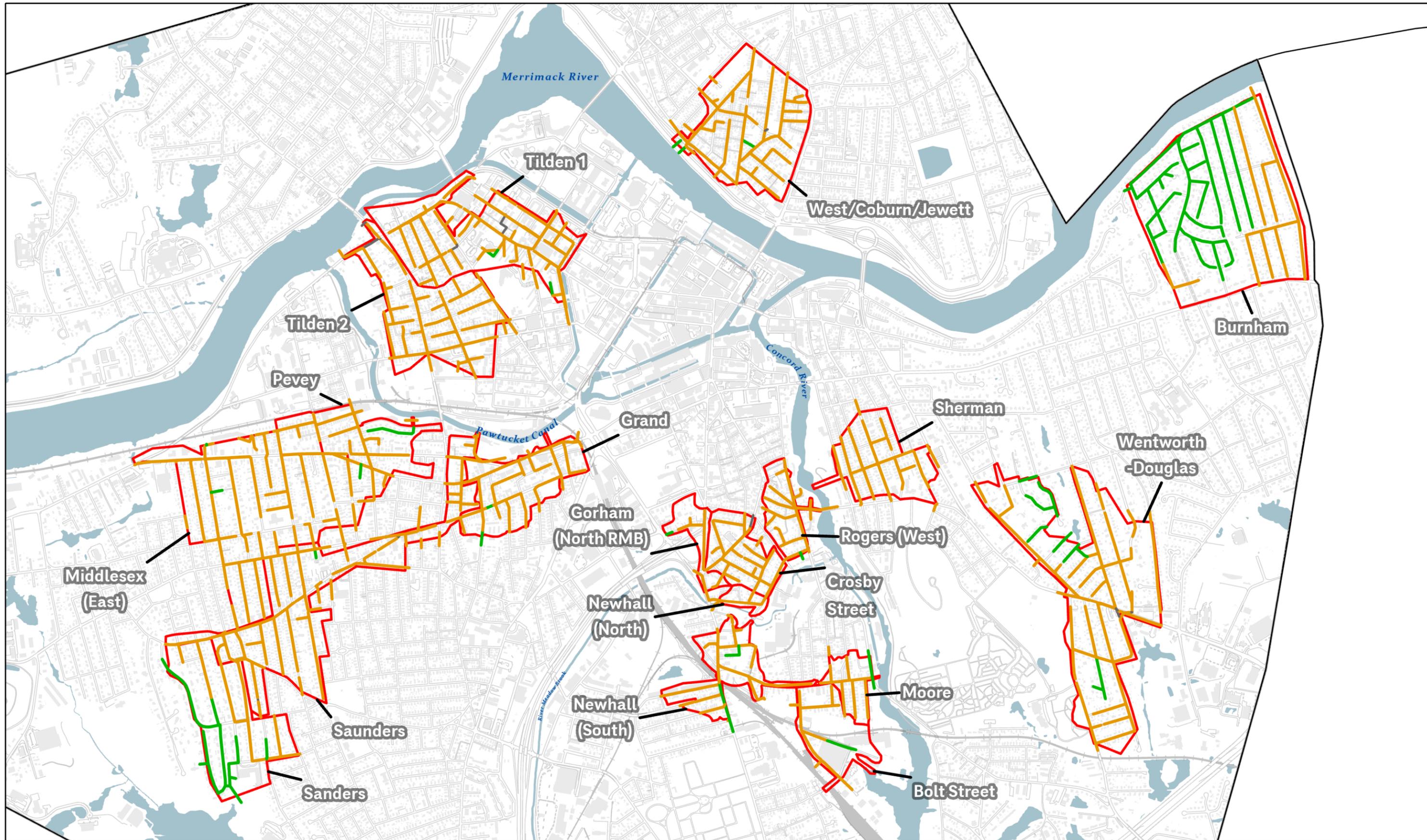


Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 3.7

Preliminary Pipe Recommendations Based on CCTV Inspections

These recommendations are based on the current condition of the pipes within the system. As time passes, pipes will continue to degrade. Approximately 80 percent of the pipes in Phase 3 Candidate Areas were constructed prior to 1950. **Figure 3.8** and **Figure 3.9** show existing pipe age distribution and material, respectively, within the Phase 3 Candidate Areas. The expected useful life of sewer pipe varies based on its material, construction and installation method, subsurface conditions, frequency of use, and past disturbances. Expected useful life of pipes in wastewater collection systems are typically estimated to be 50 to 100 years old. Based on the age of the Utility's system, many of these pipes are at or nearing the end of their useful life.

Based on recommendations of the CCTV inspection presented in Table 3.4, approximately 73 percent of the pipes are in need of lining rehabilitation, point repair, or full replacement. This compares similarly to the known 80 percent of pipes in the Phase 3 Candidate Areas dating to pre-1950. As part of infrastructure renewal during sewer separation projects, lining should be considered for a larger percentage of pipes to mitigate I/I and extend the useful life of the existing sewer collection system. The Utility should consider lining all pipes installed before 1950, because this approach achieves infrastructure renewal and will significantly extend the life of the existing sewer collection system. The extent of actual pipe rehabilitation and replacement necessary for infrastructure renewal should be considered during final design of prioritized projects.



Legend

Sewer Gravity Main

Age / Date Installed

— 2 - 72 Years (1951 - 2021)

— 73 - 187 Years (1836 - 1950)

— Unknown Age

□ Phase 3 Candidate Areas

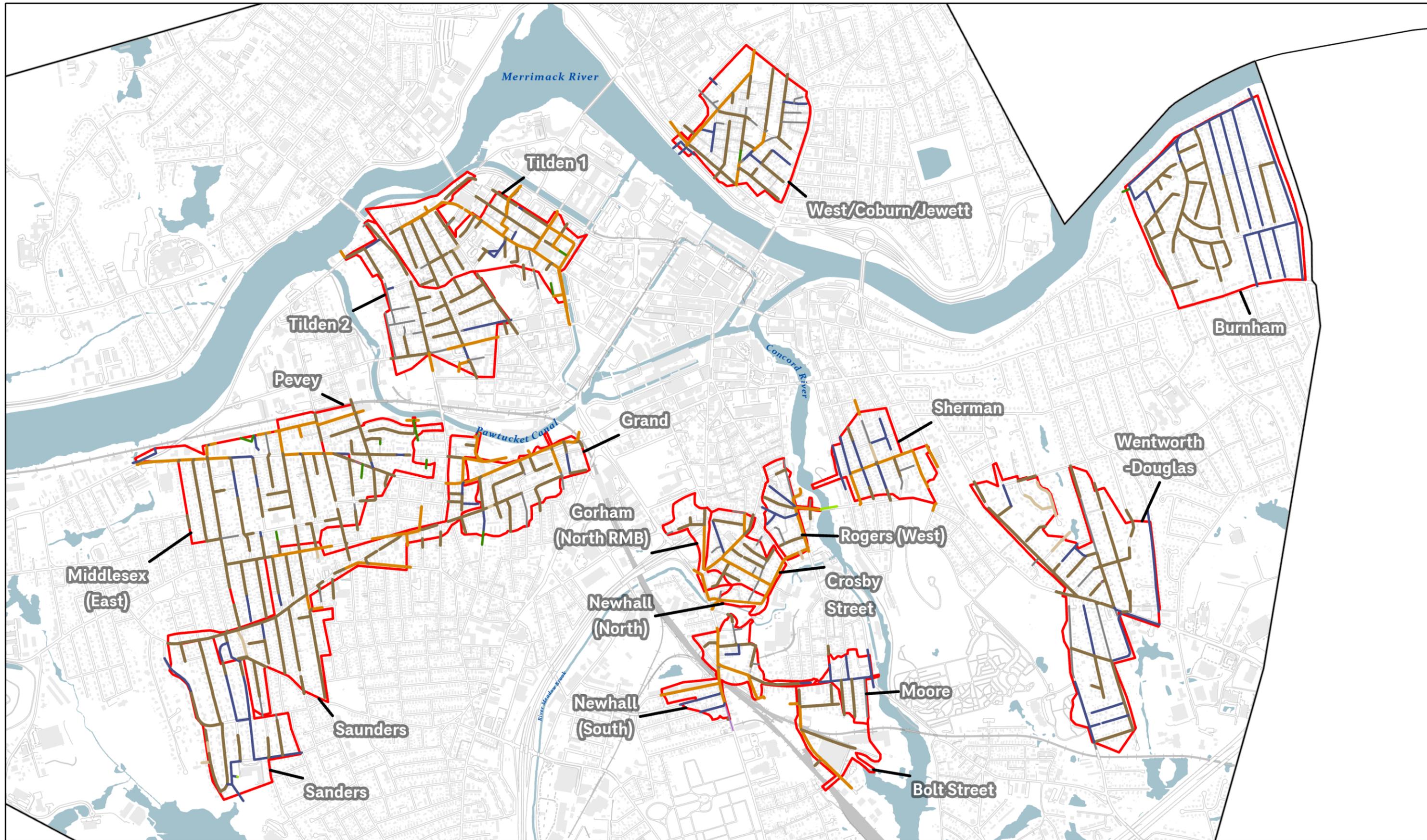
0 1,000 2,000 4,000 Feet



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 3.8

Pipe Age of the Phase 3 Candidate Areas



Legend

Sewer Gravity Main Material

- Vitrified Clay
- Asbestos Concrete
- Brick
- Ductile Iron
- Cast Iron
- PVC
- Concrete
- Unknown
- Phase 3 Candidate Areas



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 3.9
Pipe Material of the Phase 3 Candidate Areas

Construction costs for pipe rehabilitation (**Table 3.5**) were estimated using a unit cost by pipe diameter, obtained from recent historical construction costs. This assumes rehabilitation of the 80 percent of pipe present in Phase 3 Candidate Areas older than 1950.

Table 3.5 Projected Pipe Rehabilitation Construction Costs for Candidate Areas

Phase 3 Candidate Area	Linear Feet of Pipe Older than 1950	Cost (million \$) ⁽¹⁾
Bolt Street	3,200	\$1.52
Burnham	10,500	\$1.37
Crosby Street	7,100	\$2.73
Gorham (North RMB)	2,200	\$0.72
Grand	10,000	\$3.09
Middlesex (East)	24,900	\$5.48
Moore	3,400	\$0.34
Newhall (North)	300	\$0.08
Newhall (South)	7,200	\$3.16
Pevey	400	\$1.19
Rogers (West)	4,000	\$0.61
Sanders	7,300	\$2.02
Saunders	20,300	\$5.44
Sherman	8,200	\$2.51
Tilden 1	19,600	\$7.31
Tilden 2	15,400	\$2.32
Wentworth-Douglas	22,700	\$3.97
West/Coburn/Jewett	15,700	\$3.90
Total	182,400	\$47.76

(1) Costs based on cured-in-place lining for pipes older than 1950.

3.4.2 Manhole Recommendations

The manhole inspection program (Section 3.2.2) presents recommendations for the 632 manholes that were inspected during this program. These preliminary recommendations represent the future action that should be considered based on the severity of the manhole condition. **Table 3.6** summarizes those recommendations, and the approximate construction cost of the recommendations based on recent historical construction costs.

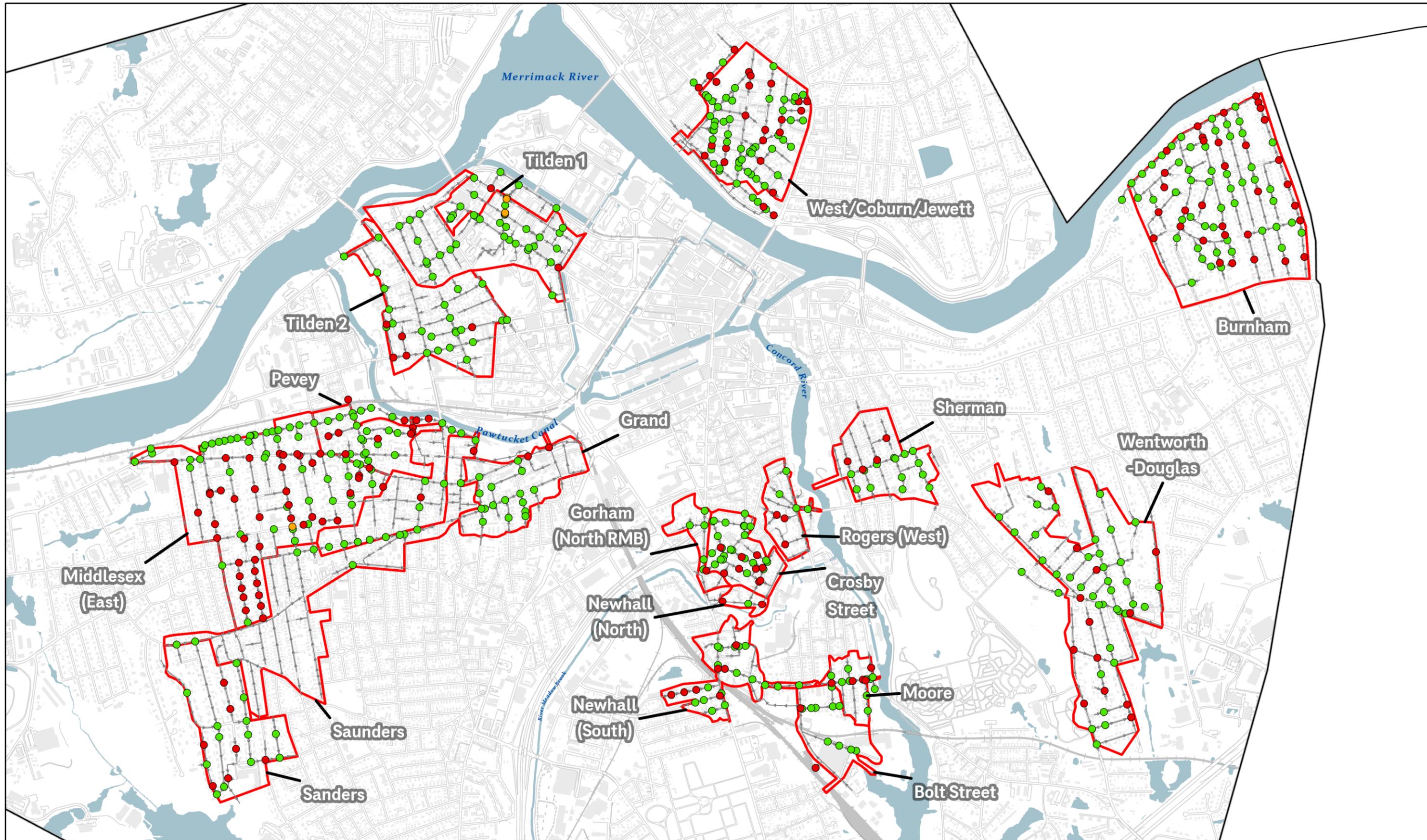
Table 3.6 Summary of Manhole Rehabilitation Recommendations

Preliminary Rehabilitation Recommendation	Number of Manholes	Estimated Construction Cost
No Action Required	415	\$0
Rehabilitation of the Manhole	177	\$885,000
Full Replacement of the Manhole	5	\$50,000
Reinspection Needed	35	-
Total	632	\$935,000

Note: Costs are only representative of the manholes inspected.

Most manholes are recommended for “no action required,” meaning that most of the manholes are sound and do not need further rehabilitation. Manholes that are recommended for rehabilitation have defects that will not require a full replacement of the manhole but may need a lining installed or require a point repair. Manholes that were recommended for reinspection are those where prior manhole inspection results were inconclusive. **Figure 3.10** shows the preliminary rehabilitation recommendations for these manholes.

As part of any future sewer separation project, the condition of all existing manholes within the subject project area should be evaluated relative to the full extent of sewer rehabilitation needed. Manhole rehabilitation for the remaining non-prioritized Phase 3 Candidate Areas could be addressed under the City’s SSES program. If the Utility desires to perform maintenance on infrastructure older than 1950, then based on the manhole inspection findings and costs presented in Table 3.6, it is estimated that repair of all remaining manholes within Phase 3 Candidate Areas (older than 1950) may cost between \$1.5 million to \$2.0 million.



Legend

- | | |
|----------------------------|-------------------------|
| Sewer Manhole | — Sewer Gravity Main |
| Preliminary Recommendation | Phase 3 Candidate Areas |
| ● Replace | |
| ● Rehabilitation | |
| ● No Action | |



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 3.10
 Preliminary Manhole Recommendations

3.4.3 Other Potential Rehabilitation Options

During final design, other assessments may be considered to address potential future rehabilitation options to mitigate I/I, separate from the pipe and manhole rehabilitation presented in Section 3.4. Such assessments might include, but are not limited to, the following:

- Building Inspection – Conduct building inspections to identify private inflow sources for removal. Targeted buildings would include potential sources identified during smoke testing and flat roof programs. Presence of sump pumps and backflow preventers could also be identified. The intention of identifying inflow sources would be to remove them during construction of a separation project.
- Sewer Lateral Rehabilitation – Since sewer laterals can be a significant source of I/I, it is recommended that the Utility work with private owners to address service lateral rehabilitation as well as lateral/mainline sewer connection rehabilitation. Alternatively, where existing sewers are replaced, sewer services should be replaced within the street at minimum.
- I/I Analysis – Conduct continued assessment of I/I contributions over time. Such efforts will help guide further sewer line rehabilitation during future separation projects in the Phase 3 Candidate Areas.



4.0 Hydraulic Modeling

4.1 Introduction

Hydraulic modeling of drainage and collection systems helps determine the capacity and pipe sizes necessary to convey wet-weather flow. The City's existing SWMM model of the CSS represents all flow from Lowell and outlying communities through major pipes in the collection system as well as streamflow in the Merrimack River, Concord River, Beaver Brook, and principal canals. The City's Collection System Model was updated for this study using data from a comprehensive flow metering program performed in spring 2023 and various other data sets spanning the period from 2020 through 2024, as discussed in Section 4.2. The updated SWMM was used to estimate CSO reduction potential for Phase 3 Candidate Areas, and SSO reduction in the Pevey and Wentworth-Douglas Areas.

SWMM was also used to create new independent drainage system models for each Phase 3 Candidate Area to support drainpipe network design. The modeled networks include drains required to capture flow from existing catch basins.

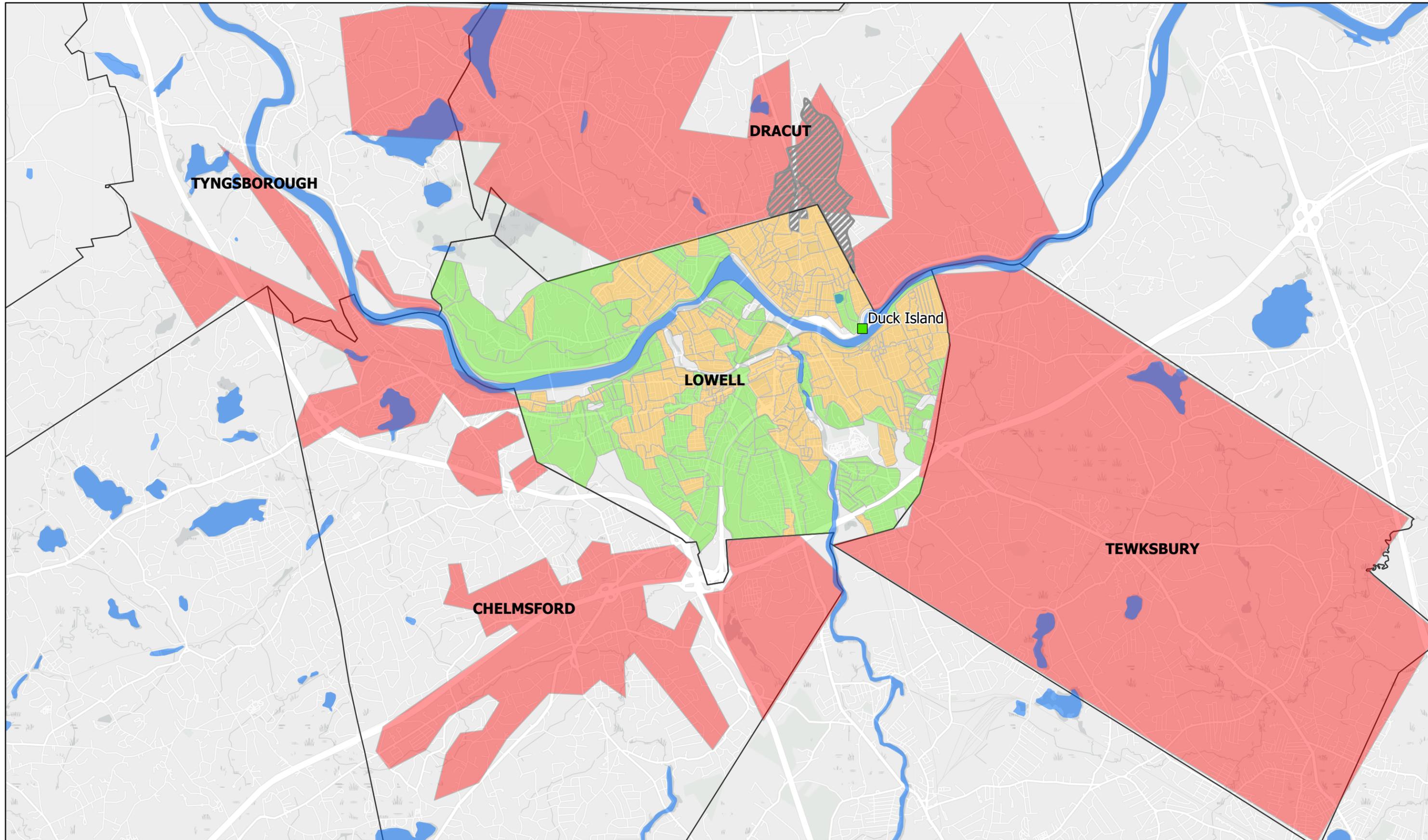
4.2 Collection System Model

Lowell's Collection System Model was previously updated by CDM Smith in 2014 and by Hazen and Sawyer for the 2019 Integrated Capital Plan. The model was revised and recalibrated by CDM Smith using March through June 2023 flow metering data obtained from the Kleinfelder Infiltration and Inflow (I/I) Analysis Report, 2023 data from Utility's supervisory control and data acquisition (SCADA) and sewer system surcharge level metering, and other data sets. **Appendix D** documents details of the Collection System Model update, calibration, and verification for this report.

4.2.1 Model Overview

SWMM 5 (version 5.2.4) was used to model the City's collection system. The SWMM model includes combined service areas in Lowell, sanitary service areas in Lowell, Dracut, Chelmsford, Tewksbury, and Tyngsborough, and stormwater runoff and baseflow from part of Dracut. It consists of 700 pipes and 450 subcatchments. **Figure 4.1** identifies all areas draining to Duck Island. The figure shows modeled subcatchments, distinguishing areas contributing combined, sanitary, and stormwater-only flow. The Centralville Revised PDR details the stormwater-only areas in Dracut (CDM Smith 2024).

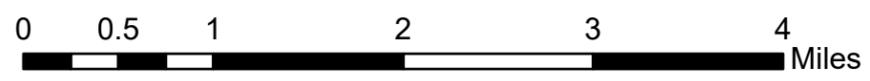
The model incorporates portions of the Merrimack River, Beaver Brook, Concord River, and the Lowell Locks and Canals system. Accurate representation of hydraulics in the City's waterways allows robust simulation of hydraulic conditions at the CSO Diversion Stations, and thus appropriate representation of wet-weather hydraulic grade lines in the collection system upgradient of the CSO Diversion Stations.



Legend

- Duck Island - WWTF
- Town Boundaries
- Waterbodies

- SystemType**
- Combined (sanitary and drainage)
 - Outside Communities (sanitary only)
 - Sanitary
 - Stormwater



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 4.1

Lowell Collection System Model Subcatchments

Flows in the open channels are driven by upstream flow boundary conditions on the Merrimack River, Beaver Brook, and Concord River apportioned from reported flows at U.S. Geological Survey (USGS) Gage 01100000 on the Merrimack River. The gage lies 1,100 feet downstream of the Concord River confluence and 300 feet downstream of the Hunts Falls Bridge. The model's downstream head boundary condition on the Merrimack River is hydraulically controlled by Hunts Falls. The river drops 10 feet at the falls, which are situated alongside Duck Island, 1,400 feet downstream of the USGS gage.

Figure 4.2 is a representation of the model's hydraulic components inclusive of collection system pipes, CSO Diversion Stations, open channel network, streamflow load points, and Hunts Falls.

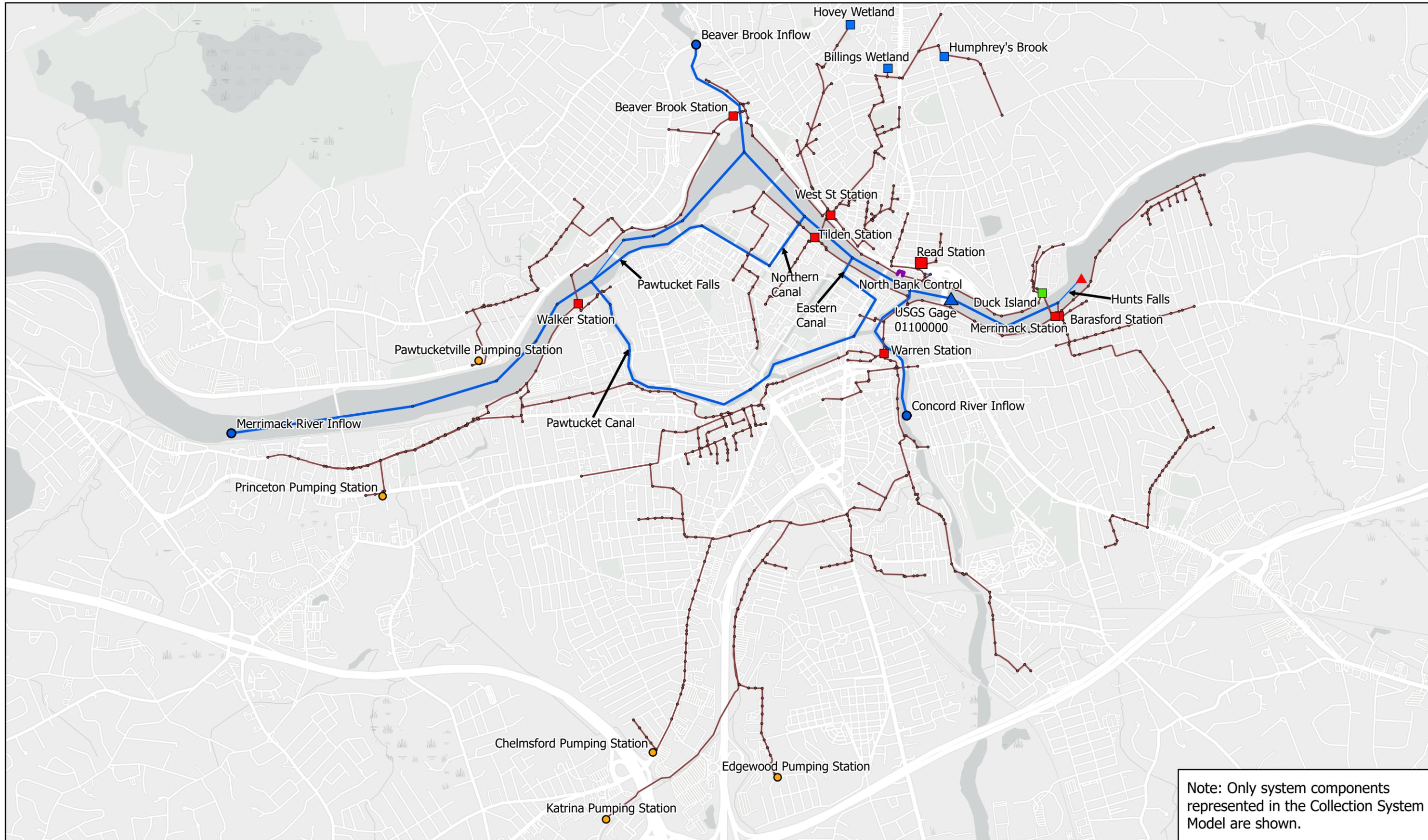
4.2.2 SCADA and Flow Metering

Multiple data sets were used to support model calibration and validation. These included:

- Area-velocity flow metering at 63 sites across Lowell obtained by ADS from March through June 2023. The model was calibrated to data from most of these sites, as discussed in Appendix D.
- Sixty timeseries of flow, level, and gate position measurements for all of 2023 at the City's CSO Diversion Stations, the North Bank Flow Control Gate, and Duck Island.
- Continuous flow measurements at intermunicipal wastewater meters measuring from Dracut (Book Street, First Street, and Willard Street) and Tewksbury (Merrimack Meadows) for September 2022 through September 2023. Monthly flow summaries from five sites in Chelmsford were also used to inform calibration.
- 2020 through 2024 level measurements collected from 12 surcharge level metering sites.
- 2023 flow measurements at the Humphreys Brook outfall into Lowell's collection system.

A schematic of the flow metering sites and flow connectivity is shown in **Figure 4.3**, and **Figure 4.4** shows these sites on a map. Because of the data quality issues in the spring 2023 metering program, ADS re-metered 10 sites in spring 2024. All 2023 metering data were evaluated for model calibration but with consideration of the data quality issues, which primarily affected dry weather flow measurements. Wet-weather data from most meters were good. Appendix D provides a full discussion of meter validity and robustness.

The Utility provided 2023 SCADA for the eight CSO Diversion Stations that report to SCADA (First Street Diversion Station does not report flow data). The SCADA included time series of gate operations (percent open), channel and interceptor depths, and station flow rates. For the spring 2023 calibration period, gate operations from SCADA were used directly in the model to ensure correct gate settings. Control logic was interpreted from the High Flow Management Plan (Wright-Pierce 2023).



Note: Only system components represented in the Collection System Model are shown.



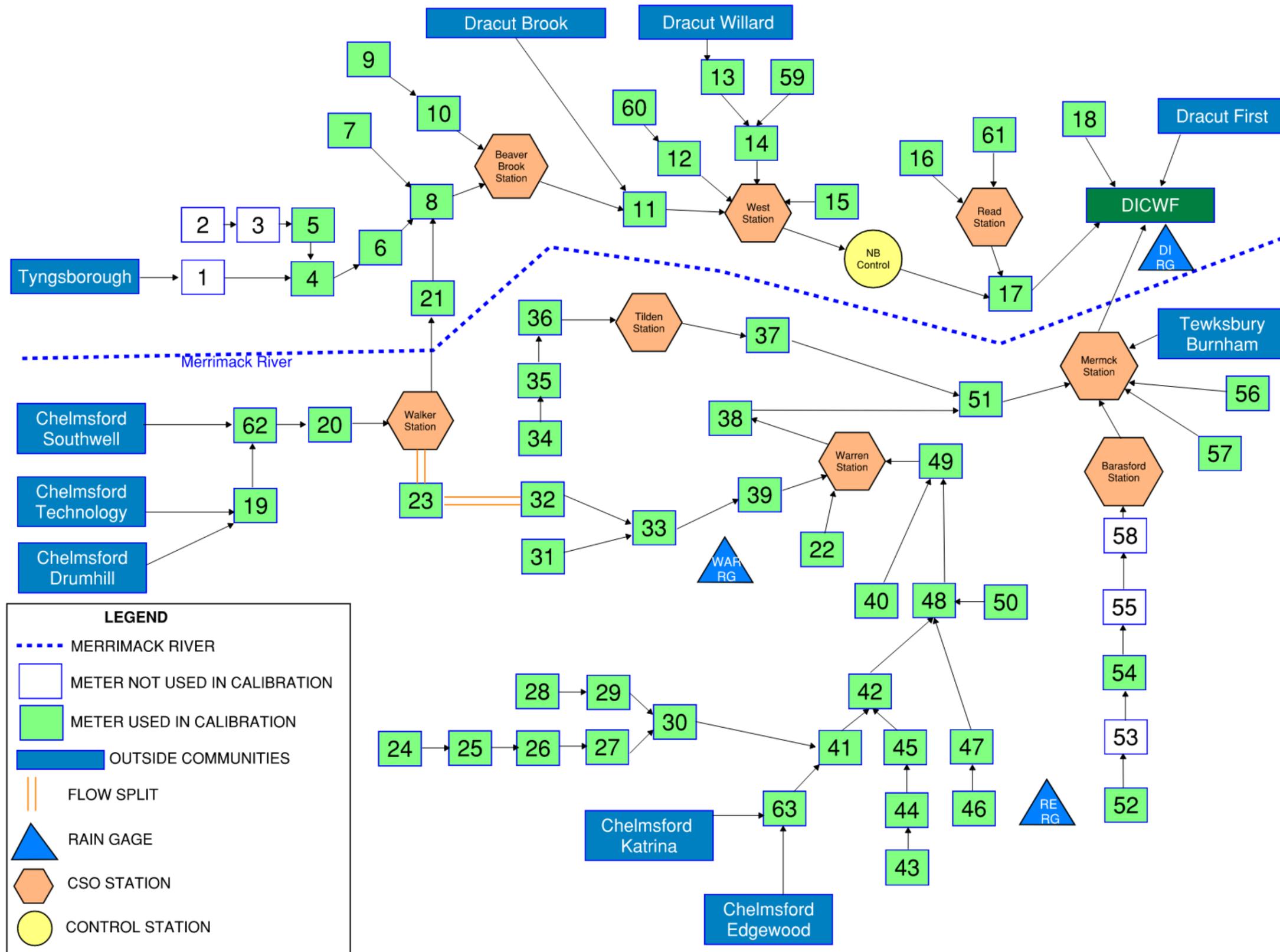
Legend

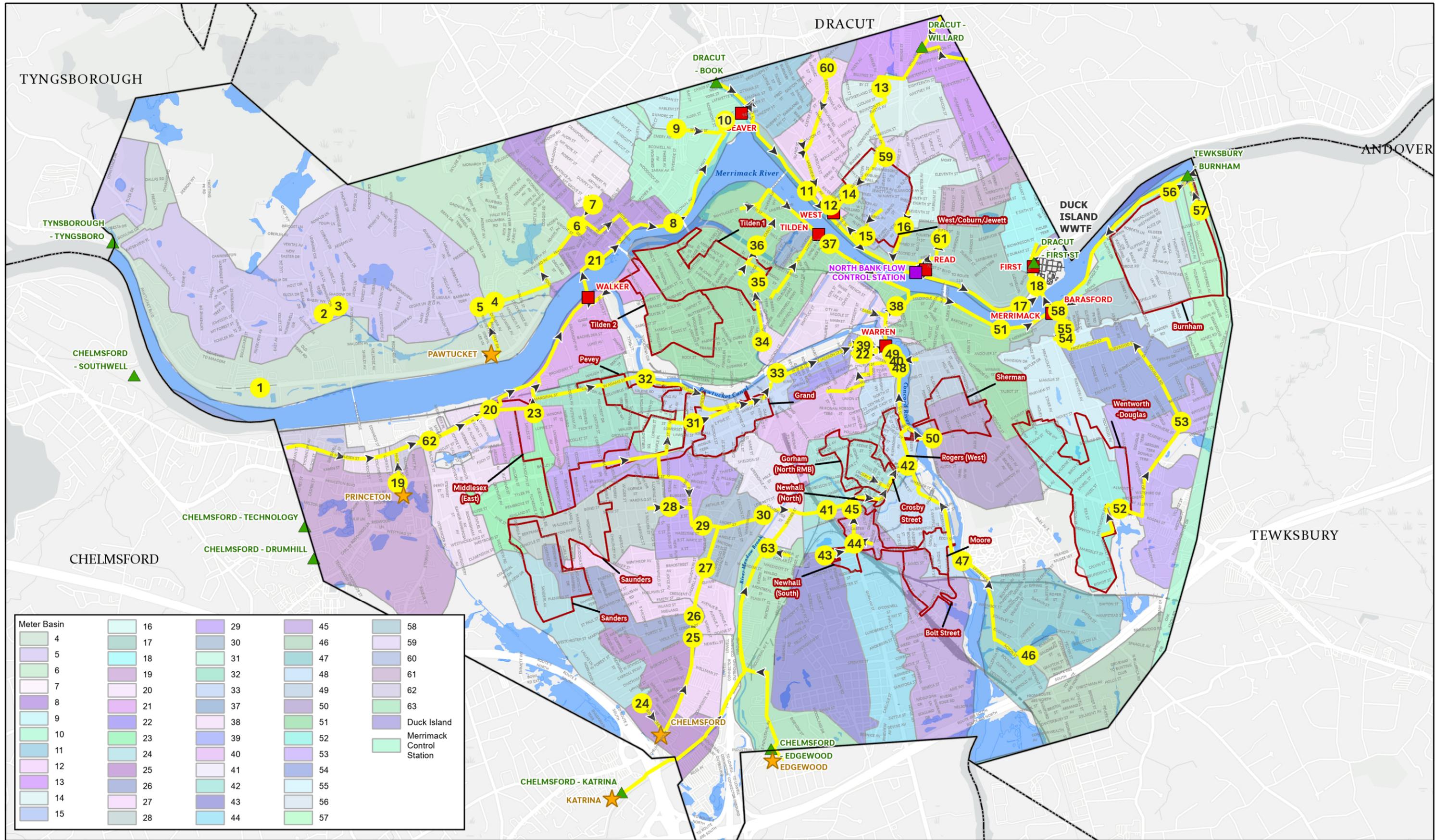
- Modeled Conduits**
 — Sewer Pipes
 — Open Channel

- Structures**
 ■ CSO Diversion Station
 ■ WWTF - Duck Island
 ● Pump Station
 ■ Stormwater Inflow

- ▲ Model Outflow
 — North Bank Control
 ● Model Inflows
 ▲ USGS Gage







Meter Basin	Color	Meter Basin	Color	Meter Basin	Color	Meter Basin	Color
4	Light Green	16	Light Blue	29	Light Purple	45	Light Green
5	Light Purple	17	Light Green	30	Light Blue	46	Light Green
6	Light Green	18	Light Blue	31	Light Green	47	Light Green
7	Light Purple	19	Light Purple	32	Light Green	48	Light Green
8	Light Purple	20	Light Purple	33	Light Blue	49	Light Green
9	Light Green	21	Light Purple	34	Light Blue	50	Light Green
10	Light Green	22	Light Purple	35	Light Blue	51	Light Green
11	Light Green	23	Light Green	36	Light Blue	52	Light Green
12	Light Purple	24	Light Blue	37	Light Blue	53	Light Green
13	Light Purple	25	Light Purple	38	Light Blue	54	Light Green
14	Light Green	26	Light Purple	39	Light Blue	55	Light Green
15	Light Blue	27	Light Purple	40	Light Blue	56	Light Green
		28	Light Purple	41	Light Blue	57	Light Green
				42	Light Blue		
				43	Light Blue		
				44	Light Blue		
				45	Light Blue		
				46	Light Blue		
				47	Light Blue		
				48	Light Blue		
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				56	Light Blue		
				57	Light Blue		
				58	Light Blue		
				59	Light Blue		
				60	Light Blue		
				61	Light Blue		
				62	Light Blue		
				63	Light Blue		
				Duck Island			
				Merrimack Control Station			

Legend

- Flow Meter Location
- ▲ Community Revenue Meter
- ★ Pump Station in Hydraulic Model
- Diversion Station and CSO Outfall
- North Bank Flow Control Station
- Hydraulic Model Conduit
- Phase 3 Candidate Areas



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 4.4
Flow Meter Location Map

4.2.3 Model Calibration and Validation

Flow metering program data were used for updating and calibrating the City’s Collection System Model to assist in the selection of prioritized sewer separation projects and to help guide I/I reduction efforts by accurately representing current flow conditions.

National Oceanic and Atmospheric Administration’s (NOAA’s) Multi-Radar Multi-Sensor Quantitative Precipitation Estimation (QPE) data for all of 2023 was used to support model calibration. The QPE data set provides accurate rainfall estimates on a 1-kilometer (km) grid across the contiguous United States based on data from 180 radars and 20,000 rain gages. The 2023 data measured surcharge and CSO across a wide range of storms, including several intense summer storms. A July 21, 2023 storm was classified as a 20-year, 1-hour event and as a 3-year, 6-hour event. The QPE data facilitated calibration of the model to the high spatial variability of the summer storms.

Appendix D presents further details on the flow metering data, dry- and wet-weather calibration, and validation to surcharge level meters and CSO data. The recalibrated model serves as the primary tool for assessing the effectiveness of future separation projects discussed in Section 7.

Key points of Appendix D include:

- Outlining the update, adding 300 pipe segments, and calibrating the City’s Collection System Model.
- The model was updated with the best available information on the existing collection system. Key data sources include ADS spring 2023 metering data, precipitation data from various sources, SCADA, record drawings, field and CCTV inspection data, and geographic information system (GIS) data.
- Updates included revision of sanitary flow rates using 2020 census data, creating an updated hourly diurnal pattern, adding detail in areas of interest, updating control rules, and improving the representation of model hydrology.
- Calibrating to dry weather, wet weather, and a 12-month continuous period based on 2023 SCADA.
- All of 2023 was simulated to compare simulated and observed CSO.

4.3 Combined Sewer Overflow / Sanitary Sewer Overflow Baseline Conditions

Section 4.3.1 discusses use of the calibrated and validated Collection System Model to simulate two 5-year design storms for assessing SSO. Section 4.3.2 discusses simulation of a 5-year representative period for assessing CSO.

4.3.1 Design Storms and Sanitary Sewer Overflow Statistics

A 5-year synthetic design storm was developed based on NOAA Atlas 14 (Perica et al. 2015).

Development of the design storm was previously described in Section 4.2 of the Centralville Revised PDR (CDM Smith 2024). The 5-year storm totals 4.51 inches with 0.86 inches in its peak 15 minutes and 1.49

inches in its peak hour. The MassDEP 5-year design storm for estimating peak inflow for I/I analyses (4.61 inches over 24 hours with a peak hour depth of 0.73 inches) was also simulated to assess SSO potential.

The 5-year design storm has a centrally peaked alternating block design storm with 15-minute increments. It is constructed using nested depth-duration statistics from Atlas 14 with a 10 percent increase to account for future climate change. This adjustment was based on a report “Analysis of Impact of Nonstationary Climate on NOAA Atlas 14 Estimates” (National Weather Service Office of Water Prediction 2022) that predicts that 2-year, 1-day rainfall in the Northeast will increase by between 6 percent and 11 percent by 2075 relative to Atlas 14 estimates based on Representative Concentration Pathway 4.5 climate model results.

A 10-year storm hyetograph was scaled from the 5-year event. **Table 4.1** characterizes the 5-year and 10-year design storms at selected durations. The 10-year design storm parameters are also shown because they will be discussed in Section 4.4. The 5.38-inch, 10-year, 24-hour depth shown in the table is 10 percent greater than Atlas 14’s 10-year, 24-hour depth of 4.89 inches for Lowell. **Figure 4.5** shows cumulative rainfall for the 5-year and 10-year, 24-hour climate change–adjusted alternating block design storms.

Table 4.1 Atlas 14 and Design Storm Rainfall Depths (inches) for Lowell at Selected Durations

Duration	Atlas 14		Design Storm	
	5-Year	10-Year	5-Year	10-Year
15 minutes	0.79	0.93	0.86	1.02
1 hour	1.38	1.62	1.49	1.78
24 hours	4.10	4.90	4.51	5.38

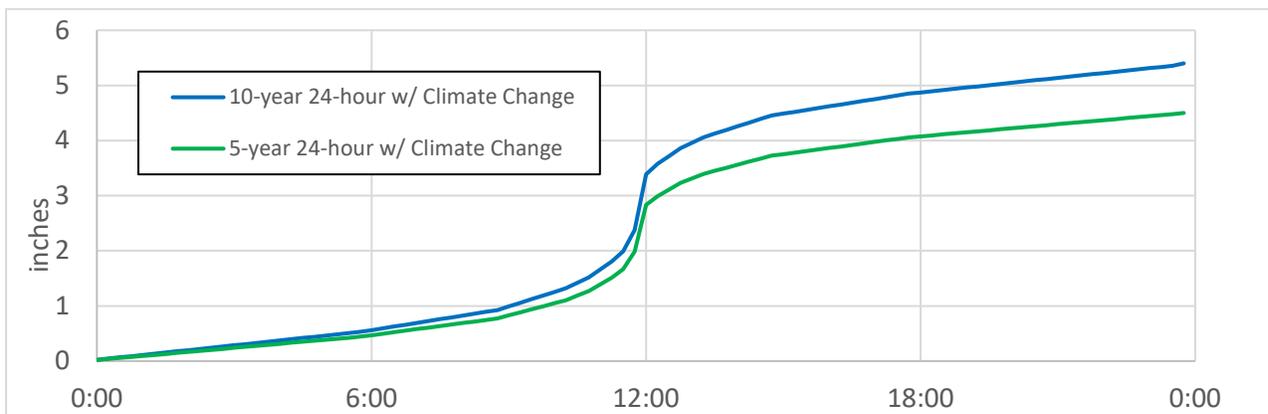


Figure 4.5 24-Hour Design Storm Cumulative Rainfall

The design storms were used to evaluate SSO potential in the Pevey and Douglas Road/Windward Road areas. For the MassDEP 5-year design storm, no SSO was simulated. **Table 4.2** shows a total of 1.1 MG of SSO for the Atlas 14 climate change–adjusted 5-year design storm at 35 Windward Road, 67 Payne Street, and Eagle Court.

Table 4.2 Sanitary Sewer Overflow for 5-Year Synthetic Design Storm

SSO Meter Location	Pipe Size (inches)	Manhole Depth (feet)	Overflow Duration (minutes)	Overflow (MG)
35 Windward Road	20	5.6	28	0.07
96 Marginal Street	36	16.6	0	0
91 Pevey Street	36	15.0	0	0
67 Payne Street	36	9.5	19	0.1
Eagle Court / 657 Middlesex Street	42	9.4	38	0.9

4.3.2 Long-Term Simulations and Average Annual Combined Sewer Overflow Statistics

Continuous simulation of a 5-year representative period was completed to estimate average annual CSO. **Table 4.3** summarizes these simulations results. Average annual CSO for existing conditions based on the calibrated model is 385 MG per year. Because 2023 was a very wet year in Lowell, CSO for the year exceeded the average conditions represented by the representative period. Precipitation at Lowell’s National Weather Service COOP site in 2023 totaled 61.5 inches, the third wettest year on record based on data since the 1890s. Appendix D discusses selection of the representative period and provides additional CSO and precipitation statistics for 2023.

Table 4.3 CSO Diversion Station Average Annual Statistics

CSO Diversion Station	Volume (MG/yr)	Events (discharges/yr)
North Bank		
Walker	2.1	4
Beaver Brook	38.7	6
West	115.1	18
Read	0.2	0.4
South Bank		
Tilden	19.2	14
Warren	68.5	21
Merrimack	100.7	25
Barasford	40.4	24
Total	385	112

4.4 Drain System Modeling

The modeled Phase 3 Candidate Areas listed in **Table 4.4** and shown in **Figure 4.6**. This subsection describes the methodology for development of drainage models to size pipes on a preliminary basis for assessing feasibility and costs relative to the prioritization and selection of projects under the proposed Phase 3 program. The Wentworth-Douglas Area was excluded from Phase 3 drainage modeling; this area is being addressed through other projects, as discussed in Section 7. The West/Coburn/Jewett Area was previously modeled for the Centralville Revised PDR and discussed in Section 6. The table further divides the Tilden 1 and Tilden 2 Areas into five subareas; Section 6 presents the rationale for these distinctions.

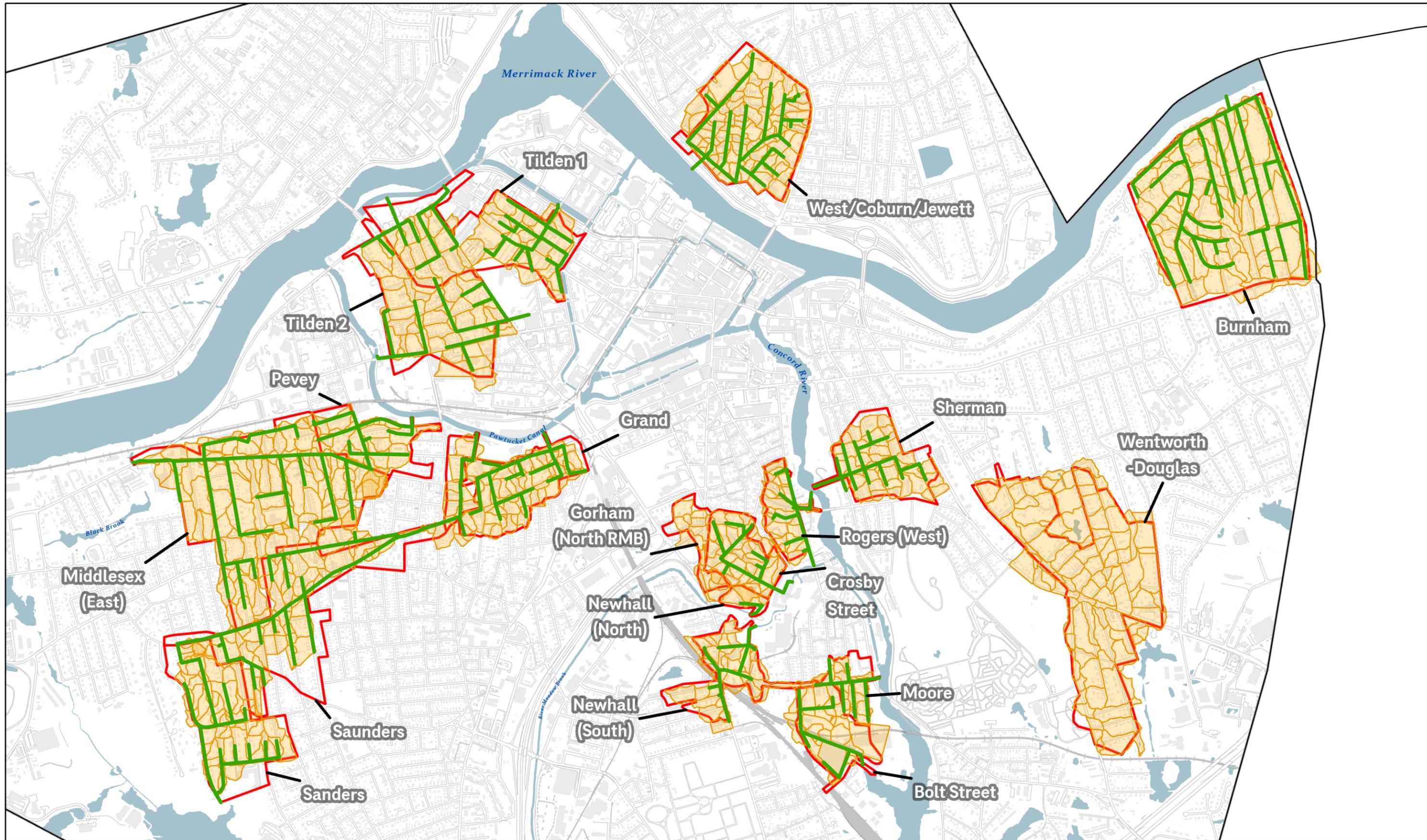
Table 4.4 Modeled Phase 3 Candidate Areas

Name ¹	Drain Model Area (acres)	Receiving Water
Bolt Street	30	Wetland to Concord River
Burnham	152	Merrimack River
Crosby Street	27	River Meadow Brook
Gorham (North RMB)	13	River Meadow Brook
Grand	44	Pawtucket Canal
Middlesex (East)	140	Black Brook at Merrimack River
Moore	14	Concord River
Newhall (North)	5	River Meadow Brook
Newhall (South)	31	River Meadow Brook
Pevey	31	Pawtucket Canal
Rogers (West)	18	Concord River
Sanders	64	Wetland to Black Brook
Saunders	100	Pawtucket Canal
Sherman	40	Concord River

Name ¹	Drain Model Area (acres)	Receiving Water
Tilden 1 ²		Lower Northern Canal
▪ Cabot Street	41	Lower Northern Canal
▪ Fanning Street	15	Upper Northern Canal
▪ Pawtucket Street	17	Upper Northern Canal
Tilden 2 ²		Merrimack River
▪ Broadway Street	19	Pawtucket Canal
▪ Cross Street	44	Western Canal
West/Coburn/Jewett	77	Merrimack River

¹. Wentworth-Douglas was excluded as sewer separation as being addressed via other projects.

². Tilden subareas are presented in Section 6.



Legend

- Modeled Conduits
- Subcatchments
- Phase 3 Candidate Areas



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 4.6
 Candidate Area Drain Model Subcatchments

4.4.1 Rainfall Design Criteria

Design storms are commonly used to size drainage systems. A range of design storms, based on average recurrence intervals (ARI), may be considered to evaluate the costs and benefits achieved by increasing conveyance capacity. Evaluation criteria for municipal systems may consider design storms ranging from 2-year to 25-year ARIs.

As discussed in Section 1, most of the candidate sewer separation projects identified in this report were studied in prior reports, such as the 2004 Warren PDR. That report concluded that 5-year and 10-year design criteria were reasonable in urban areas and that drains would be designed so the 10-year hydraulic grade line does not surcharge to within 2 feet of the manhole rim elevation.

For the Phase 3 conceptual drain system layouts, three pipe size alternatives based upon simulation of 24-hour design storms were considered; these criteria largely match those presented in the Centralville Revised PDR (CDM Smith, July 2024):

- 10-year storm; no surcharge allowed.
- 5-year storm; no surcharge allowed.
- 5-year storm with 10-year storm; surcharge allowed to within 1 foot of manhole rim.

A 10-year storm with surcharge allowed was used as the basis for sizing pipes in all Candidate Areas; Section 6 of this report discusses design alternatives for any deviation from this approach.

4.4.2 Hydrologic Model Development

Hydrologic model development defines what happens to stormwater runoff on the ground surface. This involves identifying the pathway by which stormwater runoff flows on the surface to the collection system. Subcatchments are used to define the flow boundaries and assign the runoff flow to an inflow source (such as a catch basin) and, ultimately, the collection pipe. This process also involves determining the amount of stormwater flow that can enter the collection system, in consideration of such factors as perviousness, slope, and runoff length. This subsection defines parameters used in subcatchment delineation.

Subcatchment delineation was initially performed to best represent surface runoff within the Candidate Areas using Personal Computer Storm Water Management Model (PCSWMM) software. Subcatchment boundaries were then further delineated using 2-foot contours and adjusted to account for roadways and other surface features. Hydrologic parameters were assigned based on local data and best engineering practices. Hydrologic parameters for the SWMM model were developed as follows:

- Imperviousness was calculated using Massachusetts Impervious Surface 2016 data obtained from MassGIS.
- Percent routed identifies the fraction of a subcatchment impervious surface that drains onto adjacent pervious ground (e.g., roof leaders draining to lawns). Percent routed was specified as 100 percent minus percent imperviousness, yielding effective imperviousness equal to the square of total imperviousness. For example, a subcatchment with 75 percent imperviousness would be specified with a 25 percent routing coefficient, yielding 56 percent effective

imperviousness. CDM Smith has found that this yields reliable runoff estimates in numerous studies across New England.

- Average surface slope for each subcatchment was calculated using a digital elevation model developed from the contours.
- Surficial Manning’s n was specified as 0.02 for impervious surfaces and 0.08 for pervious ground.
- Subcatchment width (measured in feet; this is the hydrograph shape parameter) was estimated as 300 times the square root of the area.
- Infiltration from pervious areas is modeled using the modified Horton method. The principal soil type in the study area is sandy loam according to National Resources Conservation Service data. Soil parameters were uniformly specified as 2 inches per hour maximum infiltration rate and 1 inch per hour minimum infiltration rate.

Table 4.5 summarizes the hydrologic parameters for each modeled area. Figure 4.6 shows the candidate area catchments.

Table 4.5 Phase 3 Model Hydrology

Name	Acres	# Subcatchments	Average Total Imperviousness (%)	Average Effective Imperviousness (%)	Average Slope
Bolt Street	36	24	63	41	5
Burnham	159	86	41	18	3
Crosby Street	39	46	80	66	6
Gorham (North RMB)	32	32	77	60	5
Grand	42	53	82	70	6
Middlesex (East)	137	94	62	41	4
Moore	13	20	70	57	10
Newhall North and South ¹	18	19	72	53	6
Pevey	31	29	72	54	5
Rogers (West)	19	27	83	70	7
Sanders	54	49	39	16	4
Saunders	135	117	73	55	3
Tilden 1	74	49	75	59	3
Tilden 2	65	43	80	64	4
Sherman	37	37	82	69	4
West/Coburn/Jewett	80	79	78	64	3
Total	971	804	66	46	4

¹ Newhall North and South were represented as a single model because of their proximity and shared receiving water.

4.4.3 Hydraulic Model Development

Hydraulic model development is the pipe flow portion of the drain modeling. This involves hydraulic analysis for pipe size optimization. Drainage models were constructed for all pipes within the proposed separation areas using North American Vertical Datum of 1988 (NAVD88) vertical datum (feet) and the Massachusetts Mainland coordinate system (feet, North American Datum of 1983 [NAD83]).

A Manning’s n of 0.013 was used for all pipes. Tailwater levels were assessed based on receiving water conditions. The values in **Table 4.6** were used to specify form losses (“ k ” values) at bends and junctions.

Table 4.6 Conduit Form Losses

Angle (Degrees)	Loss Coefficient
0	0
15	0.08
30	0.20
45	0.38
60	0.65
75	0.94
90	1.33

Conceptual pipe layouts, elevations, and sizing were used to develop plan and profile drawings. The initial pipe layout and sizing was adopted from previous studies and reports for the Candidate Areas. Pipe sizes were then optimized using the drainage model to ensure design criteria would be met. This iterative process involved adjusting pipe slopes and inverts based on utility conflicts, alternate routing, and topography. These conceptual level system layouts generally conform with design standards for conveyance piping such as minimum cover, slopes, minimization of surcharge, etc. The layouts include drain manholes (model junctions) near all existing catch basins to allow redirection from the combined sewer system. Pipe grades were configured to match downstream crowns where feasible. Pipe slopes and sizes may need to be further refined, post-survey, during later design phases to better identify and resolve utility conflicts.

4.5 Collection System Model Capabilities

Section 7 of this report uses results from the Collection System Model to assess the impact of proposed projects on CSO reduction and SSO mitigation.

The model was originally developed to characterize CSO frequency and volume. Its detail upgradient of CSO Diversion Stations was primarily along major interceptors and where flowmeters had been deployed in prior calibration efforts. For this project, detail was initially extended to incorporate selected flowmeters included in the 2023 I/I metering program. As the project progressed, the model was also used to evaluate SSO occurrence and mitigation strategies. To meet these objectives, detail was added in the Wentworth-Douglas Area and near the Pevey Area.

As currently constituted, the model is a valuable tool for assessing CSO and is effective for evaluating SSO where detail has been added for that purpose. However, the model cannot currently examine SSO potential citywide, other than to generally identify areas where ground levels are low relative to typical hydraulic grade lines during heavy rainfall. Excessive inflow in sanitary sewersheds, hydraulic constraints anywhere in the collection system, blockages, and other maintenance issues can contribute to SSOs. The model’s value for identifying SSO potential is determined by the level of detail in a particular area and whether sufficient data exist to accurately represent local hydrology and hydraulics. While it is not difficult to add detail in a particular area, the model is constrained by the availability of data to support

robust parameterization of model variables such as inflow rates into sanitary sewers, pipe conditions, and the presence of sediment and other blockages.



5.0 Preliminary Design Considerations

5.1 Introduction

Potential construction issues and environmental impacts that may be encountered during implementation of a sewer separation project, whether the installation is to be new drains or sewers, should be considered as part of the design process. This type of work becomes increasingly challenging when pipe diameters exceed 36 inches because of potential conflicts with other underground utilities. Other construction challenges typically considered during the design process include potential disruptions to property and pedestrian access, impacts to traffic flow, local impacts such as noise and dust, and wetland and permitting issues (driven by the wetland impacts and land ownership). While there may be short-term negative impacts during construction, many of these impacts can be reduced by implementing various mitigation measures. The selection of pipe routes, depths, sizes, and configurations is often driven by approaches to avoid or mitigate such impacts. This section generally reviews design considerations for sewer separation projects. Preliminary layouts of potential Phase 3 sewer separation projects described in Section 6 incorporate these considerations for the development and selection of priority projects presented in Section 7.

5.2 Reuse of the Existing Combined Sewer System

One of the first considerations when developing a combined system separation plan is choosing between (1) reuse of the existing CSS system as sewer pipes and building a new stormwater collection system or (2) reuse of the existing CSS system as drainpipes and constructing a new sewer collection system.

The options for reuse of the existing CSS system were evaluated in the Centralville Sewer Separation Revised Preliminary Design Report (CDM Smith July 2024). The recommended approach for sewer separation in the Phase 1, 2A, and 2B Centralville project areas is to construct a new stormwater collection system. This recommendation resulted from industry-recognized advantages of continuing to use the existing combined system as the sewer and constructing a new stormwater system. Also considered for Centralville were concerns regarding constructability and cost of constructing a new wastewater collection system. For consistency, CDM Smith recommends that the Utility continue with the same approach within the Phase 3 Candidate Areas; however, there may be limited exceptions for certain streets as the design of each separation area advances.

When implementing this approach, removal of existing I/I sources (CBs, roof/yard drains, sump pumps, etc.) to the existing sanitary sewer system should be conducted to further flow reduction efforts to Duck Island. Sewer separation projects considered under this report aim to eliminate CB connections within each Candidate Area. Removal of other I/I sources also should be considered during the design process. The subsequent section presents these and other design considerations for a new stormwater system.

5.3 Design Considerations

Key considerations of the Phase 3 Candidate Area separation projects for the implementation of new drainpipe systems include the following:

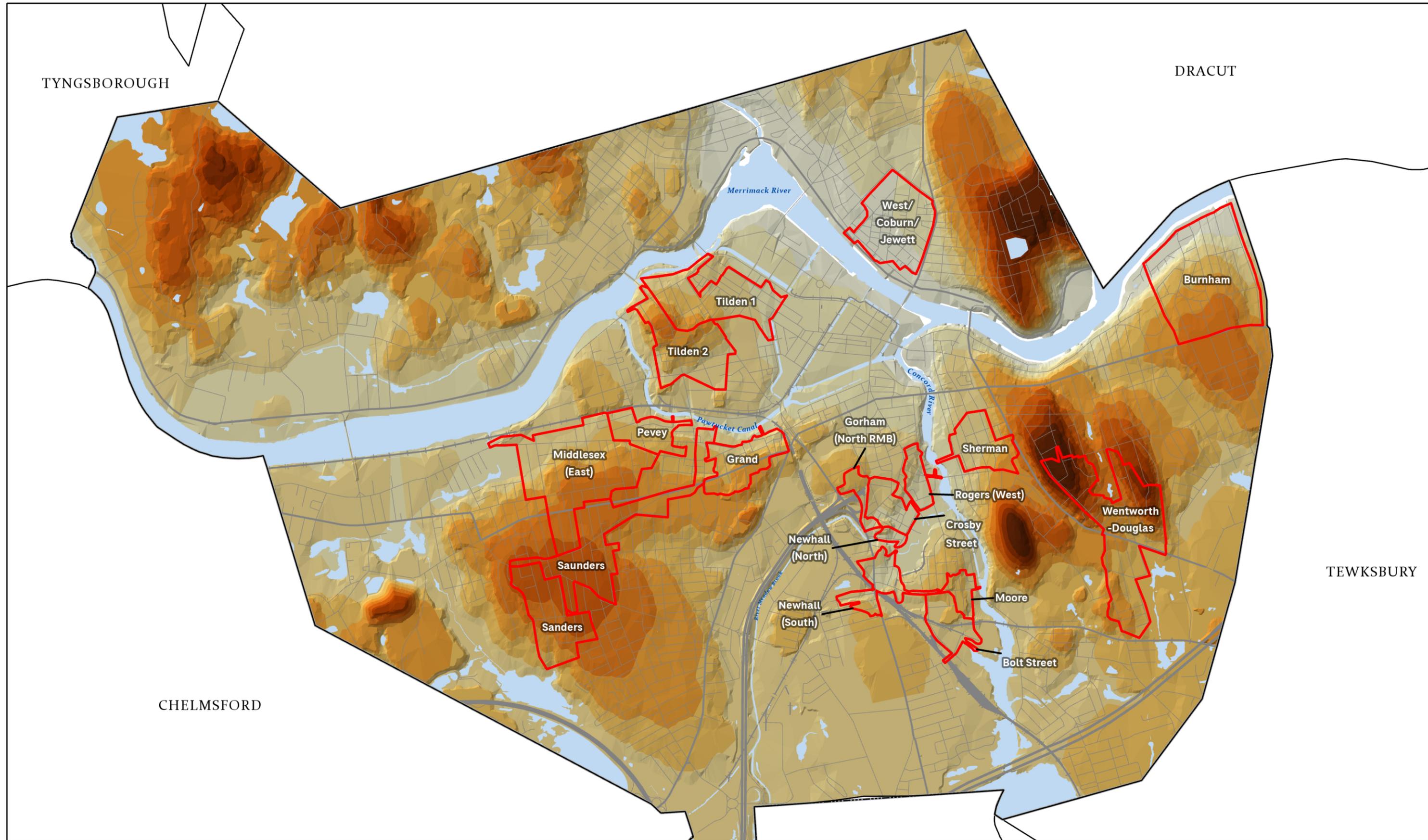
- General topography
- Pipeline design considerations
- Public and private I/I connections
- Use of existing drain systems
- Utility and construction impacts
- Soil disposal and hazardous waste

These factors were all considered during development of the conceptual drainage/sewer separation plans for the Phase 3 Candidate Areas. Further details relative to individual Phase 3 Candidate Area priority projects are discussed in subsequent sections of this report.

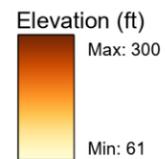
5.3.1 General Topography

Topography refers to the natural and human-made physical features of an area such as hills, valleys, and rivers. Such topographic features are a significant consideration in the design of new stormwater collection systems. Slope of the terrain is one of the most important factors to evaluate, because most drain systems rely on gravity to move the stormwater to the receiving water; therefore, the pipe network needs to slope downhill. Additionally, the slope of a drainpipe and the depth of pipe required to meet minimum slope requirements for gravity flow are influenced by the terrain; project costs increase if deeper excavations are required to meet minimum pipe slope requirements. In some cases, pump stations may be needed to push the stormwater uphill through pressurized pipes, which also increases project cost. Areas with steeper terrain can have steeper pipe slopes that can decrease the new pipe sizes. In the lower-lying areas, closer to bodies of water, pipe slopes will tend to be flatter to match the terrain. Flatter pipe slopes require increased pipe size to provide the same conveyance capacity.

Figure 5.1 shows the topography of Lowell relative to the Phase 3 Candidate Areas. Lower-lying elevations are noted along the Concord River, Merrimack River, and associated canal system. To the extent practical, conceptual routing of proposed drainage piping should follow the natural topography of the area from its highest points to the receiving water bodies. Generally, pipeline routes should follow city streets to minimize the need for private land acquisition or easements.



Legend



Phase 3 Candidate Areas



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 5.1
Topography of Lowell

5.3.2 Pipeline Design Considerations

This section summarizes pipeline design criteria that were applied to develop a conceptual design for proposed drainage networks in each Phase 3 Candidate Area.

5.3.2.1 Pipe Material

Selection of an appropriate pipe material for the intended application is an important design consideration. Different pipe materials have varying levels of strength, constructability, durability, and cost. Ductile iron (DI), polyvinyl chloride (PVC), and reinforced concrete (RC) are considered appropriate pipe materials for a stormwater project. The selection of pipe material for a specific length of pipe will depend on the pipe diameter, depth of cover, and other geotechnical considerations.

Previous separation projects in Lowell have typically used PVC for smaller pipe diameters (between 12 to 24-inch diameter) and RC for larger (more than 24-inch diameter) pipes. On these projects, DI pipe has been used for smaller pipe diameter when there is less than 4 feet of cover. Following is a description of each product.

Ductile Iron

DI pipes are often used in drainage systems because of their strength, durability, and flexibility. These pipes are made from a type of cast iron that includes nodular graphite, which enhances the ductility of the pipe, allowing the pipe to bend and stretch without breaking. This flexibility makes DI pipes particularly resilient under heavy loads, thereby reducing the risk of fractures. DI pipes also offer excellent corrosion resistance, making them suitable for various environmental conditions. The robust nature and long service life of DI pipe make them a reliable choice for drainage applications. Some cases where DI might be considered are locations with shallow cover or tight clearance between utilities since it has thinner wall than RC.

Polyvinyl Chloride

PVC is the industry standard for small diameter (less than 24 inches) drainpipe. PVC pipes are lightweight and easy to handle, which simplifies installation. Additionally, PVC pipes are corrosion-resistant, ensuring longevity and reliability even when exposed to various chemicals and harsh environmental conditions. The smooth interior surface of PVC pipe minimizes friction, which promotes efficient water flow and reduces the likelihood of blockages. Additionally, PVC pipes are durable and strong.

Reinforced Concrete

RC pipe is the most commonly used material for large-diameter (24 inches and greater) drains because of its cost effectiveness, durability, and life expectancy. RC pipe is typically produced by pouring concrete into a steel reinforced precast form having a standard 8-foot laying length. RC pipe is a rigid pipe and pipe class is selected to satisfy various pipe bedding and depth situations. Generally, Class IV and Class V RC pipe is most common for traditional drainage applications.

Where large-diameter pipe is used, RC pipe manufacturers can produce precast tee sections in lieu of large-diameter manholes. These tee sections require the same trench excavation limits as the pipe, and standard 4-foot-diameter precast riser sections can be used from the tee to finish grade. RC pipe bends can also be custom precast for many angles required.

RC is also used for box culverts of varying sizes. Box culverts are used when circular pipe cannot provide adequate hydraulic capacity or when pipe height/depth is a limiting factor. RC box culverts are preferred for their strength, durability, and ability to handle large volumes of water.

5.3.2.2 Design Parameters

Proper pipe sizing, velocity considerations, and installation elevations are necessary to ensure that the new drain system can handle peak flow rates without causing backups and overflows. Hydraulic modeling has been conducted for new drainage piping in each of the Phase 3 Candidate Areas to determine appropriate pipe sizes; this hydraulic modeling effort is described in Section 4.

Table 5.1 shows the design parameters that influence the size and slope of the proposed stormwater system. Additionally, minimum pipe cover is needed to provide insulation against cold temperatures in the winter months and protection against heavy surface loads such as traffic and equipment. The hydraulic model used to determine pipe sizes for the Phase 3 drainage systems balanced these considerations and allowed for sizing of a system that meets these hydraulic and physical design parameters.

Table 5.1 Typical Design Parameters for New Drainage Pipes

Parameters	Value
Minimum Pipe Size	12 inches
Minimum Velocity	3.0 feet/second
Maximum Velocity	10 feet/second
Minimum Pipe Cover	3 feet

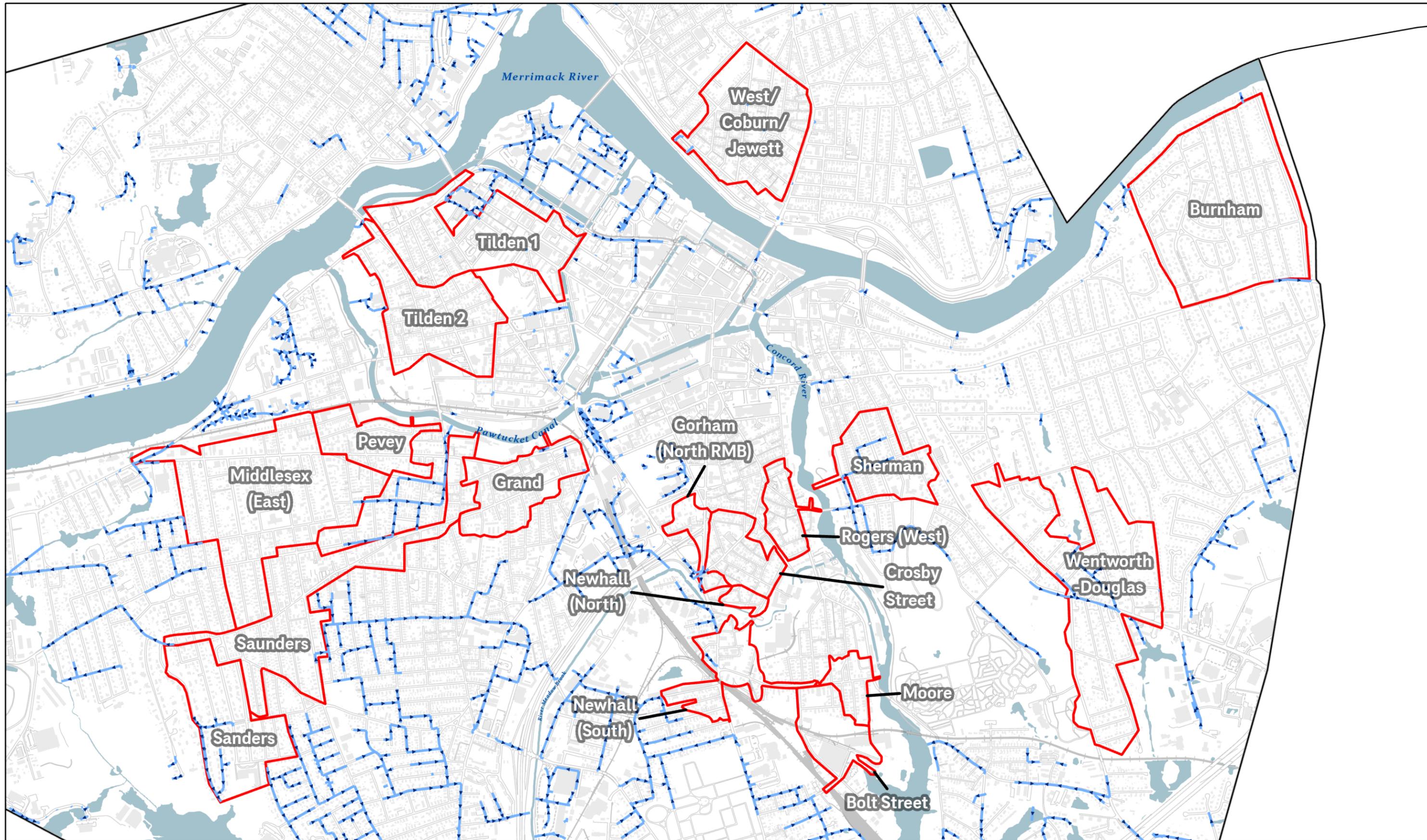
5.3.3 Public and Private Inflow and Infiltration Connections

The elimination of private I/I connections to the existing sewer system should be investigated as part of the planning, design, and implementation of a sewer separation program. Section 3 discusses the windshield survey and representative building inspection program that was conducted to identify private inflow sources such as building roof drains, yard drains, and driveway drains that discharge flow to the CSS through existing service connections. Disconnection of these illicit inflow sources from the CSS should be considered during final design and construction of individual sewer separation projects.

Another source of extraneous flow to the sewer system is sump pumps, which sometimes discharge directly to local sewers through existing service connections. The City implemented an online Sewer and Street Flooding Issues Survey (described in Section 2), which includes questions about whether buildings have sump pumps and where these sump pumps discharge. This information will be helpful in identifying properties that have sump pumps. However, as part of a comprehensive private inflow removal program, the City might consider the implementation of house-to-house inspection and sump pump removal programs in conjunction with the design of its Phase 3 sewer separation projects.

5.3.4 Use of Existing Drain Systems

Figure 5.2 presents the existing drainage network in the City and as shown there are several Phase 3 Candidate Areas with short extents of existing drainpipe. Some of these are independent drainage systems with outfall discharges, while others are connected to the CSS. Reuse of existing drainpipes



Legend

- Existing Drain
- Phase 3 Candidate Areas



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 5.2
 Existing Drainage Network

should be considered as a component of any drainage system design to achieve sewer separation. As Phase 3 separation projects were evaluated, the feasibility of drainpipe reuse has been considered and should be explored further during future design phases. Modeling of stormwater flows to achieve pipe size optimization will be important in this process, including an assessment of any requirements to upsize existing drainpipes. Where needed, local drainpipes reconnected to the existing CSS at their terminus will need to be rerouted to new drains. The drainpipes should also be investigated to confirm there are no illicit connections conveying sewage.

5.3.5 Utility and Construction Impacts

Potential construction issues that may be encountered during the installation of new drains should be evaluated as part of the design process. This type of work becomes more difficult when pipe diameters exceed 36 inches because of potential conflicts with other underground utilities. In addition, consideration should be given to construction challenges such as disruptions to pedestrian access, impacts to traffic flow, and local impacts such as noise and dust along with private property impacts.

While there will be short-term negative impacts during construction, many of these impacts can be reduced by implementing various mitigation measures. The selection of pipe routes, depths, sizes, and configurations is often driven by considerations that are intended to avoid or mitigate such impacts.

The following describes utility and construction impacts expected to be encountered.

5.3.5.1 Utility Conflicts

Underground utility conflicts represent a challenge for pipeline projects. Construction near adjacent utilities needs to consider the installation method to avoid undermining an existing adjacent utility if it is bedded higher than the new pipe. The preferred installation method usually is a function of the type of trench support used, which can mitigate the impact on existing utilities. In addition, pipe trenches must be dewatered to install the pipe in dry bedding material so there is no differential settlement. Dewatering for the pipe installation must be planned carefully to avoid excessive dewatering of nearby utilities that could create differential settling within the street.

To avoid conflicts, new drainpipe may be installed at a shallower depth. However, the drain inverts may still be below other existing utilities such as water mains, gas, telephone, and electric utilities. Large shallow drains may also block the reconnection of existing sewer services to the sewer pipe, creating the need for new parallel sewers.

Finally, new drains may have to be installed within the profile of existing sewer pipe, which can “block” the advance of the drain. In this situation, either the drain or the sewer profile needs to be modified to resolve the conflict, but the ability to change the sewer profile may be limited because the sewer generally must connect to a downstream fixed connection point. As a result, each situation requires an evaluation to determine which utility to move.

These issues will be considered further in the final design process when pipe routing, connectivity, and pipe inverts are confirmed during development of final plans and profiles.

5.3.5.2 Traffic Management and Pedestrian Access

Maintenance of traffic and property access along the construction zone is important during project implementation. The Phase 3 Candidate Areas are a mix of residential, multifamily, commercial, and industrial uses. Some areas are more compact and densely populated, which complicates traffic management issues; other less populated areas may handle traffic flow more efficiently and can better accommodate traffic disruptions due to construction.

Traffic management issues to be considered include access for emergency vehicles, minimized disturbance to local businesses, safety of school children, and access to residences along the affected routes. Some of these concerns can be addressed during project preliminary design by avoiding sensitive areas such as schools, medical centers, and places of worship, if feasible. If these areas cannot be avoided, appropriate mitigation must be developed and implemented during final design to minimize impacts.

Typical traffic mitigation measures include the following:

- Advance signage
- Parking restrictions
- Relocating bus stops or bus routes, including integration with the Lowell Regional Transit Authority, Senior Transportation, and School Department
- Shifting travel lanes
- Lane reductions
- Limited access and detours

Mitigation measures should consider the implications that work zones have for abutters in terms of construction time of day, driveway locations, detour suggestions, noise, and consideration of pedestrian access with proper signage. Areas that can be used to accommodate displaced parking will be identified and coordinated with the City. The public will be engaged to reduce impacts to daily life to the extent possible.

Many of these traffic and pedestrian concerns are generally addressed as part of the preliminary and final design process. More detail is provided in the traffic management plan prepared by the construction contractor, which will be subject to review and approval by several City departments, including the Lowell Police Department, Fire Department, Department of Planning and Development – Traffic Engineer, and City Engineering.

The traffic management plan will address road closings, signage, traffic patterns, bus routes, and traffic light timing adjustments and should include the following elements:

- Provide access to all buildings, businesses, and parking areas. Provide specific signs to affected businesses when normal access is modified.
- Maintain one lane of traffic on all major routes to the best extent possible. However, for the installation of large-diameter pipes and/or under certain construction conditions, maintenance

of even one lane of traffic may be infeasible and detours will have to be adopted. To the extent possible, this will be avoided along the major access streets.

- Identify vehicular and pedestrian traffic patterns around schools, playgrounds, and any other “pedestrian sensitive” areas.
- Develop detailed traffic and detour planning.
- Provide advance and robust notification and signage of all traffic detours due to construction as approved by other City departments.
- Use police details where required at all active work zone locations.

Each area will be analyzed to determine the best method to provide access to all entrances. At times, snow fencing will be used to direct traffic flow. Advanced planning and phasing of construction to address traffic issues will minimize disturbances to affected businesses and residents.

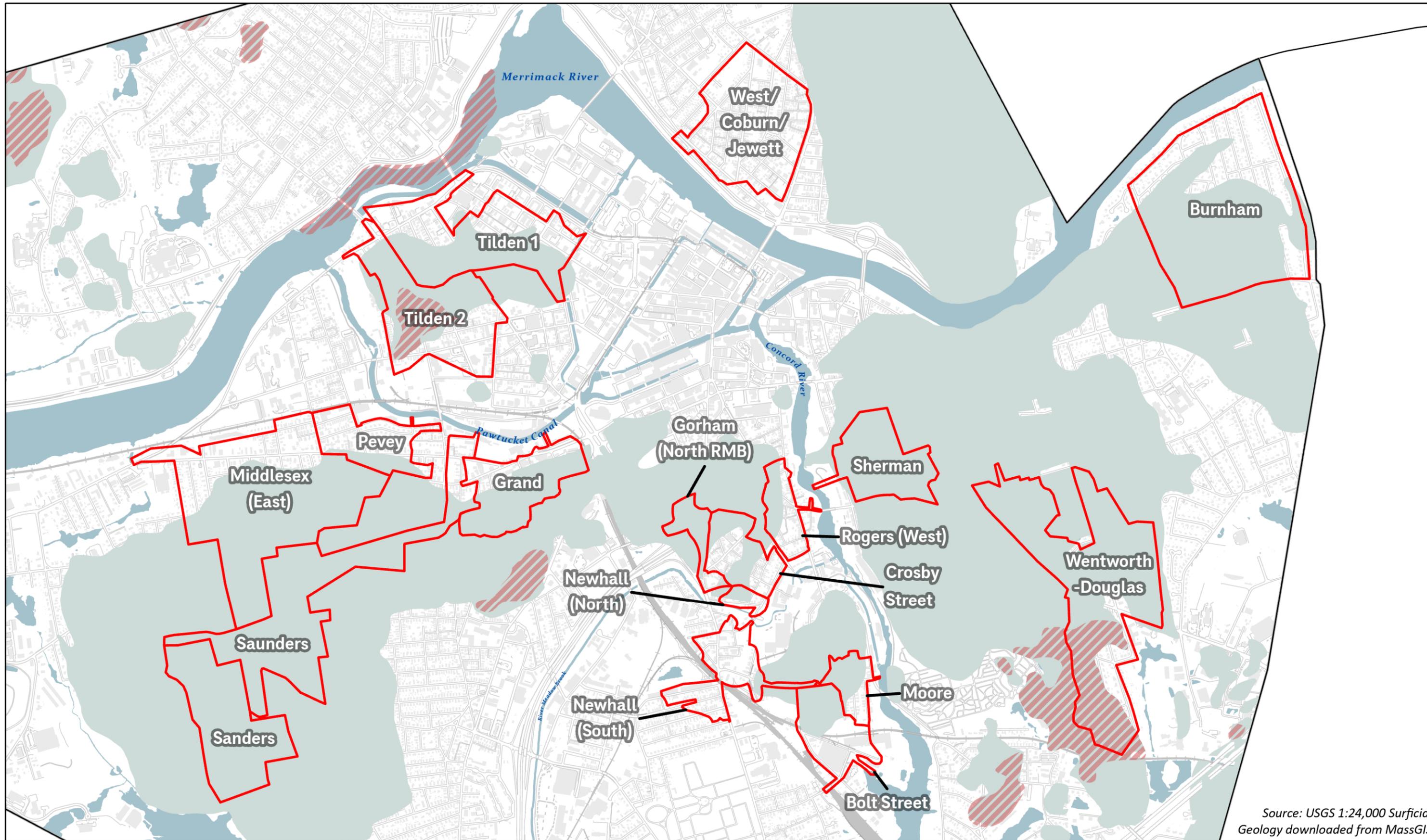
5.3.5.3 Noise

Potential noise impacts are evaluated based on the proximity of construction activities to sensitive land uses and receptors including businesses, residences, schools, medical centers, places of worship, and recreational sites. There will be a noticeable increase in noise during construction; blasting of ledge or rock also will have a significant impact on noise levels. To mitigate noise impacts, the following measures are recommended:

- Use new or well-maintained equipment with standard intake/exhaust mufflers and engine jackets. The best available noise-reducing technology, such as specialized mufflers and shields, may be necessary to reduce impacts at some locations. Decibel level restrictions could be added to the design documents in sensitive areas provided these safeguards are practical and would not significantly increase construction costs, unless warranted.
- Use the most quiet and practical construction techniques, such as replacing standard pile drivers, if needed, with vibratory or sonic drivers to eliminate noise from the hammer hitting the pile.
- Restrict construction activities to daytime hours and/or schedule noisier activities to take place during less sensitive times of day.
- Surround loud equipment such as generators with straw bales or plywood to reduce impacts of sound to the neighborhood.

5.3.5.4 Rock Removal

The presence of shallow bedrock may necessitate rock excavation for pipe installation. Indicators that shallow bedrock may be present include visible ledge outcrops within the project area. Glacial till may also be an indicator of shallow bedrock below the ground surface. **Figure 5.3** shows areas of mapped shallow bedrock and glacial till within the Phase 3 Candidate Areas and can be used as a preliminary indicator of potential bedrock that might be encountered within each project area. To determine the exact depths of the bedrock and glacial till, a geotechnical boring program will be required. The geotechnical borings will be obtained during the design phase to



Source: USGS 1:24,000 Surficial Geology downloaded from MassGIS



Legend

- Areas of Abundant Outcrop or Shallow Bedrock
- Glacial Till
- Phase 3 Candidate Areas



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR
Figure 5.3
Areas of Potential Shallow Bedrock

assess the soil type and presence of bedrock (type, depth, strength) along the proposed drain pipeline routes.

When present, and if permitted, rock may be excavated by numerous techniques including drilling, blasting (if permitted), wedging, sledging, or barring. If blasting is permitted, before starting rock excavation or blasting work, a pre-blast survey of all existing structures and conditions near the work area will be conducted by the contractor. This survey will include videotaping each building's exterior to establish preconstruction conditions.

Vibration monitoring will be required during all blasting activities. Should blasting be permitted for removal of rock, a blasting plan will be required that will describe proposed methods and sequence of excavation, including blasting procedures. Blasting would be limited to business hours, Monday through Friday, unless prior permission is received from the Lowell Fire Department. An adequate warning system will be provided to ensure that all persons are at a safe distance before a blast is detonated. Blasting signals will be required to conform to 29 Code of Federal Regulations (CFR) 1926.909 (OSHA) and posted.

All blasting will be performed in compliance with state, federal, and OSHA health and safety standards for construction. Persons responsible for blasting will be licensed blasters in the Commonwealth of Massachusetts and will be required to have acceptable experience with similar rock excavations and controlled blasting techniques. Before blasting, a blasting permit will be obtained from the Chief of the Fire Department.

3.3.5.5 Fugitive Dust

Construction activities such as excavation, grading, backfilling, and hauling can generate airborne dust. Particulate matter (PM) less than 10 micrometers in aerodynamic diameter (PM-10) has the potential to be a health hazard as well as a nuisance. Tests conducted for the USEPA concluded that the dominant source of construction PM-10 emissions is not passive wind erosion but movement of heavy vehicles over unpaved surfaces or construction excavation activities. These emissions are a function of vehicle activity, weights, speeds, number of wheels, soil silt, and moisture content.

Construction activities such as excavation, scraping, and jack hammering also will generate airborne dust. Fugitive dust mitigation measures will be required since some residences and sensitive receptors will be within 50 feet of construction. However, impacts will be temporary and can be controlled with mitigation measures such as regular watering of active construction areas, street sweeping, covering trucks carrying earth material, and clean-up of spillage on paved and unpaved travel surfaces. These mitigation measures should reduce fugitive dust impacts to an acceptable level.

3.3.5.6 Schools, Park/Playgrounds, and Sensitive Receptors

There are several schools, public parks, and playgrounds that are adjacent to streets that may be impacted by construction within the Phase 3 Candidate Areas. Schools require a significant level of coordination, especially during the school year, to minimize pedestrian impacts and facilitate bus transportation for the students. The contract documents may identify special conditions such as limiting allowable times of construction to non-school hours (or, if feasible, the summer), maintaining access to schools, coordinating with school bus schedules, noise and dust control, safety requirements, and final

restoration. Additionally, the contract documents will address traffic control and access requirements for construction in abutting streets around the schools, especially for students who walk to school.

Other sensitive receptors include daycare and nursery centers, churches, medical facilities, and local businesses. During final design and construction, there will be frequent communications with these entities and the City's Department of Planning and Development Neighborhood Outreach Coordinator to make sure that access is maintained and detours accommodate the use of these facilities.

3.3.5.7 Private Property

Routing of the drains and outfalls may fall within or next to residential or commercial private property, requiring easements. The need for easements and property acquisitions should be identified and established during the design process, so easements can be obtained prior to project bidding and construction.

5.3.6 Soil Disposal and Hazardous Waste

During construction, the project will require excavation of soils, mostly in the street. The soils will be stockpiled and subsequently backfilled into the excavation and compacted before the final pavement is put into place. During design, an initial investigation is performed to identify known areas of contamination to anticipate potentially hazardous soil conditions along the route.

In addition, surplus soils/spoils are created as the new pipe fills the trench area, and, as a result, not all excavated soils can necessarily be returned to the trench. These surplus soils must be characterized through environmental sampling to identify appropriate methods for final off-site disposal. This soil disposal characterization can be done either before construction begins or during construction, when arrangements need to be made for final disposal of the surplus materials.

As an initial step, the MassDEP Massachusetts Contingency Plan (MCP) website may be consulted to identify the status of all potential and confirmed contaminated sites in the project area. When a site is found to be contaminated and reported to MassDEP, the site is assigned with a unique identifying number that is used to track the site in agency databases. These are called Regional Tracking Numbers (RTNs). An understanding of the occurrence and/or presence of such sites in proximity to drainpipe construction can assist in pre-identification of potential contamination. A geotechnical boring program implemented during the design phase in combination with environmental sampling is another means of identifying soil contamination.

Design specifications should include contractor requirements for soils management, including transport and disposal. Management of contaminated soils, inclusive of disposal, must be conducted in accordance with the MCP. The City will require a Licensed Site Professional (LSP) to certify the management of any contaminated soils encountered. Contractor health and safety protocols will be required for workers, as well as the general public, in regard to the potential presence of contaminated soils.

Existing buried asbestos cement pipe used for either sewer or water main may also be encountered during construction work. Asbestos cement pipe must be addressed under 310 CMR 7.15(12A) and the Asbestos Cement Pipe Guidance Document (MassDEP 2019). A pre-survey will be completed in the

design phase to identify, to the extent possible, the presence of these materials and to develop a plan for handling and disposal of the materials. If unanticipated materials are encountered during construction, the Massachusetts guidance document and qualified inspectors will be used to follow proper procedures for identification of the material, notifications to the state, and the handling and disposal of the pipe and the soil around it. A trained and certified person will complete the field inspections and material handling/disposal oversight.

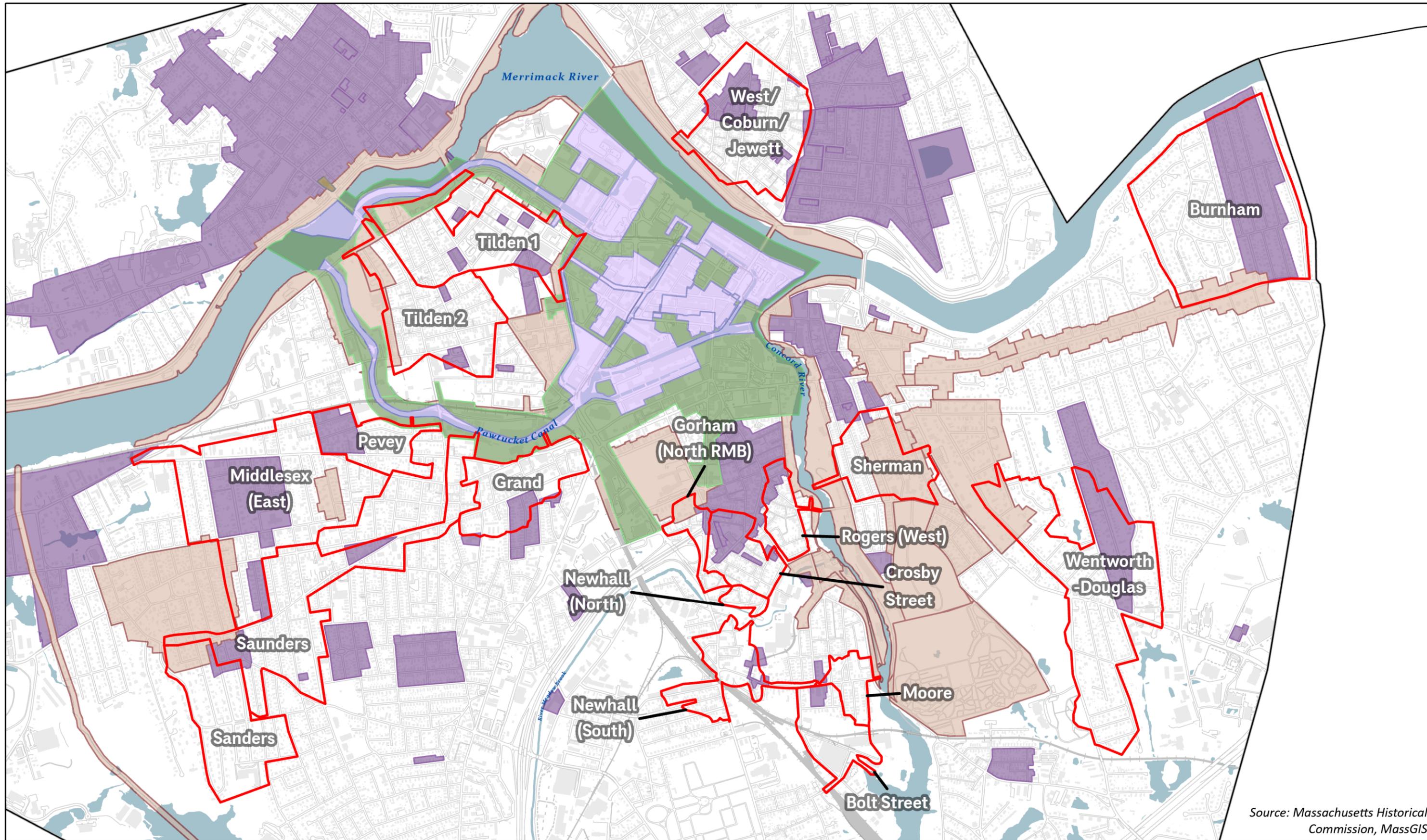
5.4 Environmental Permitting

While not a direct construction impact, permitting activities are needed to notify all appropriate federal, state, and local agencies about the project and its impacts, and to comply with applicable regulations. Permitting can be extensive for a construction project of this size and complexity. Permitting activities include an accounting of historic and archaeological resources, addressing environmental impacts to wetland and water bodies, as well as addressing any Article 97 change in use requirements relative to Department of Conservation and Recreation (DCR) lands. Excess soil characterization and disposal is also subject to permitting but is addressed as a potential design consideration in Section 5.3.6.

5.4.1 Historic and Archaeological Resources

Historic and archaeological resources should be identified before the start of construction either through database research and/or coordination with the Massachusetts Historical Commission (MHC). The MHC is the state agency that functions as the State Historic Preservation Office (SHPO) in Massachusetts and identifies, evaluates, and protects the state's significant cultural resources under Section 106 of the National Historic Preservation Act (NHPA). Compliance with Section 106 and/or M.G.L Chapter 9, Sections 26–27c, as amended by Chapter 254 of the Acts of 1988 (950 CMR 71.00), is also a requirement of the USACE permitting review process. A Project Notification Form (PNF) is required to initiate MHC review. This effort is typically done during the final design process when the immediate construction area is well defined. A typical approach is to consult with the National Registry (NRDIS designated 1978) to identify areas of historical or archaeological significance, as shown in **Figure 5.4** for the Phase 3 Candidate Areas. The areas of significance may include:

- National Register of Historic Places
- Areas of Preservation Restriction
- Local Historical Districts (these include areas or groupings of inventoried points)
- Individual Inventoried Points



Source: Massachusetts Historical Commission, MassGIS



Legend

- | | | |
|---|---|---|
|  National Register of Historic Places (NRHP) |  Local Historic District (LHD) |  Phase 3 Candidate Areas |
|  Preservation Restriction |  NRHP and LHD | |
| |  Inventoried Property | |



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 5.4
Massachusetts Historic Districts

Phase 3 separation projects will not result in the destruction of any historical structures. Most of the work under these projects will occur within streets or at existing structures (i.e., areas that have already been disturbed), so impacts to archaeological resources are not anticipated.

Note that potential separation projects for the Phase 3 Candidate Areas have been submitted to the MHC for review, in anticipation of future implementation. Any MHC review will need to be reviewed again once final design plans are available.

5.4.2 Wetlands and Water Bodies

Wetlands are classified along every water body in the Commonwealth of Massachusetts and the work required for this project may impact these areas. Pipe construction within or in proximity to wetlands as well as new storm system outfalls for discharges to rivers/streams will require specific permits relative to project impacts.

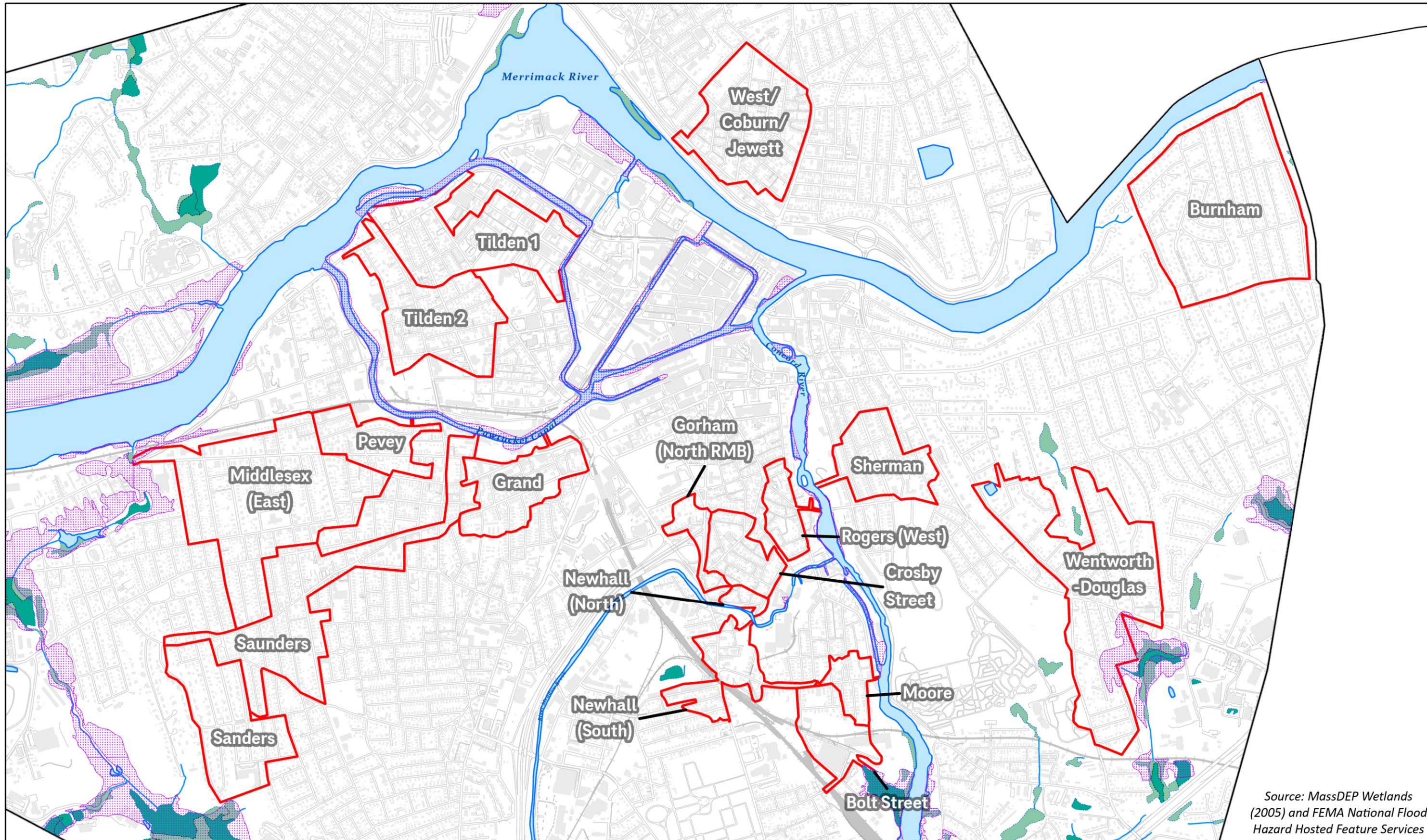
Figure 5.5 identifies all MassDEP-mapped wetlands within the City of Lowell. As displayed in the figure, there are no substantial wetlands along many of the Phase 3 Candidate Areas. Wetland delineation will be required as part of the design process along all pipeline and outfall routes to identify impacts. The presence of floodplain along any receiving waters at which outfalls are to be located must also be considered relative to wetland permitting.

Figure 5.5 also identifies the Federal Emergency Management Agency (FEMA) 100-year floodplain. The 100-year floodplain is critical to the design and permitting of outfall placement. When designing drains, it is important to consider flood zones because of the potential increase in water depth and volume during storm events. Outfalls located near or within the floodplain should be evaluated under certain flood elevations to ensure the drainage systems can continue to discharge during flood conditions. If needed, backflow prevention devices such as flap gates or check valves can be installed to prevent floodwaters from entering the drainage system through the outfalls.

Measures to mitigate temporary impacts to wetland resource areas will be required, including sedimentation controls (e.g., silt fence and straw bales and/or compost sock on land, silt curtains, coffer dams, sheeting in water) to prevent siltation of downgradient wetlands or water bodies, and restoration of disturbed areas to the extent feasible (restoring existing contours and reseeding with native seed mixtures as needed). The design will be developed accordingly to mitigate wetland impacts in accordance with all local, state, and federal regulations.

Following is a summary of the wetland-related permits and approvals that potentially may be required as part of the Phase 3 sewer separation projects:

- During the design phase, written notification to the Lowell Conservation Commission is required for geotechnical borings within the 100-foot Buffer Zone and Riverfront Area. If geotechnical borings need to be collected from wetland resource areas (i.e., Land Under Water, Inland Bank, or Bordering Vegetated Wetlands), then a Notice of Intent (NOI) in accordance with the Massachusetts Wetlands Protection Act (MWPA) [310 CMR 10.00] would need to be filed with the Lowell Conservation Commission for approval.



Source: MassDEP Wetlands (2005) and FEMA National Flood Hazard Hosted Feature Services



Legend

- MassDEP Wetlands Linear Features**
- Shoreline
 - Hydrologic Connection
 - - - Mean Low Water Line
 - Wetland Limit
 - Closure Line

- MassDEP Wetland Areas**
- Marsh/Bog
 - Wooded Marsh
 - Cranberry Bog
 - Salt Marsh
 - Open Water

- FEMA National Flood Hazard Layer**
- Reservoir (with PWSID)
 - Tidal Flats
 - Beach/Dune
 - 100-Yr Floodplain

- Phase 3 Candidate Areas

0 1,000 2,000

4,000 Feet



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 5.5

MassDEP Mapped Wetlands & FEMA Floodplains

- Compliance with the MWPA is required by submitting an NOI for receipt of an Order of Conditions (OOC) from the Lowell Conservation Commission relative to any impacts to wetland resource areas (i.e., Inland Bank, Bordering Vegetated Wetland [BVW], Land Under Water [LUW], 25-foot Riverfront Area, and Land Subject to Flooding) and 50-foot Offset and 100-foot Buffer Zones. If wetland alterations are less than 5,000 square feet of BVW and LUW, then a 401 Water Quality Certification (WQC) will not be required. In Massachusetts, the OOC serves as the 401 WQC if impacts to wetlands/watercourses is below 5,000 square feet.
- Massachusetts Environmental Policy Act (MEPA) compliance is required. An Expanded Environmental Notification Form (EENF)/Proposed Environmental Impact Report (EIR) is being filed with the Executive Office of Energy and Environmental Affairs (EEA) for all phases of the project (i.e., Phases 1, 2A, and 2B Centralville sewer separation design projects, as well as the Phase 3 Candidate Area Sewer Separation Projects). A Special Review Procedure request is also being filed to allow Phase 3 projects to progress in the future with minimal supplemental review by MEPA.
- Pre-Construction Notification (PCN) under the Massachusetts U.S. Army Corps of Engineers General Permit (GP) 6 (effective June 2, 2023) will be required for construction of any new outfalls that alter waterbodies/wetlands regulated as Waters of the United States.
- Any new stormwater outfalls to the Merrimack River, Concord River, Pawtucket Canal, Northern Canal, and Western Canal may require Chapter 91 licenses from MassDEP Waterways.

5.5 Other Permitting

5.5.1 Department of Conservation and Recreation

For properties owned by DCR, a DCR Access Permit will be required for construction and accessing those areas managed by DCR. Further, an Article 97 change in use petition to the state legislature will be required for any new utility easement on DCR land protected in perpetuity as public conservation land. An Article 97 change in use petition is also subject to approval under the 2022 Public Lands Preservation Act (PLPA) which established by statute the requirements and a process for submission to the Legislature for petitions to authorize the use of Article 97 land for another purpose. The PLPA is administered by the EEA and requires an alternatives analysis for the petition and placement of land, comparable in location and of equal or greater natural resource value, in a conservation Article 97 restriction.

5.5.2 Massachusetts Department of Transportation

If there is any work required in Massachusetts Department of Transportation (MassDOT) roadways, then a Massachusetts Highway Department Access Permit will be required.

5.5.3 Local Permitting

In addition to the aforementioned permits, the contractor will be responsible for obtaining any other local approvals needed for pipe installation, including, but not limited to, the National Pollutant Discharge Elimination System (NPDES) Construction GP from USEPA, Street Opening and Trench Permits

from the Lowell Department of Public Works, and Trades Permits from the Lowell Division of Development Services.

5.6 Public Relations

A well-informed public is critical to a successful construction project. A lack of public outreach can create significant project delays, public relations concerns for the utility, and long-term negative impacts for all parties involved.

The City has established strong lines of communication and public notification processes in conjunction with the Phase 1 Centralville Sewer Separation Project. Working in unison with the Department of Planning and Development, that framework will continue during implementation of Phase 3 sewer separation projects. Public notifications, newspaper articles, neighborhood public meetings, City Council meetings, and social media blasts will all be instrumental in keeping the public informed. Public meetings held in the design stages will be important to solicit local knowledge of issues and potential construction impacts so that final design documents can adopt approaches to mitigate these impacts (particularly related to property access, safety, traffic management, utility services, and construction activities). In addition, CDM Smith worked with the City to develop the online Lowell Sewer and Street Flooding Issues Survey described in Section 2. This survey allowed the public to provide real-time input on various issues in the project areas.

This public outreach effort will continue through the construction phase using a similar public notification process. Flyers, door hangers, notices, newspaper articles, neighborhood public meetings, City Council meetings, and social media blasts can be instrumental in mitigating issues before they arise. Notices may be provided to residents announcing special construction activities such as blasting, detours, parking restrictions, relocated bus stops, etc. An experienced on-site resident engineer who is visible to the public, together with a public relations component aimed at inviting public feedback, helps to formulate a proactive response to anticipate issues and create resolutions ahead of time.



6.0 Conceptual Drainage Planning of Phase 3 Candidate Areas

6.1 Introduction

This section presents the development and conceptual layouts of the potential sewer separation drain projects for each of the 18 Phase 3 Candidate Areas presented in Section 2.3. Development of these drainage layouts is based on a number of factors, including:

- Development of SWMM models for each Phase 3 Candidate Area's drain network to establish pipe size based on pipe slope, flow, and outfall conditions, as presented in Section 4.
- Incorporation of preliminary design considerations presented in Section 5. Wherever possible, connections of the new drainage to existing drainpipe and/or existing outfalls were considered.
- Consideration of wetland-related permits and approvals that may need to be incorporated into any local or state permitting, as discussed in Section 5.
- Development of plans and profiles of each drain network to determine the best route for conveying flow to the nearest receiving water for discharge. As discussed in Section 6.2, pipe plans and profiles were used to evaluate potential for utility conflicts, and adjustments were made to raise or lower the new pipe to avoid these identified conflicts, where possible.
- Use of topography to route drainpipes to the closest receiving water in each Phase 3 area. Receiving waters include Black Brook, the Concord River, the Merrimack River, the Upper Northern Canal, the Lower Northern Canal, the Pawtucket Canal, the Western Canal, Phoenix Avenue Wetland, River Meadow Brook, and an unnamed wetland that connects to the Concord River.
- Evaluation of potential outfall locations to identify discharge limitations and construction challenges. In many cases, one of the Utility's interceptors or large trunk sewers restricts discharge to the receiving water. Installation of a new drainpipe under an existing large-diameter interceptor would result in the discharge being below the existing receiving water bottom, which is not feasible. Installation of a new drainpipe above an existing large-diameter interceptor could result in drainpipes having very shallow cover at the downstream flat areas just before discharge.
- Consideration of impacts from the hydraulic controls and operations of the Upper Northern Canal, Lower Northern Canal, Pawtucket Canal, and the Western Canal system when using the canal system as receiving waters for new drainpipe networks.
- Consideration of historic permitting requirements, given that the canal system is a National Historic Landmark, and the potential need for Article 97 conversion if lands owned by the Department of Recreation and Conservation (DCR) are currently listed as conservation.
- The potential for site contamination as identified on the MassDEP Massachusetts Contingency Plan (MCP) website, and the additional permitting and costs associated with handling the contamination during construction.

- Consideration of construction cost estimates when evaluating sewer separation projects based on costs presented in Section 6.4.

Based on this approach, Section 7 presents prioritization of the potential sewer separation drain projects within the Phase 3 Candidate Areas that would provide the Utility with the best SSO and CSO benefits.

6.2 Base Mapping

CDM Smith developed drainpipe plans and profiles using existing information for base mapping. The City's GIS provides a robust source of information used to create preliminary base maps. These maps include information on sewer and drainpipes, manholes, catch basins, and water system infrastructure, supplemented by available sewer and facility record drawings. For private utility information, major utility companies were contacted, including Verizon and National Grid, to obtain mapping, size, material, and location of their utilities. Information on these communications, gas, and electric utilities in the Phase 3 Candidate Areas was used to identify potential utility conflicts to the most reasonable extent possible. These data were used to prepare preliminary drawings.

During preliminary design of the drainage routes and profiles, conflicts with existing combined sewer, water mains, and non-City utilities were identified. Generally, drainage pipes were routed above existing sewers to maintain the elevation needed for gravity discharge to receiving waters. In most cases of conflicts with other non-City utilities, the new drains were placed below the utility. Water main conflicts were addressed on a case-by-case basis. Many existing water mains are older cast iron, which may be susceptible to damage during construction due to vibration or excavation. Cast iron water mains that are not relocated for the drain could be replaced with new ductile iron water main if it falls within the capital improvements program of the Utility.

Relocating non-City utilities for the new drains also presents a challenge. If the gas mains are older cast iron, the gas utility (National Grid) may be responsible for relocating or replacing the gas mains impacted by project construction, because those may be targeted for betterment as part of the utility's infrastructure renewal program. The City may fund other gas utility relocations. To the extent possible, the new drains avoided conflicts with underground electric and telephone because relocating these utilities is more expensive and often cannot be completed in a timely manner.

Utility conflicts would require identification and resolution during a future final design effort because, often, non-City utility information is not confirmed. A completed field survey for final design should confirm and establish any utility conflicts and resolutions.

6.3 Candidate Areas Conceptual Drainage Descriptions

This section provides a description of the conceptual drainage network developed for each Phase 3 Candidate Area identified in Section 2.3. Each network is described regarding size, outfall location, permitting, utility conflicts, and general design considerations.

Figure 6.1 through Figure 6.17 depict a plan view of the conceptual layouts by area, respectively, with modeled pipe sizes, outfall locations, nearby interceptors and trunk sewers, and CBs. The CBs were

identified from the City's GIS, use of Google Earth, and spot field checks. The following figures and descriptions are organized relative to the CSO basin to which the Candidate Area contributes.

6.3.1 Warren Combined Sewer Basin

6.3.1.1 Bolt Street

The Bolt Street Area comprises 30 acres, with approximately 4,100 linear feet of drainpipe conceptually proposed to achieve separation as shown in **Figure 6.1**.

The conceptual outfall location directs flow across at least one privately owned parcel to the unnamed wetland that discharges directly into the Concord River. This receiving water is an expansive, low-lying wetland with flat banks extending to the Concord River. The Federal Emergency Management Agency (FEMA) maps the wetland as lying within the 100-year floodplain of the Concord River, creating construction challenges regarding design, permitting, and implementation. An elevation survey of the impacted wetland would be required to determine the extent of potential dredging for outfall construction. It may be possible to redirect the outfall to the end of Bolt Street, directly to the Concord River, and reduce the potential need for dredging. However, this route adds approximately 900 linear feet of pipe length, crosses at least three privately owned parcels, which have known contamination related to urban fill and transformer fluid spills identified by MassDEP under the MCP. Any separation project in the Bolt Street area would include crossing under the railroad tracks on Meadowcroft Street, which would require trenchless installation methods. As such, extensive coordination would be required with the Massachusetts Bay Transportation Authority (MBTA), who owns and operates this railroad.

6.3.1.2 Crosby Street

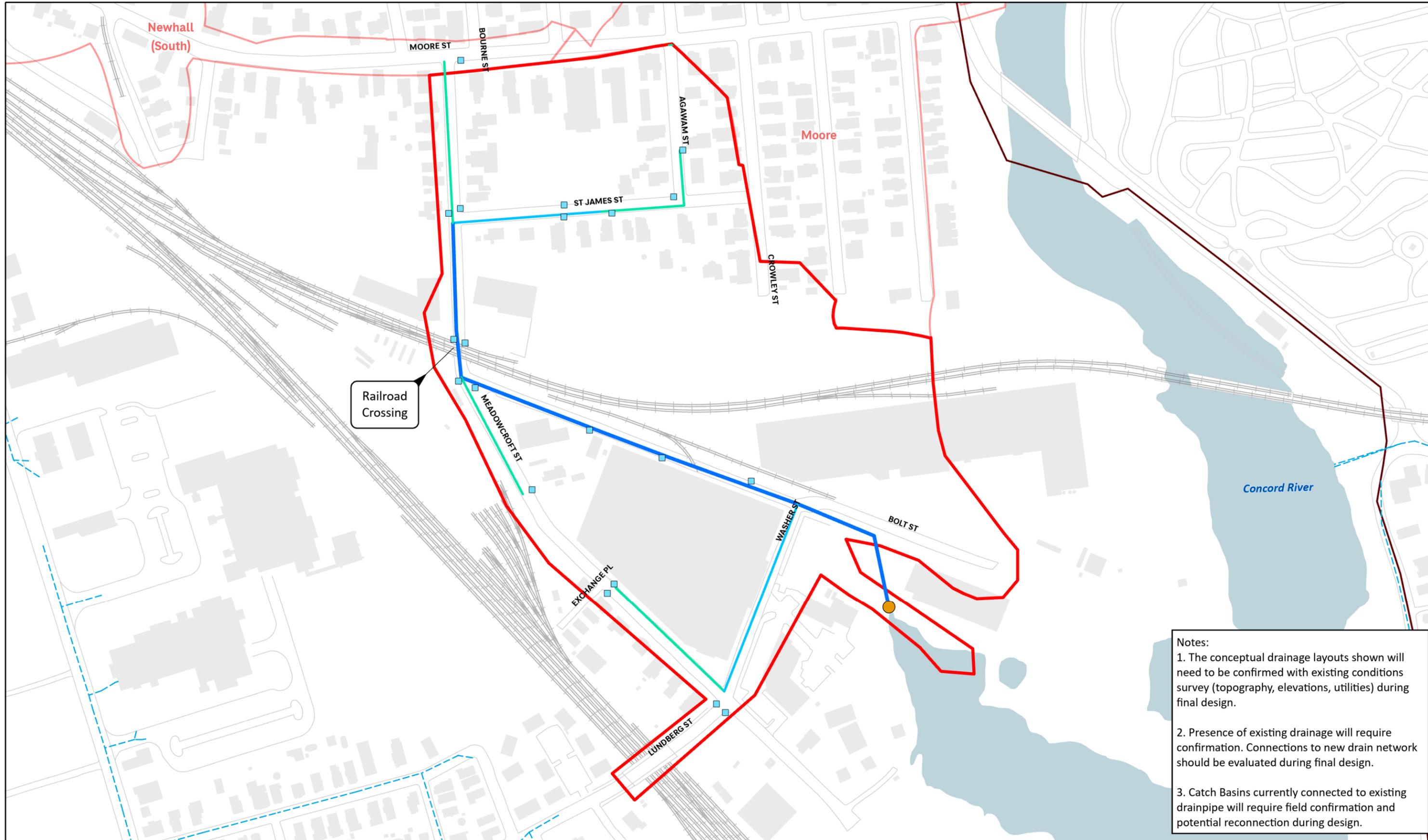
The Crosby Street Area comprises 27 acres (primarily residential), with approximately 2,900 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.2**.

The proposed outfall discharges to River Meadow Brook through a short stretch of privately owned land. Because of the streambed elevation of River Meadow Brook, the outfall elevation must be raised, which is further complicated by the crossing of an 84-inch trunk sewer on Newhall Street. With the streambed elevation forcing the drain crossing over the 84-inch trunk sewer, there is limited space for drain separation from the sewer with appropriate cover, thereby, likely requiring a shallow box culvert. Other challenges include sewer separation on the relatively flat Kinsman Street, in which minimally sloped drainpipe would need to cross moderately sized water and gas lines.

6.3.1.3 Gorham (North RMB)

The Gorham (North RMB) Area comprises 13 acres (primarily residential), with approximately 2,100 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.3**.

Most of the project requires installation of drainpipe on Gorham Street (Route 3A), adjacent to and east of the Lowell Connector. The proposed outfall daylights to River Meadow Brook directly from Gorham Street/Route 3A, requiring coordination and permissions from the Massachusetts Department of Transportation (MassDOT). Furthermore, Gorham Street/Route 3A is heavily congested with telephone and electrical conduits and vaults, large-diameter water and gas mains, a large-diameter sewer, and



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

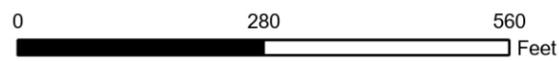
Conceptual Drain System
Pipe Diameter (In)

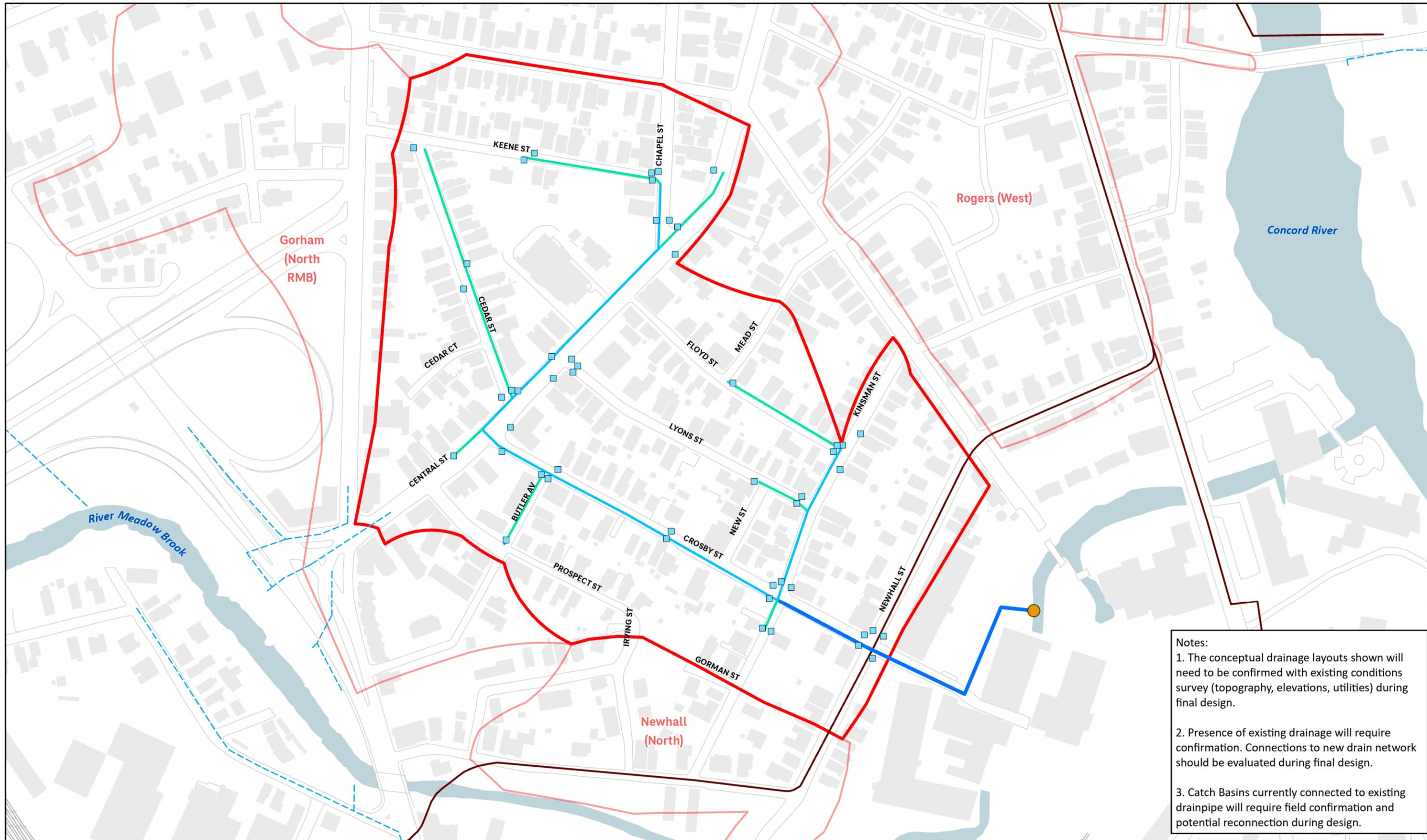
- 12 - 15
- 18 - 36
- 42 - 48
- 54 - 60
- Box Culvert (Size Varies)

- Catch Basin Separation to Proposed Drain
- Catch Basin Connected to Existing Drain (See Note 3)
- Outfall Location (Conceptual)
- Existing Drain

- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Bolt Street Area
- Other Phase 3 Candidate Area





Notes:

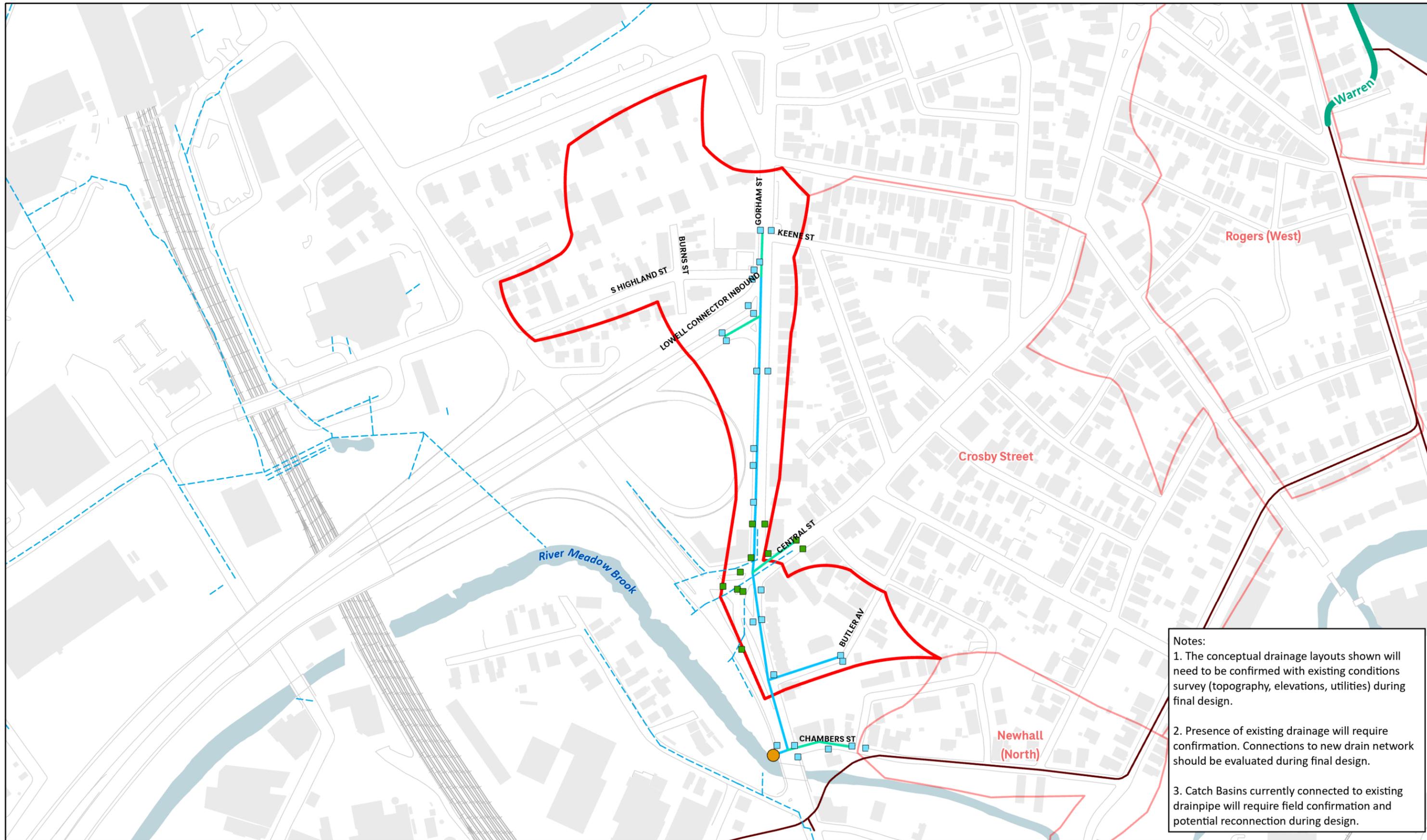
1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

- | | | | |
|---|--|--|--|
| <p>Conceptual Drain System
Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) | <ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) - - - Existing Drain | <ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall | <ul style="list-style-type: none"> Crosby Street Area Other Phase 3 Candidate Area |
|---|--|--|--|





Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.

Legend

<p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) 	<ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) - - - Existing Drain 	<ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall 	<ul style="list-style-type: none"> Gorham (North RMB) Area Other Phase 3 Candidate Area
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Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 6.3
Conceptual Drainage Layout
Phase 3 Candidate Area: Gorham (North RMB)

0 310 620

Feet

existing drainage. Each intersection off Gorham Street/Route 3A slopes away from River Meadow Brook, resulting in minimum slope and cover to convey drainage from these streets.

The Gorham (North RMB) Area is no longer being considered as a standalone project after learning of an impending MassDOT project that will facilitate drainage and sewer separation for most of this project area. Because of its proximity to the Newhall (North) Area, there is an opportunity to incorporate separation of remaining catch basins within Gorham (North RMB) into the Newhall (North) conceptual layout, as discussed further in Section 7.

6.3.1.4 Grand

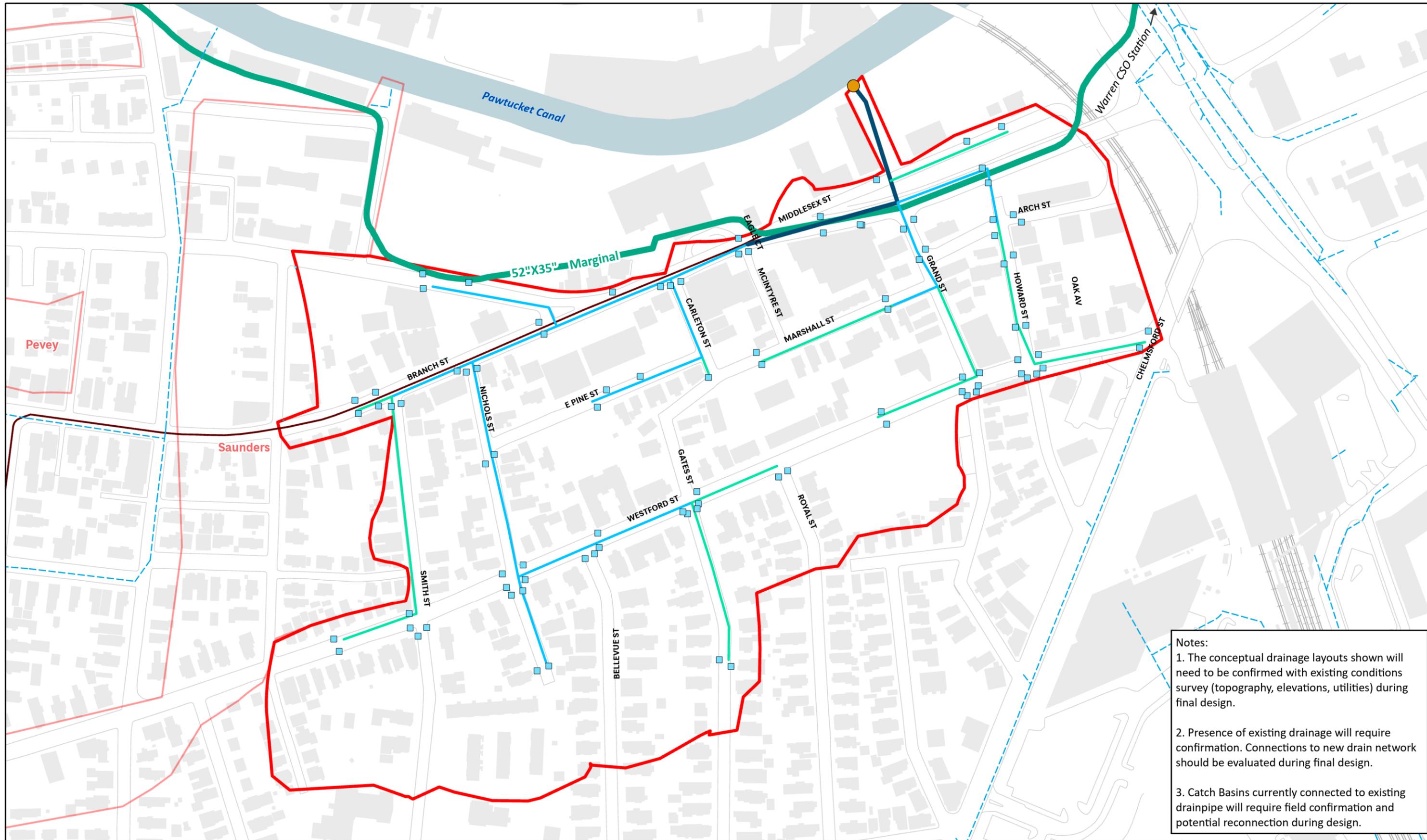
The Grand Area comprises 44 acres (primarily residential), with approximately 7,000 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.4**.

The conceptual outfall discharges to the Pawtucket Canal, which is owned and managed by Boott Hydropower. To reach the Canal, the outfall passes through private land and DCR property, requiring acquisition or an easement by the Utility as well as an Article 97 conversion and a DCR Access Permit. Coordination with the Massachusetts Historical Commission would also be required. The Grand Street/Middlesex Street intersection, directly upstream of the outfall, contains a number of utilities. Because of these utilities, the proposed drainpipe must pass over the Marginal Interceptor, over large-diameter water and gas mains, and around utility vaults. There are a handful of other intersections in this project area with similar utility congestion that would require careful consideration and planning during future design. To facilitate sewer separation on Howard Street, the proposed drainage must pass through a City-owned berm under Middlesex Street, at a shallow elevation with minimal cover, making separation of existing CBs on Howard Street difficult.

6.3.1.5 Middlesex (East)

The Middlesex (East) Area comprises 140 acres, with approximately 15,600 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.5**.

The receiving water for this area is Black Brook, just upstream of an intersection with the Merrimack River. The conceptual outfall is located at the intersection of Pawtucket Street and Middlesex Street, which crosses two private parcels used for auto repair and sales. There is an existing drainage system with 1,400 linear feet of drainpipe conveying a short portion of Middlesex Street and Pawtucket Street that discharges adjacent to the conceptual outfall. Although this small existing drainage outfall is present at the same location, it likely does not provide sufficient capacity for the entirety of the Middlesex (East) Area. The outfall location is a heavily congested area with traffic and multiple large-diameter water and gas mains, utility vaults, and a small existing drainage network. The location would require the crossing of both the Marginal Interceptor and the Walker Interceptor. Given the elevation of the interceptors, the conceptual alignment is forced to cross under the Marginal Interceptor and then over the Walker Interceptor at the outfall location, leaving only 6.5 feet of vertical separation for a crossing. Given the large acreage of the Middlesex (East) Area, drainpipe design requires a wide box culvert, further complicating the utility congestion. Considering the difficulties regarding utilities and outfall size, constructability of this Candidate Area may be infeasible. If this project is considered in the future a cross-country outfall off Middlesex



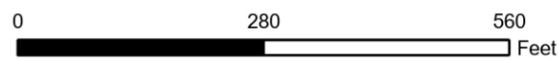
Notes:

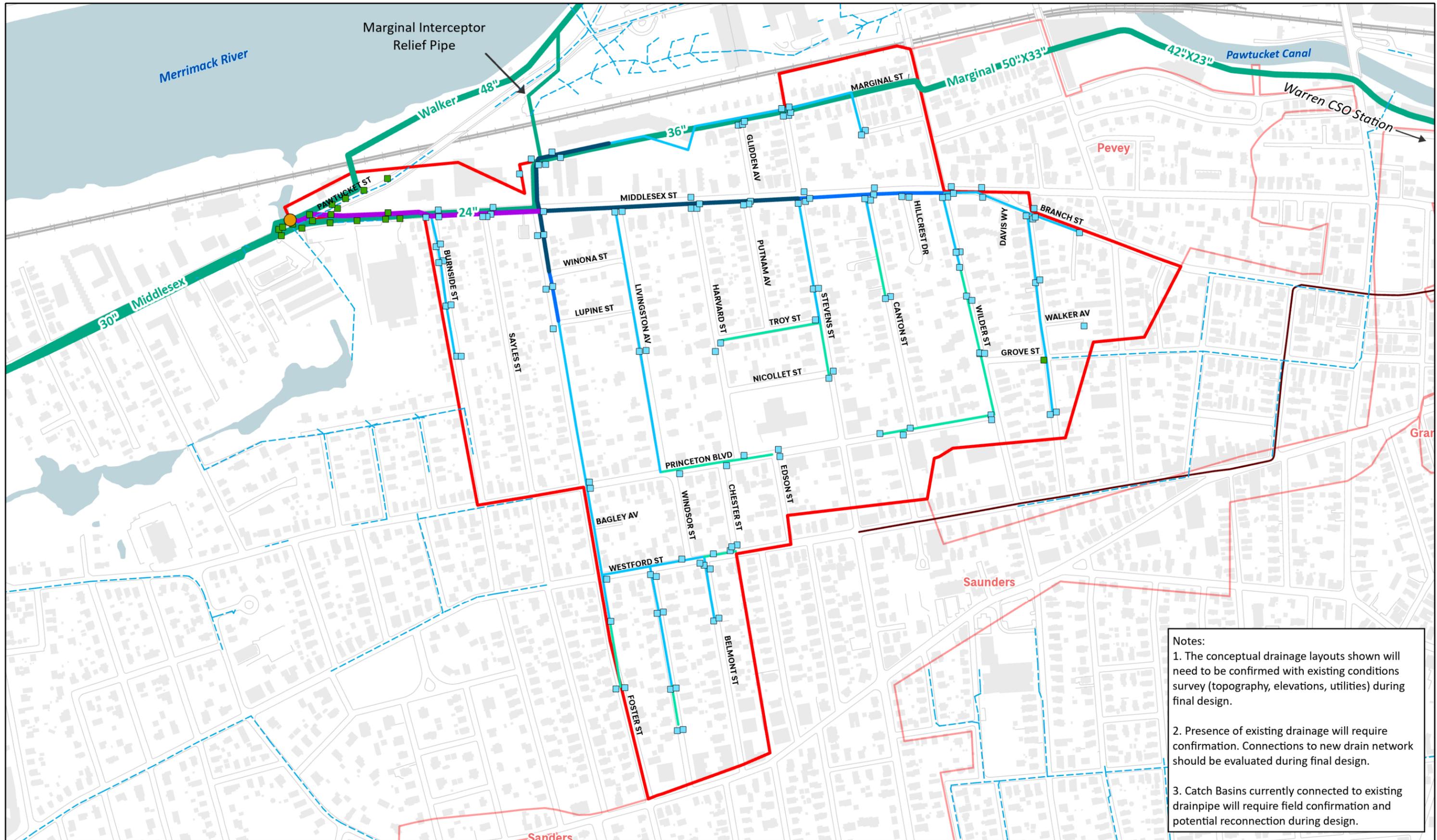
1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

- | | | | |
|--|---|---|--|
| <p>Conceptual Drain System
Pipe Diameter (In)</p> <ul style="list-style-type: none"> 12 - 15 18 - 36 42 - 48 54 - 60 Box Culvert (Size Varies) | <ul style="list-style-type: none"> Catch Basin Separation to Proposed Drain Catch Basin Connected to Existing Drain (See Note 3) Outfall Location (Conceptual) Existing Drain | <ul style="list-style-type: none"> Trunk Sewer Interceptor Diversion Station and CSO Outfall | <ul style="list-style-type: none"> Grand Area Other Phase 3 Candidate Area |
|--|---|---|--|





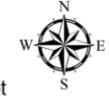
Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

- | | | | |
|--|---|---|---|
| <p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> 12 - 15 18 - 36 42 - 48 54 - 60 Box Culvert (Size Varies) | <ul style="list-style-type: none"> Catch Basin Separation to Proposed Drain Catch Basin Connected to Existing Drain (See Note 3) Outfall Location (Conceptual) Existing Drain | <ul style="list-style-type: none"> Trunk Sewer Interceptor Diversion Station and CSO Outfall | <ul style="list-style-type: none"> Middlesex (East) Area Other Phase 3 Candidate Area |
|--|---|---|---|



Street, extending north to the Merrimack River may be required. This alternative would cross only City-owned property; however, adding a crossing under an MBTA railroad would increase costs because trenchless installation methods are more expensive.

In addition, the large pipe and culvert sizes on Middlesex Street may lead to potential sewer connection conflicts from side streets Harvard Street, Putnam Avenue, and Foster Street, and major utility crossings at Sayles Street, Wilder Street, and Branch Street. The 24-inch water main on Westford Street presents elevation challenges for a drain crossing onto Foster Street, Belmont Street, and Marlborough Street. Furthermore, this layout may result in sewer laterals being blocked, necessitating a parallel sewer installation or reinstallation of the sewer main at a lower elevation on Burnside Street, Foster Street, Westford Street, and Marginal Street.

6.3.1.6 Moore

The Moore Area comprises 14 acres, with approximately 2,900 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.6**.

The proposed outfall location is to the Concord River at the end of Moore Street, though this requires crossing a private parcel that is currently being used as a shipping bay for Nationwide Tile. Upstream of the outfall, the intersection of Moore Street and Lawrence Street presents design challenges with crossings of large-diameter water and gas mains, telephone vaults, and a trunk sewer to the Warren Interceptor. Continuing west along Moore Street, side street sewer connections from State Street, Sidney Street, and Crowley Street impact the design and may require the installation of new SMHs with drop inlets. The flat topography of State Street, Sidney Street, and Crowley Street require shallow, minimum slope pipes for separation, potentially creating cover issues.

6.3.1.7 Newhall (North)

The Newhall (North) Area comprises 5 acres, with approximately 600 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.7**.

The small area discharges to River Meadow Brook at Oliveria Park, a City-owned property in a residential neighborhood. The conceptual layout runs parallel to, but never crosses, a trunk sewer upstream of the Warren Interceptor, and the only utility crossings are two small-diameter water and gas lines.

There is an opportunity to combine the Newhall (North) Area with the remaining unseparated CBs from the adjacent Gorham (North RMB), discussed in Section 6.3.1.3 and Section 7, to create a larger separation project.

6.3.1.8 Newhall (South)

The Newhall (South) Area comprises 31 acres, with approximately 3,000 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.8**. This area includes the tie-in of 300 linear feet of existing drainage on Dix Street that currently recombines with the sewer system.

The greatest challenge for Newhall (South) is the proposed outfall to River Meadow Brook, which passes through the privately owned Markley Group property, a secure data center operating on the site formerly known as the Prince Spaghetti Factory. Aside from being a secure site with restricted access,



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

Conceptual Drain System
Pipe Diameter (In)

- 12 - 15
- 18 - 36
- 42 - 48
- 54 - 60
- Box Culvert (Size Varies)

- Catch Basin Separation to Proposed Drain
- Catch Basin Connected to Existing Drain (See Note 3)
- Outfall Location (Conceptual)
- Existing Drain

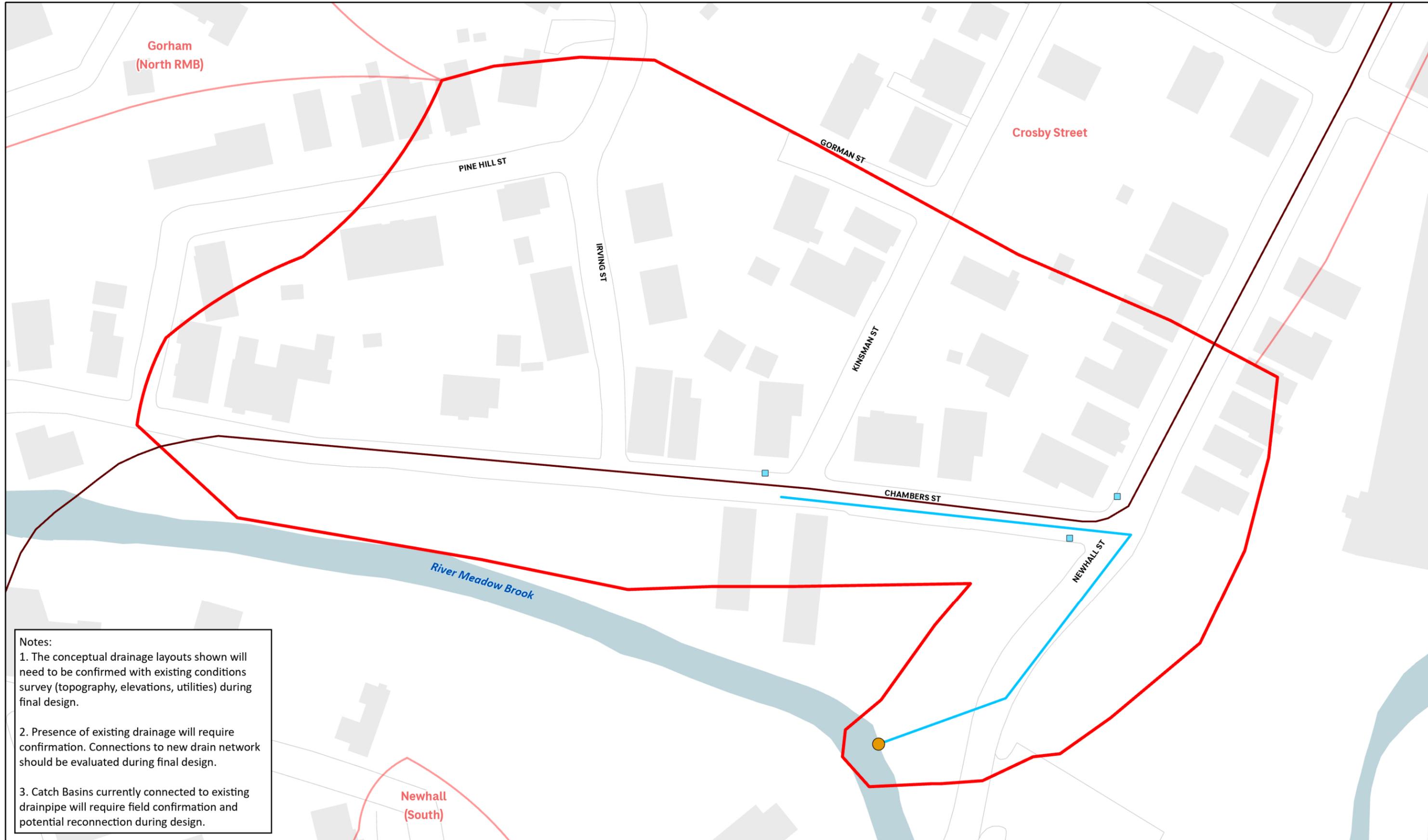
- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Moore Area
- Other Phase 3 Candidate Area



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 6.6
Conceptual Drainage Layout
Phase 3 Candidate Area: Moore



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.

Legend

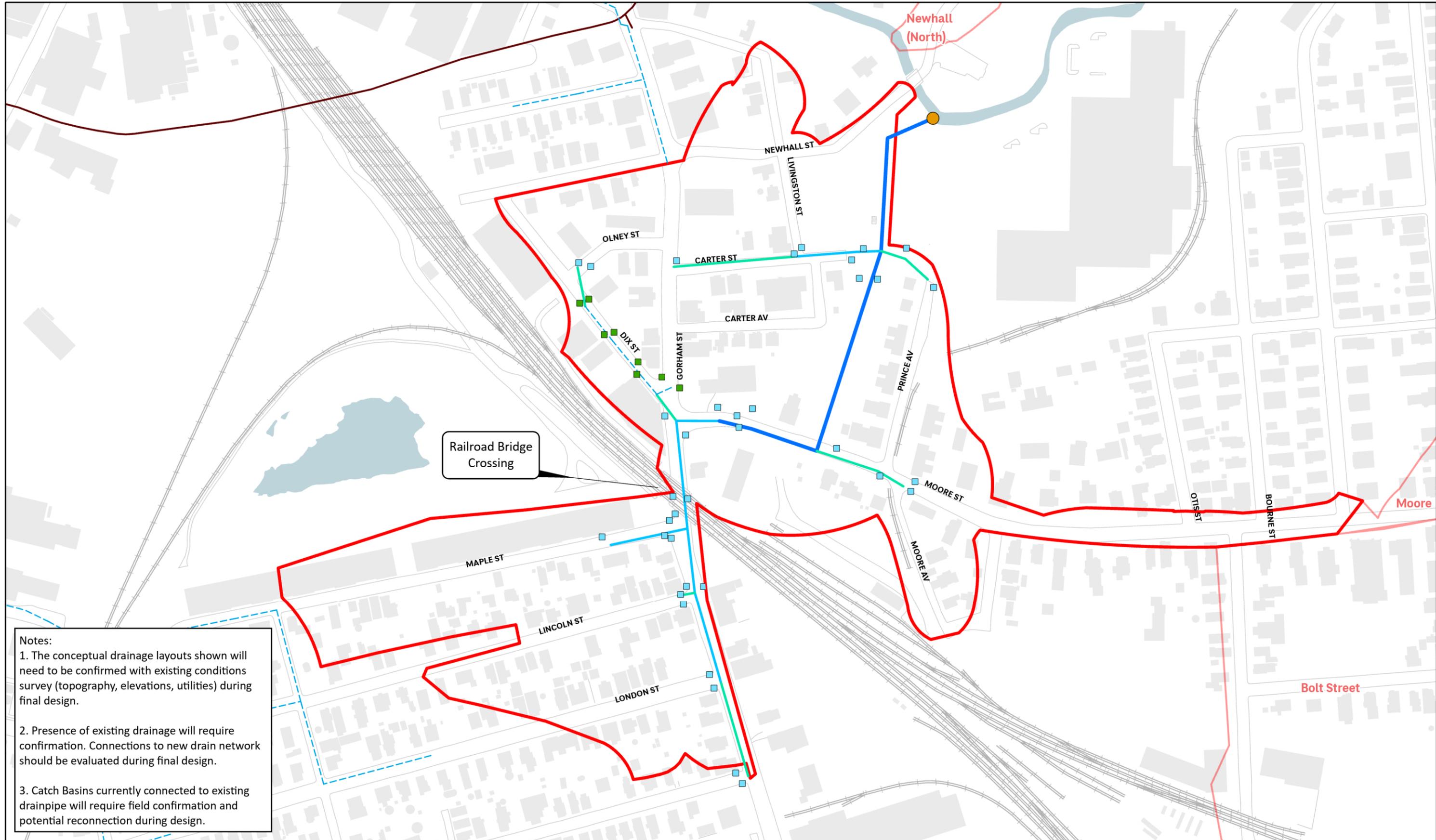
<p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) 	<ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) --- Existing Drain 	<ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall 	<ul style="list-style-type: none"> Newhall (North) Area Other Phase 3 Candidate Area
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Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 6.7
Conceptual Drainage Layout
Phase 3 Candidate Area: Newhall (North)

0 80 160

Feet



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.

Legend

<p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) 	<ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) --- Existing Drain 	<ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall 	<ul style="list-style-type: none"> □ Newhall (South) Area □ Other Phase 3 Candidate Area
--	--	--	---

Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 6.8
Conceptual Drainage Layout
Phase 3 Candidate Area: Newhall (South)

0 280 560

Feet

the Markley Group recently installed electrical ducts and stormwater infrastructure on the site, directly conflicting with the conceptual outfall alignment. Alternate routes that circumvent the private property to get to River Meadow Brook face an uphill grade that would significantly increase costs because of the deep pipe installation. Aside from the challenges surrounding the outfall, the conceptual alignment must cross over two large sewers at the Moore Street and Gorham Street intersection, as well as gas and water mains. The crossing results in minimal cover, necessitating a local sewer installation to connect existing sewer laterals on the northern side of Moore Street. The crossing also may result in drainpipe conflicting with the gas and water mains. Further upstream, the conceptual alignment passes under the railroad bridge on Gorham Street, adding difficulty during construction. Sewer and water main crossings also create challenges for separating Maple Street and Lincoln Street, potentially requiring a portion of the sewer main on Gorham Street to be lowered.

6.3.1.9 Pevey

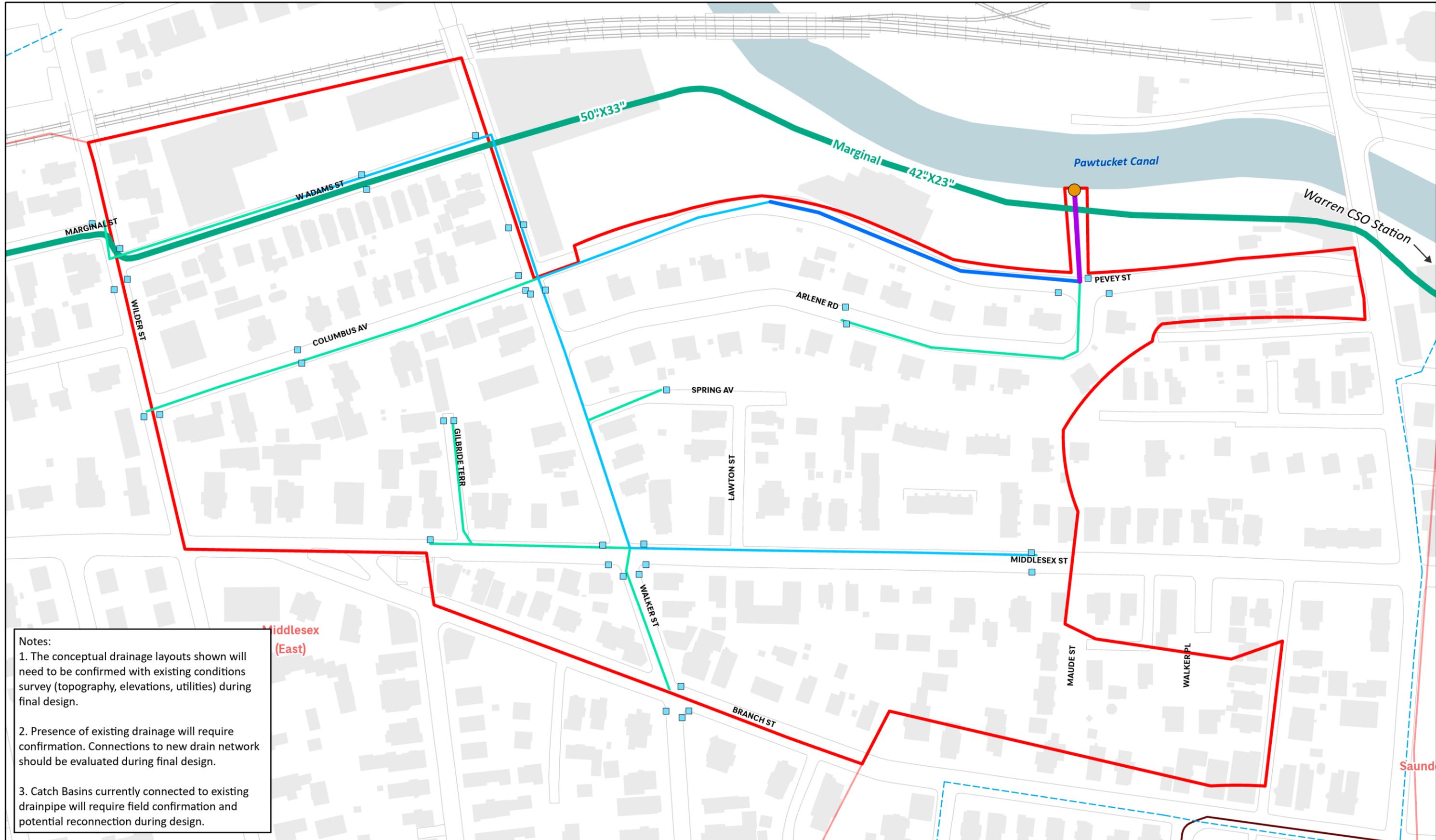
The Pevey Area comprises 31 acres, with approximately 5,100 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.9**.

The proposed outfall is to the Pawtucket Canal, which is owned and managed by Boott Hydropower. To reach the Canal, the outfall passes through private land and DCR property, requiring acquisition and/or an easement by the Utility, as well as a potential Article 97 conversion which would be subject to state legislative approval, and a DCR Access Permit. Coordination with the Massachusetts Historical Commission would also be required. There may be an alternate outfall to the Pawtucket Canal via Pevey Street, within the Pevey Street right-of-way, which should be explored in future design stages. However, this alternate would still require the same Article 97 conversion and DCR coordination. Both outfall options require passing over the Marginal Interceptor, necessitating shallow pipe and slope in the downstream portion of the network. There are several large-diameter water and gas main crossings that would impact the installation of new drain lines. Additionally, the relatively flat area results in pipe sections with minimal slopes and cover, particularly on Arlene Road, Middlesex Street, and Gilbride Terrace.

6.3.1.10 Rogers (West)

The Rogers (West) Area comprises 18 acres, with approximately 3,600 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.10**.

The Concord River would serve as the receiving water. The conceptual outfall would be routed on the Merrill Street right-of-way before passing onto property with uncertain parcel ownership, just upstream of the Warren Interceptor, where it crosses the trunk sewer. The primary challenge to separating the Rogers (West) Area is the narrow, residential nature of the streets. With houses on the edges of property lines, Merrill Street, Hudson Street, Bassett Street, and Swift Street are among the narrowest in the area, necessitating damage mitigation and potentially restoration costs after construction. In addition, Lawrence Street is utility dense (particularly the Lawrence/Wamesit/Abbott/Rogers five-way intersection), with multiple large-diameter water and gas mains and multiple telephone vaults. With nearly every drain conduit in this conceptual layout connected directly to Lawrence Street via this intersection, adding drainpipes to this already congested intersection would be a challenge. While an



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.

Legend

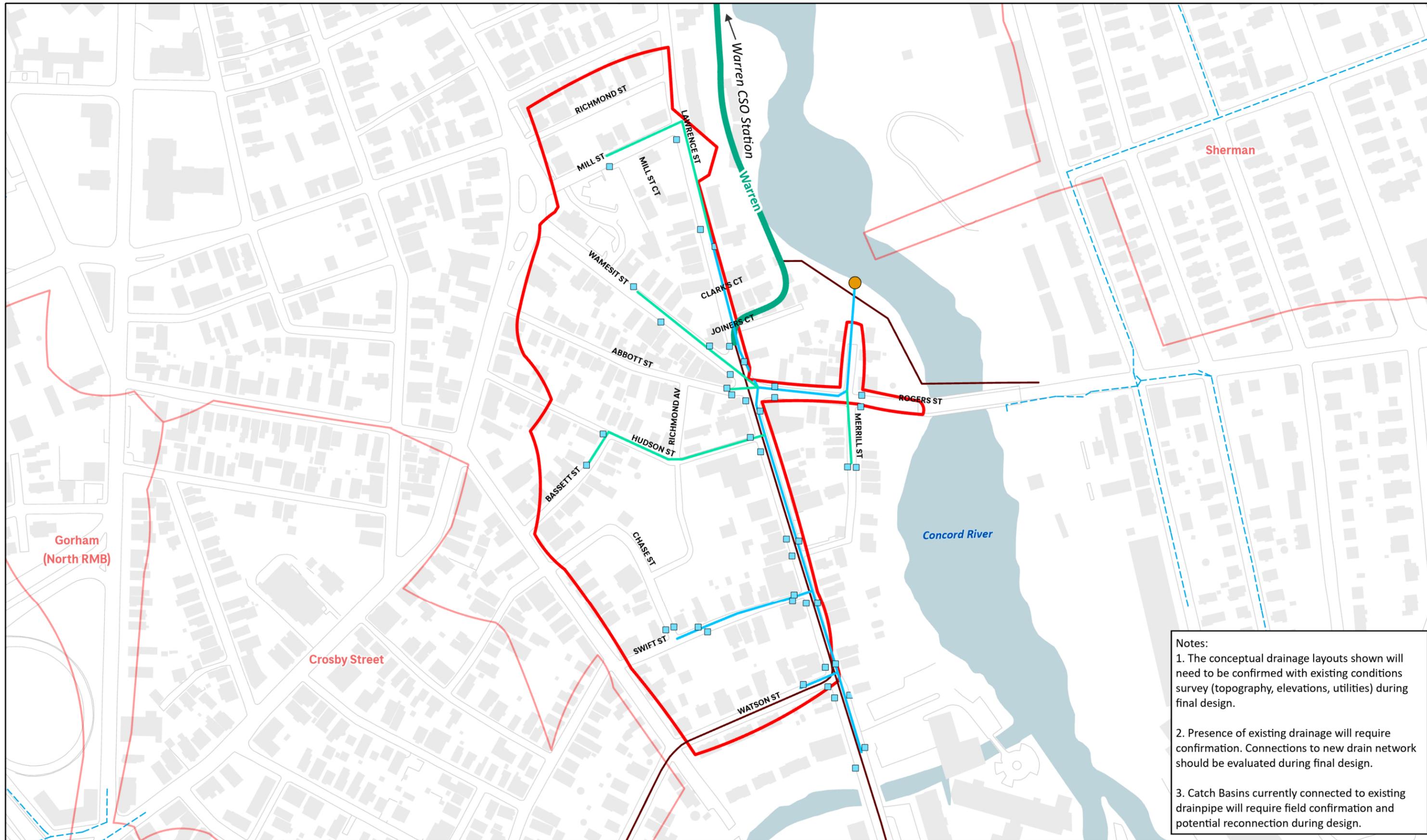
<p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) 	<ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) - - - Existing Drain 	<ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall 	<ul style="list-style-type: none"> Pevey Area Other Phase 3 Candidate Area
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Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 6.9
Conceptual Drainage Layout
Phase 3 Candidate Area: Pevey

0 200 400

Feet



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

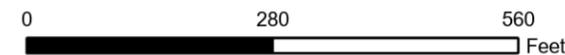
Conceptual Drain System
Pipe Diameter (In)

- 12 - 15
- 18 - 36
- 42 - 48
- 54 - 60
- Box Culvert (Size Varies)

- Catch Basin Separation to Proposed Drain
- Catch Basin Connected to Existing Drain (See Note 3)
- Outfall Location (Conceptual)
- - - Existing Drain

- - - Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Rogers (West) Area
- Other Phase 3 Candidate Area



84-inch trunk sewer also extends along on Lawrence Street, its depth is such that it should not impact construction or design.

6.3.1.11 Sanders

The Sanders Area comprises 64 acres, with approximately 5,000 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.11**.

There is 3,200 linear feet of existing drainage in the Sanders Area. This drain discharges at the end of Rindo Park Drive into a wetland that contributes to Black Brook, with an 18-inch outfall, separating approximately 28.5 acres, or 45 percent of the Sanders Area.

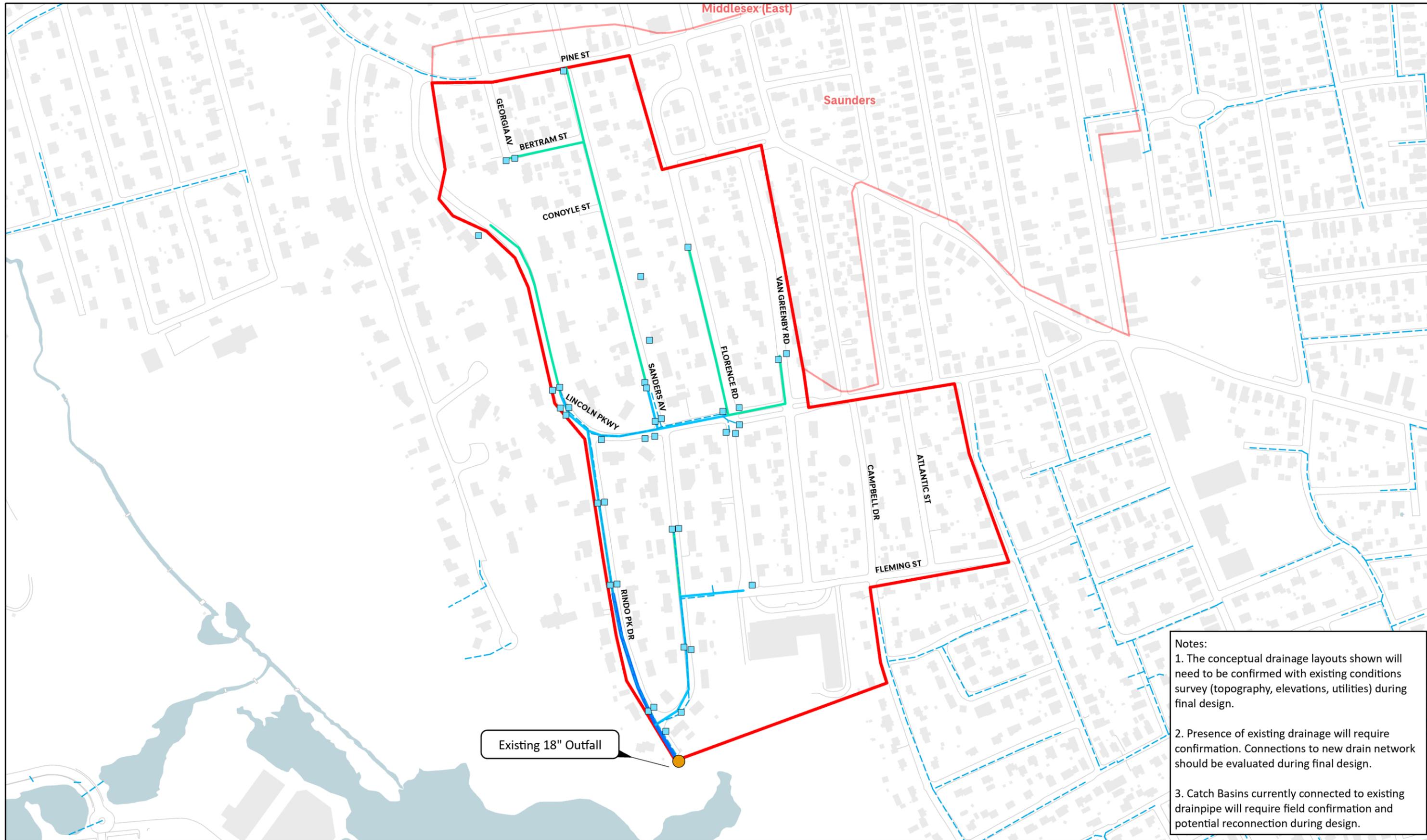
To separate the remaining 35.5 acres (55 percent) of the Sanders Area, there are two options. The first option would be to connect to the existing drainage and outfall, installing larger drainpipes than currently exist. With the additional upstream flow, the existing 18-inch outfall would be insufficiently sized, requiring much of the existing drainage to be removed and upsized. The second option would be to treat the conceptual drainage as its own system, using a new outfall and installing parallel drains on the streets within the Sanders Area that are already separated. The second option would allow for smaller drainpipe and would avoid upsizing existing drainage. It would require the permitting and installation of a new outfall location. The proposed outfall would discharge adjacent to the existing outfall to a wetland area that contributes to Black Brook. Section 6.4 presents costs assuming the drainpipe layout shown in Figure 6.11 based on the first option. These two options should be explored further during later stages of design to find the most cost-effective method of separating the Sanders Area.

6.3.1.12 Saunders

The Saunders Area comprises 100 acres, with approximately 15,000 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.12**.

The outfall would discharge into the Pawtucket Canal, which is owned and managed by Boott Hydropower. This requires an easement to cross DCR land, which means undertaking an Article 97 land use conversion which requires state legislative approval and a DCR Access Permit. Coordination with the Massachusetts Historical Commission also would be required. Although an existing 24-inch outfall is present at the same location, it likely does not provide sufficient capacity for the entirety of the Saunders Area.

This area faces tight construction conditions on Saunders Street because of the presence of an auto shop. Additionally, two sewer crossings, the Marginal Interceptor and a 14-inch by 16-inch local sewer, limit the depth of the outfall and drain conduits, necessitating either shallow or very deep installation. Shortly upstream at the Branch Street/Queen Street intersection, a trunk sewer crossing and utility vaults present more challenges. The proposed drain can either pass deep under the sewer, resulting in pipe depth of 20 feet, or shallow over the sewer. A deep sewer crossing requires more expensive construction, while a shallow sewer crossing would cause conflicts with sewer lateral connections on Queen Street. A shallow crossing would require about 300 linear feet of sewer main to be reinstalled at a greater depth, and it would result in limited cover. Multiple intersections with large water, gas, and sewer mains add to the complexity of the proposed pipe plan upstream. The Saunders Area is relatively



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

Conceptual Drain System Pipe Diameter (In)

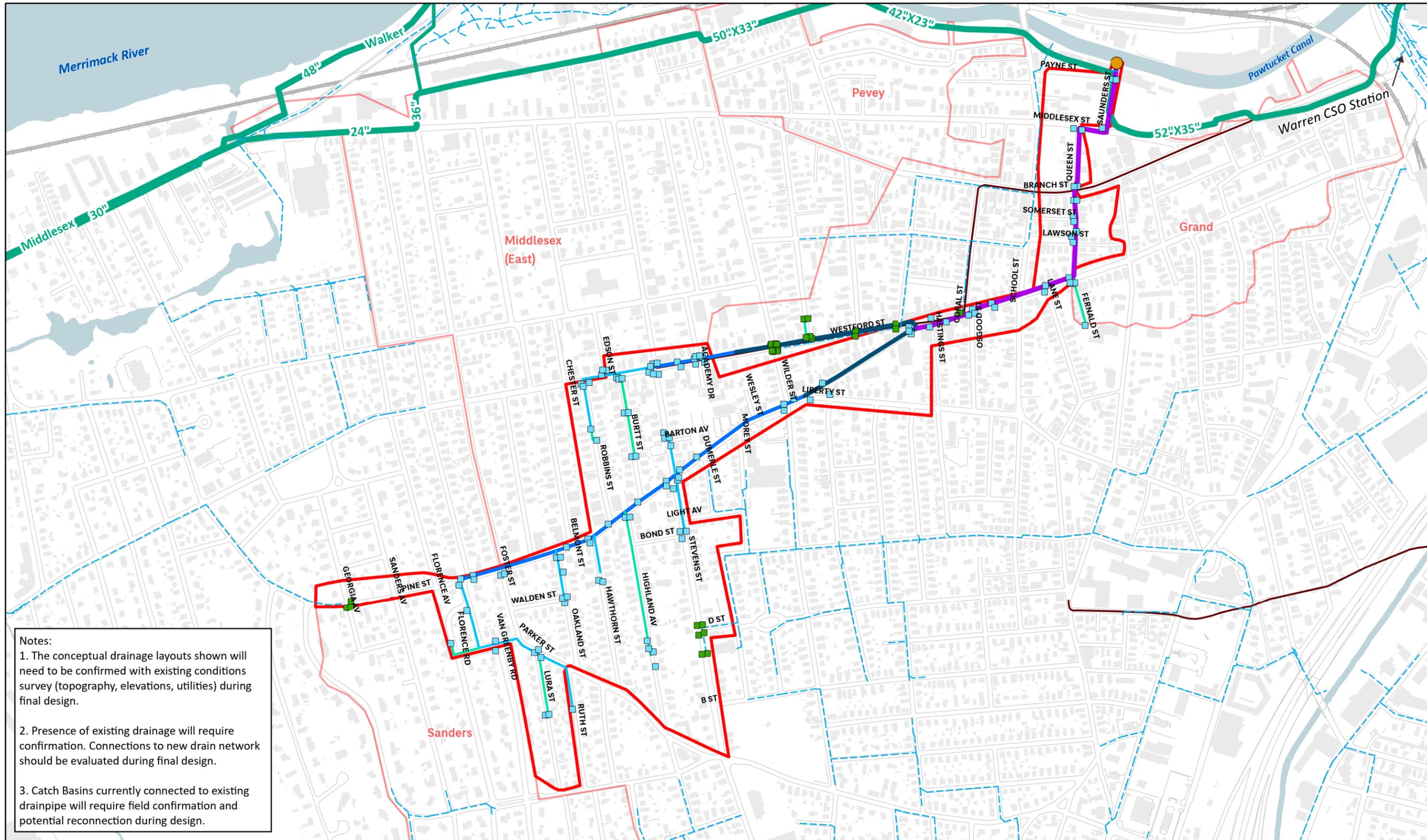
- 12 - 15
- 18 - 36
- 42 - 48
- 54 - 60
- Box Culvert (Size Varies)

- Catch Basin Separation to Proposed Drain
- Catch Basin Connected to Existing Drain (See Note 3)
- Outfall Location (Conceptual)
- Existing Drain

- Trunk Sewer
- Interceptor
- Diversion Station and CSO Outfall

- Sanders Area
- Other Phase 3 Candidate Area





Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.

Legend

<p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) 	<ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) - - - Existing Drain 	<ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall 	<ul style="list-style-type: none"> Saunders Area Other Phase 3 Candidate Area
--	--	--	--

0 770 1,540

Feet

Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 6.12
Conceptual Drainage Layout
Phase 3 Candidate Area: Saunders

flat with minimal slope upstream of the outfall, requiring large pipe sizes and a more challenging profile overall.

6.3.1.13 Sherman

The Sherman Area comprises 40 acres, with approximately 5,600 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.13**.

The presence of existing drainage piping impacts any planned separation in this area. There is 1,830 linear feet of existing drainage within the Sherman Area with additional drainage south of the area. This drainage combines prior to discharging via a 30-inch outfall to the Concord River via Rogers Street, and separates 13 acres, or 33 percent of the Candidate Area.

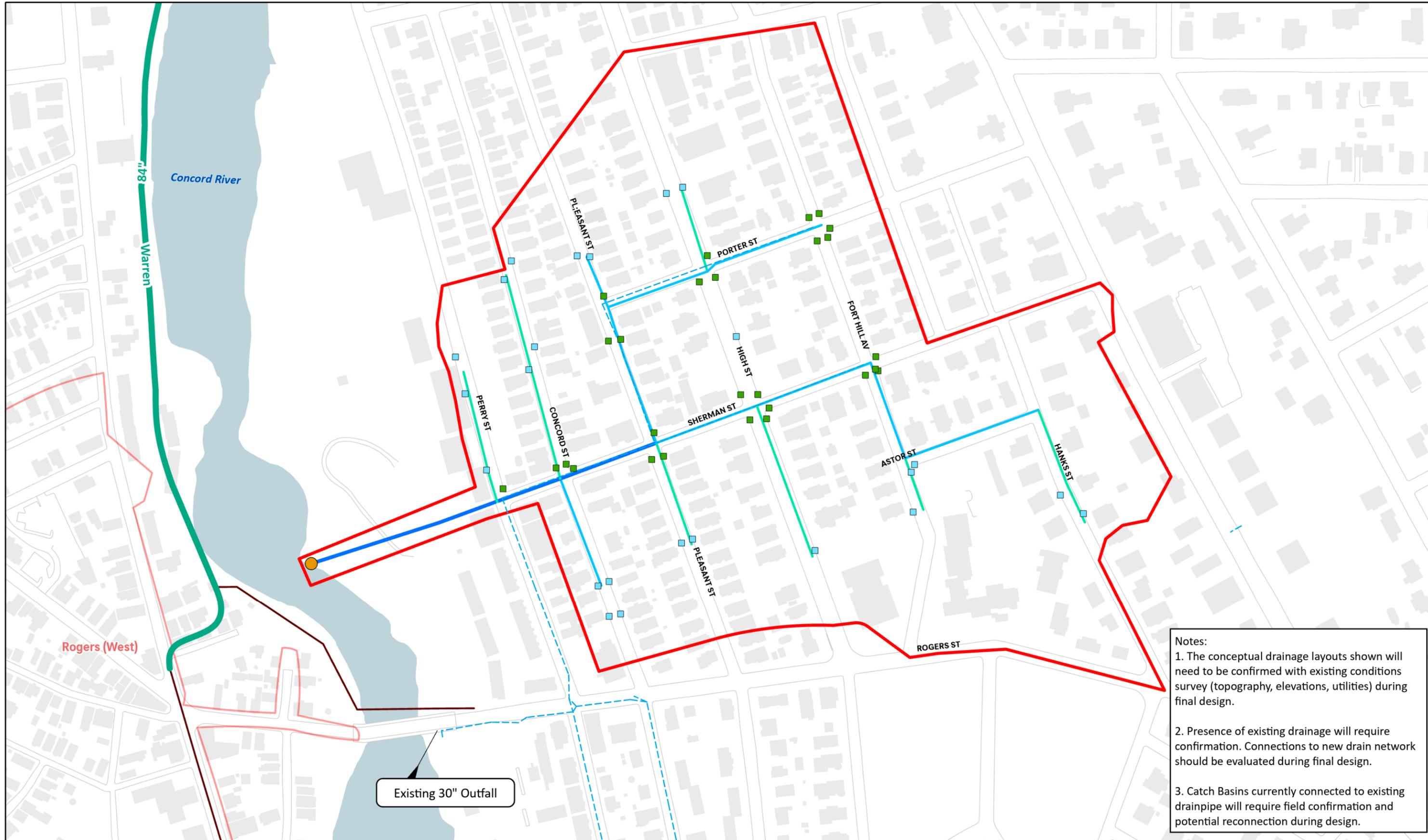
The current conceptual outfall layout crosses two privately owned parcels containing apartment complexes, New England Power Company property Mass Electric Company land, and a small strip of City-owned land before discharging to the Concord River. These Utility-owned parcels are on MassDEP's MCP RTN list because of the historic fill associated with the railroad, and they remain in Post-Temporary Solution Status. This alignment poses challenges because of the easements and permissions from the large utility companies that own these parcels, in addition to the contamination considerations. Alternative outfall options should be considered during further stages of design. One option is to discharge directly to the Concord River at the bridge on Rogers Street, using the City-owned strip of land. This option would likely require the cooperation and coordination of Mass Electric Company and/or New England Power Company, but this option impacts their lands less directly.

Section 6.4 and Figure 6.13 present the costs and conceptual layout developed to separate the Sherman Area. Drainpipes were sized to separate the entire Sherman Area, not considering the presence of existing drainage.

6.3.2 Tilden Combined Sewer Basin

The two Tilden Areas are known as Tilden 1 and Tilden 2. Tilden 1, which comprises 79 acres, is the northern of the two areas. Tilden 2, the southern and smaller of the areas, comprises 69 acres. For ease of separation and shortest route to receiving water, Tilden 1 and Tilden 2 have been further subdivided into five total Candidate Areas with five separate outfalls (**Figure 6.14** and **Figure 6.15**). Following are the subareas named for their relative outfall location.

- Tilden 1:
 - Cabot Street
 - Fanning Street
 - Pawtucket Street
- Tilden 2:
 - Broadway Street
 - Cross Street



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.

Legend

<p>Conceptual Drain System Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) 	<ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) - - - Existing Drain 	<ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall 	<ul style="list-style-type: none"> Sherman Area Other Phase 3 Candidate Area
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Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

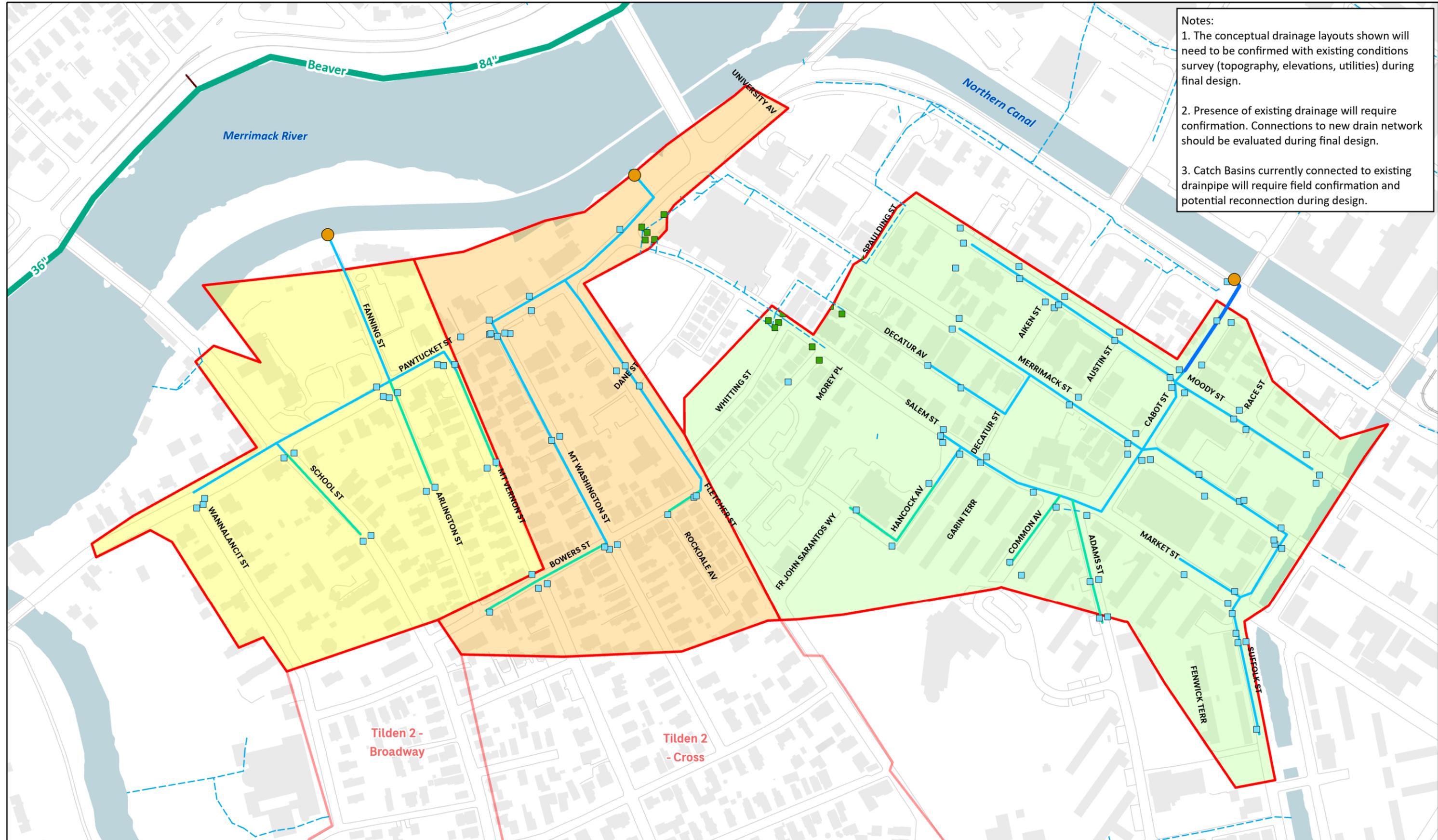
Figure 6.13
Conceptual Drainage Layout
Phase 3 Candidate Area: Sherman

Existing 30" Outfall

0 280 560
Feet

Notes:

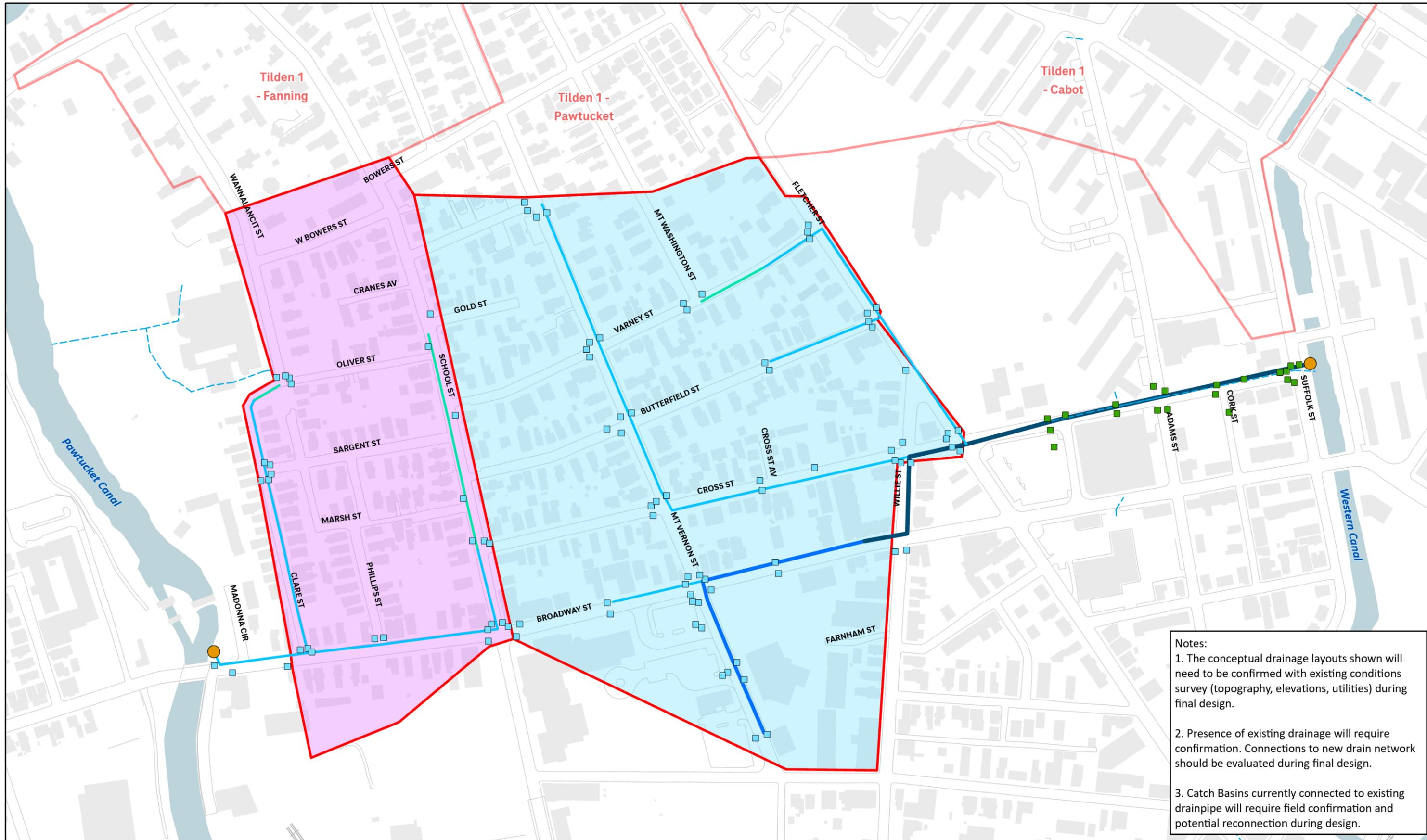
1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

- | | | | |
|---|--|--|--|
| <p>Conceptual Drain System
Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) | <ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) - - - Existing Drain | <ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall | <p>Tilden 1 Sub-Areas</p> <ul style="list-style-type: none"> ■ Cabot St ■ Fanning St ■ Pawtucket St ■ Other Phase 3 Candidate Area |
|---|--|--|--|





Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

- | | | | |
|---|--|--|--|
| <p>Conceptual Drain System
Pipe Diameter (In)</p> <ul style="list-style-type: none"> — 12 - 15 — 18 - 36 — 42 - 48 — 54 - 60 — Box Culvert (Size Varies) | <ul style="list-style-type: none"> ■ Catch Basin Separation to Proposed Drain ■ Catch Basin Connected to Existing Drain (See Note 3) ● Outfall Location (Conceptual) --- Existing Drain | <ul style="list-style-type: none"> — Trunk Sewer — Interceptor ■ Diversion Station and CSO Outfall | <p>Tilden 2 Sub-Areas</p> <ul style="list-style-type: none"> ■ Broadway St ■ Cross St ■ Other Phase 3 Candidate Area |
|---|--|--|--|



6.3.2.1 Cabot Street (Tilden 1)

The Cabot Street (Tilden 1) Area is a subset of Tilden 1 and comprises 41 acres, with approximately 4,700 linear feet of drainpipe conceptually proposed to achieve separation, as shown in Figure 6.14.

The receiving water for this area is the Northern Canal, at the intersection of Cabot Street and Father Morissette Boulevard. The Northern Canal is owned and managed by Boott Hydropower, necessitating coordination during design and construction. Coordination with the Massachusetts Historical Commission also would be required. To reach the Northern Canal, the drainpipe crosses the Cabot Street and Father Morissette Boulevard intersection as well as a short strip of City-owned land. The outfall intersection on Cabot Street is extremely dense with utilities presenting challenges relative to multiple large-diameter water and gas mains, as well as telephone and electrical vaults. Continuing southwest on Cabot Street, the intersections with Moody Street and Merrimack Street present challenges because of the multiple utility vaults and large-diameter utility crossings. The presence of these multiple utility crossings requires shallow drainpipe elevations, resulting in limited depths available for adjustment in upstream reaches of the Cabot Street Area, causing long stretches of large, relatively flat pipe with minimum cover. In addition, sewer depth on Salem Street creates multiple instances where drainpipe must be placed at shallow elevations, resulting in minimum cover. This situation requires the need to lower the existing sewer mains or create drop SMH connections.

6.3.2.2 Fanning Street (Tilden 1)

The Fanning Street (Tilden 1) Area is a subset of Tilden 1 and comprises 15 acres, with approximately 1,700 linear feet of drainpipe conceptually proposed to achieve separation, as shown in Figure 6.14.

The outfall for this area extends along Fanning Street, a road privately owned by the elderly and disabled housing complex on the property. Discharging to the Northern Canal, which is owned and managed by Boott Hydropower, would require a DCR Access Permit as well as an Article 97 land use conversion for use of DCR land, requiring state legislative approval. Coordination with the Massachusetts Historical Commission also would be required. To reach the Canal, the outfall pipe must pass through multiple privately owned parcels as well as DCR property along the bank of the Canal. Aside from the private outfall location, the utility-dense Pawtucket Street presents multiple, large-diameter utility crossings to consider. The intersections between Pawtucket Street and School Street, Mt. Vernon Street, and Arlington Street all require such considerations. However, because of the small pipe diameters necessary to separate this area, these utilities present less of a challenge than other Candidate Areas. Finally, in the westernmost reaches of the Fanning Street Area on Pawtucket Street, the surface elevation decreases, sloping opposite of the conceptual drainpipe. This results in a deep, flat drainpipe with little room for elevational changes, resulting in minimal cover at the intersection with Wannalancit Street. It also would require a short section of sewer on Pawtucket Street to be lowered or a parallel sewer to be extended to connect sewer laterals. During later stages of design, the extent of the Fanning Street Area should be determined, regarding design of this deep pipe and the fact that parts of this area contribute to the Walker CSO Station, as seen in Figure 6.14.

6.3.2.3 Pawtucket Street (Tilden 1)

The Pawtucket Street (Tilden 1) Area is a subset of Tilden 1 and comprises 17 acres, with approximately 2,500 linear feet of drainpipe conceptually proposed to achieve separation, as shown in Figure 6.14.

The outfall extends along Pawtucket Street and discharges to the Northern Canal, which is owned and managed by Boott Hydropower. Before reaching the receiving water, the outfall alignment crosses two parcels, which are owned by the UMass Building Authority and DCR, respectively. This outfall location would require DCR Access Permits as well as an Article 97 land use conversion for use of DCR land, requiring state legislative approval. Coordination with the Massachusetts Historical Commission also would be required. As discussed in relation to Fanning Street, Pawtucket Street is very utility dense. There are large-diameter water and gas mains within Pawtucket Street, in addition to multiple telephone vaults and a 33-inch by 22-inch brick sewer that the conceptual drainpipe must cross to separate Fletcher Street and Mt. Washington Street. The sewer crossing poses the greatest design challenge. Crossing over the sewer is preferable to reduce the amount of excavation necessary compared to crossing below the sewer. However, a low point on Fletcher Street, just north of Dane Street, would result in cover less than 2 feet and flooding at the low point. Therefore, a minimum slope drain from the outfall to the Fletcher Street intersection is recommended. At that intersection, a crossing below the Pawtucket Street sewer would extend south on Fletcher Street, and a higher elevation drain would continue east to the crossing with Mt. Washington Street, where it would cross over the sewer.

In 2016, 3,200 linear feet of drain was installed as a part of the Decatur separation project, located north and east of the Pawtucket Street Area. During later design stages, a connection to or extension of this existing drainage should be considered as a method to reduce flows and outfall sizes.

There is an abandoned 12-inch by 14-inch sewer located on Pawtucket Street that extends onto City-owned property adjacent to 277 Pawtucket Street. The location of this abandoned sewer conflicts with the conceptual layout and would need to be removed during construction. During the design stage, this sewer should be confirmed as abandoned.

6.3.2.4 Broadway Street (Tilden 2)

The Broadway Street (Tilden 2) Area is a subset of Tilden 2 and comprises 19 acres, with approximately 2,100 linear feet of drainpipe conceptually proposed to achieve separation, as shown in Figure 6.15.

The outfall discharge location is to the Pawtucket Canal, which is owned and managed by Boott Hydropower, via Broadway Street, just downstream of the Old Guard Locks and Gates Facility. To reach the Pawtucket Canal, the conceptual outfall must pass through land owned by DCR, requiring a DCR Access Permit as well as an Article 97 land use conversion for use of DCR land, requiring state legislative approval. Coordination with the Massachusetts Historical Commission also would be required.

The intersection of Broadway Street and School Street is quite utility dense, but most conflicts may be avoided. There is a large-diameter gas main in potential conflict with the conceptual alignment, both vertically and horizontally. This would need further evaluation during future design. A slight offset, relocation, or reinstallation of the gas main above the conceptual drain may be necessary. Slightly further upstream, a drop SMH would be installed to avoid a conflict with the sewer connection from Marsh Street. Also, approximately 200 linear feet of sewer on Clare Street may need to be reinstalled at a lower elevation to avoid the conceptual drain from conflicting with existing sewer laterals. Of all the Candidate Areas, the Broadway Street Area is the only one with shallow bedrock. This makes shallow pipe design especially cost effective, because it would minimize bedrock removal during construction.

6.3.2.5 Cross Street (Tilden 2)

The Cross Street (Tilden 2) Area is a subset of Tilden 2 and comprises 44 acres, with approximately 5,400 linear feet of drainpipe conceptually proposed to achieve separation, as shown in Figure 6.15.

The conceptual outfall is to the Western Canal at the end of Cross Street, passing through a strip of land that may have multi-ownership, including DCR, before discharging to the receiving water. This means, like many of the other Tilden Area outfalls, that a DCR Access Permit and an Article 97 land use conversion is needed, which requires state legislative approval. Furthermore, the Western Canal, is owned and operated by Boott Hydropower, requiring coordination during design and construction. Coordination with the Massachusetts Historical Commission also will be required. An existing 18-inch outfall currently discharges to the Western Canal at this location that conveys flow from approximately 700 feet of existing drainage on Cross Street. Conceptually, the current plan is to remove this existing infrastructure, and upsize the outfall as well as the existing drainage on Cross Street. The increase in drain diameter is required because of the increase in total flow from the expanded drainage area that the drain would be conveying, expanding from approximately 700 linear feet with the current drain network to 44 acres for the entire Cross Street Area.

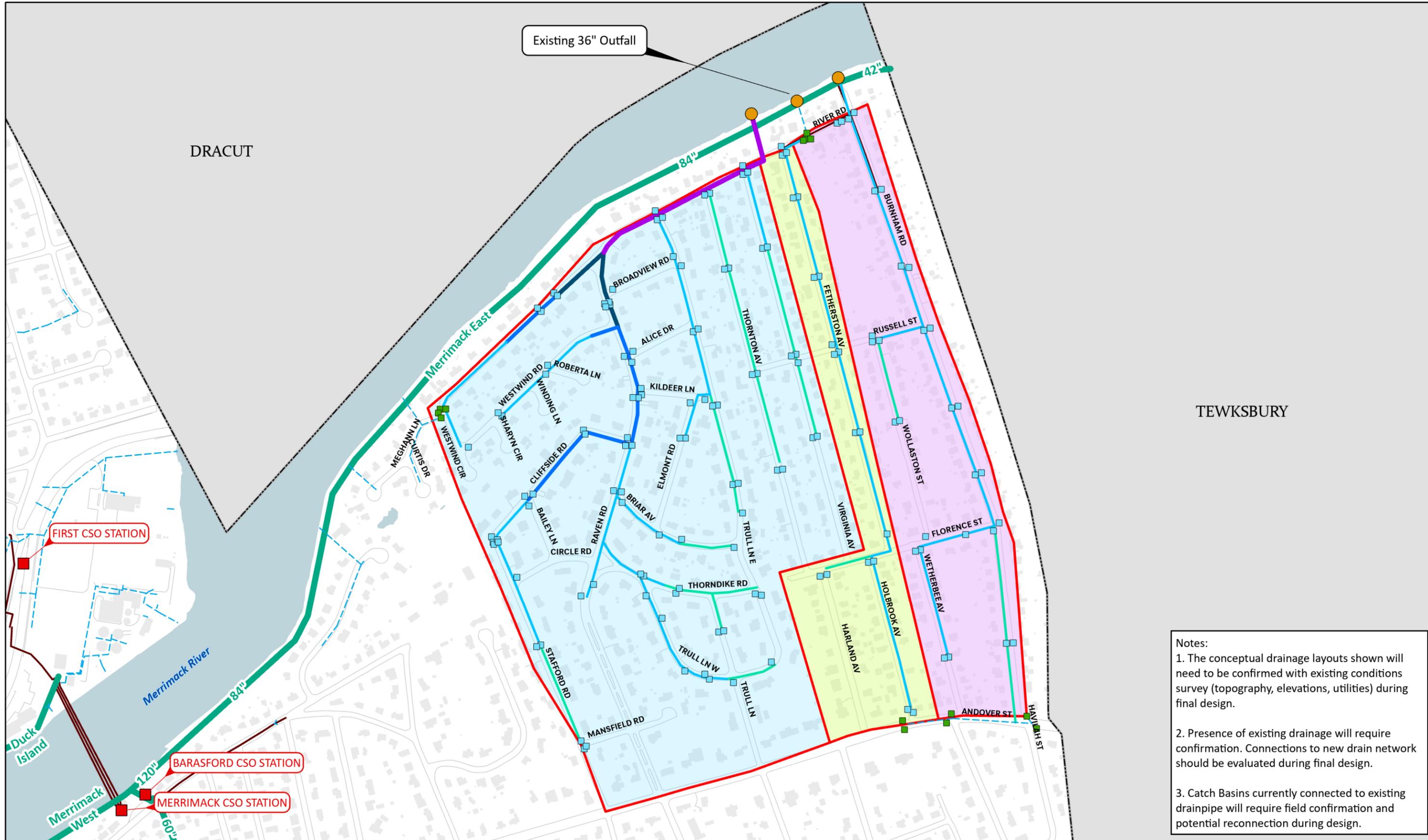
The increased diameter of the new conceptual drainage creates utility conflict challenges that the existing drainage avoided because of its size. There are four sewer crossings on Cross Street—two directly upstream of the outfall on Suffolk Street, one at the Adams Street intersection, and one at the Fletcher Street intersection—that set the boundaries of the drainpipe elevations. The first two sewer crossings require the drainpipe pass above them. Going under these sewers would push the outfall into the bottom of the Western Canal. With drainpipe running a minimum slope upstream to the Adams Street sewer crossing, the drainpipe has barely enough room to cross and maintain cover. However, this results in a conflict with a large-diameter water main that would need to be addressed in later stages of design. Further upstream, the drainpipe must cross under the sewer on Fletcher Street, with only approximately 0.5 feet of separation assuming minimum drainpipe slope. Passing over this sewer is not an option, because the tributary drains from Willie Street, Broadway Street, and southern Mt. Vernon Street would not be provided suitable cover, even with minimum slope. While the rest of the Cross Street Area presents a straightforward design, the utility considerations on Cross Street make this design difficult, with multiple large sewer crossings that require minimal separation.

6.3.3 Merrimack Combined Sewer Basin

6.3.3.1 Burnham

The Burnham Area comprises 152 acres, with approximately 25,000 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.16**.

Burnham is a large residential area with steep contours resulting from high elevations in the south. This results in flow conveying quickly to River Road on the north side of the area. The conceptual project outfall is located on a parcel on River Road, which is owned by the Utility, discharging to the Merrimack River. To outfall to the Merrimack River, the pipe must cross the 84-inch Merrimack East Interceptor. Given the size, depth, and support necessary to construct an outfall under the existing interceptor, installation of the new outfall over the interceptor would be the preferred option. However, this creates challenges regarding cover on the western side of River Road and cover and flooding on the upstream,



Existing 36" Outfall

DRACUT

TEWKSBURY

FIRST CSO STATION

BARASFORD CSO STATION

MERRIMACK CSO STATION

Notes:

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2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



Legend

Conceptual Drain System
Pipe Diameter (In)
 12 - 15
 18 - 36
 42 - 48
 54 - 60
 Box Culvert (Size Varies)

Catch Basin Separation to Proposed Drain
 Catch Basin Connected to Existing Drain (See Note 3)
 Outfall Location (Conceptual)
 Existing Drain

Trunk Sewer
 Interceptor
 Diversion Station and CSO
 Outfall

Burnham Sub-Areas

- West
- Central
- East
- Other Phase 3 Candidate Area



low-lying Westwind Road. Because of the size necessary for a single outfall to separate the entire Burnham Area, and the need to cross the Merrimack East Interceptor to reach the Merrimack River, a single outfall location is considered infeasible. To address these concerns and reduce outfall size, a multiple outfall approach was modeled and is being considered. The Burnham Area was split into three smaller subareas—Burnham East, Burnham Central, and Burnham West—with three separate outfalls to the Merrimack River. Burnham East’s conceptual outfall uses the City-owned right-of-way at the end of Burnham Road, which may be used to outfall flow from Burnham Road and its tributary streets. Burnham Central’s conceptual outfall solution is to use an existing 36-inch drain outfall, which conveys flow from just four CBs, between 220 and 230 River Road. It may be able to handle additional flow conveyed north from Fetherston Avenue. Finally, the largest conceptual outfall, conveying Burnham West, could discharge to the Merrimack River using the parcel on River Road, which is owned by the Utility. While the challenges regarding crossing the Merrimack East Interceptor with minimum cover are still valid, multiple outfalls with a reduced outfall size make this approach more feasible.

While this multiple outfall approach provides some relief regarding cover, because of the shallow pipe and low-lying elevations on River Road west of Raven Road and Westwind Road, an additional outfall via private property easement is likely necessary to separate this portion of the Burnham West Area. There is an existing 12-inch drain outfall on Meghann Lane, just west of the Burnham West Area boundary, that could convey flow from these low-lying areas. If connecting to this existing drain is not possible, separation of Westwind Road or the western side of River Road may not be feasible without further easement obtainment. Additional investigation should be completed during further design stages to identify alternate outfall locations and potential solutions to separation in the Burnham West Area.

Other than outfall considerations, the project also would likely require a handful of new sewer manholes, drop connections, and short stretches of new sewer to be installed along River Road to prevent the proposed drainpipes from conflicting with side street sewer connections.

6.3.4 Barasford Combined Sewer Basin

6.3.4.1 Wentworth-Douglas

The Wentworth-Douglas Area comprises 134 acres and was previously assessed relative to past surface flooding issues. The result has been the design of the Douglas Road Wet-Weather Storage Tank (discussed in Section 7) which is moving into the construction phase in 2025. The presence of this tank will negate the need for sewer separation in this area.

Sewer separation was not favored as there is not a viable outfall location adjacent to the Wentworth-Douglas Area. An outfall would require dredging of the Phoenix Avenue wetlands, and the outfall would likely remain entirely submerged. A prior study about alternatives to this outfall location indicated construction of more than 6,000 linear feet of large-diameter drain to the Lowell and Tewksbury municipal boundary where flow would then be conveyed into Trull Brook. Trull Brook conveys water through many properties in the Town of Tewksbury, eventually discharging to the Merrimack River. The elevations required to discharge this long portion of drain would be a challenge to achieve minimum cover along the entire alignment.

6.3.5 West Combined Sewer Basin

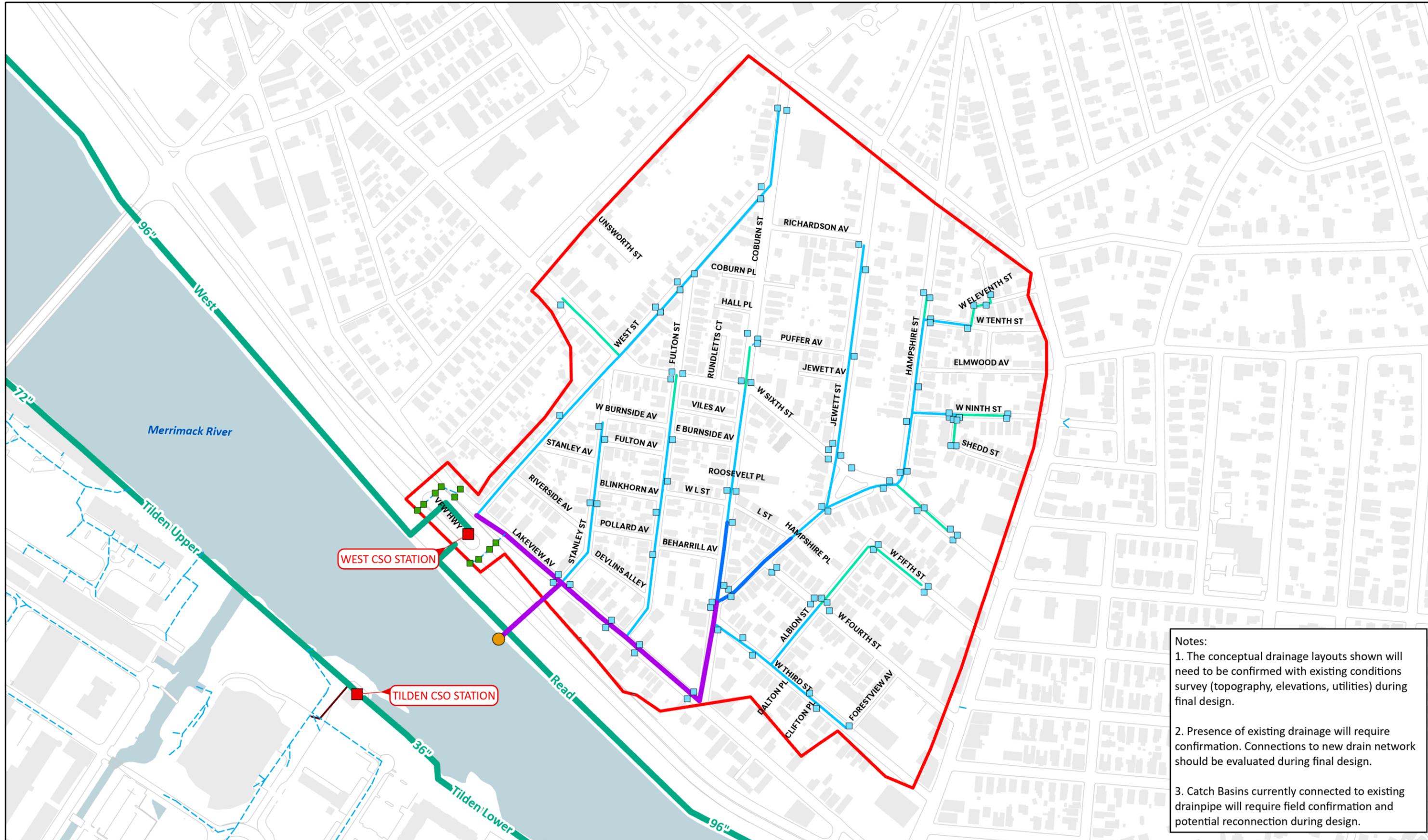
6.3.5.1 West/Coburn/Jewett

The West/Coburn/Jewett Area comprises 77 acres, with approximately 12,000 linear feet of drainpipe conceptually proposed to achieve separation, as shown in **Figure 6.17**.

The conceptual outfall location for the West/Coburn/Jewett Area is across from Stanley Street, to the Merrimack River. To reach the River, the conceptual alignment must cross several private properties, including a parcel containing a church, through the U.S. Army Corps of Engineers (USACE) levee system located under the VFW (MassDOT owned), a City-owned parcel that contains the 96-inch North Bank Interceptor, and DCR-owned land along the riverbank. Obtaining easements requires timely coordination with the individual private property owners and regulatory agencies (USACE and DCR). Siting the outfall requires an Article 97 land use conversion for use of DCR land, which requires state legislative approval.

Further complicating separation of the West/Coburn/Jewett Area is that the most downstream portions of the Area are below the elevation of the 100-year flood stage for the Merrimack River. This low-lying area is currently protected by the levee and the West Street CSO Diversion Station, with ability to pump the area no matter the river stage threat. If this area were to be separated and an outfall were to run to the Merrimack River, it would pierce the levee. This could compromise the protection provided by the levee during high flood stages, even with a backflow prevention device. The reason is that the entire drain system would surcharge and flood structures because it cannot overcome the 100-year flood stage elevation. Separating West/Coburn/Jewett with a new drain outfall driven by gravity would leave this area more vulnerable to flooding.

In addition, more stringent requirements and approvals would be required for the separation of low areas such as Lakeview Avenue, Coburn Street, and Jewett Street. A Letter of Map Revision is required for submission to FEMA for any modification to the drainage system, including combined systems such as this one, serving a low-lying area where an average of 1 foot or greater depth could accumulate during high river flood stages. Additionally, an interior drainage analysis study would be required to document capacity conditions, including coincidental analysis, use of diversion structures, or use of stormwater pumping. This study would need to be submitted to FEMA for review and approval. In general, this review and approval process would have a long lead time that would result in a more expensive project than already projected.



Notes:

1. The conceptual drainage layouts shown will need to be confirmed with existing conditions survey (topography, elevations, utilities) during final design.
2. Presence of existing drainage will require confirmation. Connections to new drain network should be evaluated during final design.
3. Catch Basins currently connected to existing drainpipe will require field confirmation and potential reconnection during design.



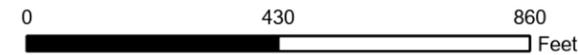
Legend

Conceptual Drain System
Pipe Diameter (In)
 12 - 15
 18 - 36
 42 - 48
 54 - 60
 Box Culvert (Size Varies)

Catch Basin Separation to Proposed Drain
 Catch Basin Connected to Existing Drain (See Note 3)
 Outfall Location (Conceptual)
 Existing Drain

Trunk Sewer
 Interceptor
 Diversion Station and CSO Outfall

West/Coburn/Jewett Area
 Other Phase 3 Candidate Area



Lowell, Massachusetts
 Phase 3 Candidate Area
 Sewer Separation PDR

Figure 6.17
Conceptual Drainage Layout
Phase 3 Candidate Area: West/Coburn/Jewett

6.4 Project Cost Estimates

Project cost estimates presented in **Table 6.1** have been developed for implementation of sewer separation projects in each of the Phase 3 Candidate Areas, except for Wentworth-Douglas. Wentworth-Douglas does not have a proposed separation project, and it will be addressed by construction of a stormwater storage tank as discussed in Section 7.

The project cost estimates presented in Table 6.1 are used in Section 7 for a comparative assessment of CSO removal benefits for each Candidate Area. The costs are based on the conceptual drainpipe layouts for each of the Phase 3 Candidate Areas and the associated conceptual plans and profiles developed for cost estimating purposes. As indicated in Section 4, pipe optimization was not performed for Gorham (North RMB). Instead pipe sizing from previous studies was used to develop the Gorham (North RMB) cost estimate.

Assumed project components included in the drainpipe project cost estimates are as follows:

- New drainpipes (diameter, length), structures (inlets, outfalls, manholes), and associated installation costs (excavation and backfill).
- Surface restoration including temporary trench paving, milling, asphalt paving, limited curbing, and final full width paving.
- Limited rock removal with costs assumed covered by project contingency.
- Allowances for contractor mobilization/demobilization, maintenance of traffic, and general utility relocation/offsets.
- Allowance for contractor general conditions, indirect costs, contractor's overhead and profit, and construction contingency.
- Allowances for engineering (20 percent) and project contingency (35 percent), with percentages selected based on the conceptual design level.
- These construction costs do not include sewer rehabilitation, manhole rehabilitation, or sewer laterals, which are incorporated into the Opinion of Probable Project Costs presented in Section 8 for the priority projects recommended.

Table 6.1 does not include inflation costs, because the cost estimates are meant for a comparison of current-day costs to assess CSO removal benefit. The cost estimates also do not include such items as finance or funding costs, legal fees, land acquisitions, temporary/permanent easements, Article 97 and permit fees, public outreach efforts, or any other costs associated with the project that are not anticipated to be part of the bidding contractor's work.

Table 6.1 Summary of Drainpipe Project Cost Estimates for Phase 3 Candidate Areas

Phase 3 Candidate Area	Project Cost Estimate (\$ Millions)
Bolt Street	\$9.0
Burnham	\$41.8
Crosby Street	\$7.6
Grand	\$15.7
Gorham (North RMB)	\$5.0
Middlesex (East)	\$43.1
Moore	\$4.8
Newhall (North)	\$1.1
Newhall (South)	\$7.3
Pevey	\$9.2
Rogers (West)	\$7.5
Sanders	\$10.2
Saunders	\$51.2
Sherman	\$10.6
Tilden 1	
▪ <i>Cabot Street</i>	\$13.1
▪ <i>Fanning Street</i>	\$3.8
▪ <i>Pawtucket Street</i>	\$6.3
Tilden 2	
▪ <i>Broadway Street</i>	\$4.8
▪ <i>Cross Street</i>	\$15.2
Wentworth-Douglas ⁽¹⁾	-
West/Coburn/Jewett	\$25.4

Notes:

- 1 No separation cost; Wentworth-Douglas is being addressed by installation of stormwater tank.
- 2 Costs in 2024 dollars.



7.0 Candidate Sewer Separation Projects Phase 3 Project Prioritization

7.1 Introduction

The CD requires the Utility to assess sewer separation in the Warren, Tilden, Merrimack and Barasford CSO Basins to control CSOs, and address SSOs, namely the Wentworth-Douglas and Pevey Street SSO areas. Accordingly, the purpose of Section 7 is to evaluate potential sewer separation projects in the Candidate Areas presented in this report and prioritize those which provide the Utility with the best SSO and CSO benefit.

7.2 Sanitary Sewer Overflow Mitigation

Paragraph 11.c.iii of the CD requires that an assessment be completed of “the range of operational measures and capital improvements which are feasible to mitigate the risk and impacts of surcharge/overflow events” at the Wentworth-Douglas and Pevey Street locations.

7.2.1 Wentworth-Douglas Area

The Wentworth-Douglas Area included in the CD is located in the upstream portion of the Barasford CSO Basin as shown in **Figure 7.1**. This area has historically experienced sewer system surcharging along Douglas and Windward Roads.

Accordingly, the focus of this section is on the Douglas Road area near Cawley Stadium including Windward Road. This area has experienced several SSOs in recent history. The Utility has installed a sewer depth monitoring meter at Windward Road for the last four years to help assess the frequency of surcharge and serve as a reporting tool for SSO notifications.

Figure 7.1 shows the tributary sewer system and the locations of wet-weather SSOs, as well as the locations of SWMM-simulated manhole flooding under existing conditions during the 5-year synthetic design storm discussed in Section 4. This synthetic design storm is more conservative than the 5-year design storm established by MassDEP for I/I analysis. Modeled flooding is defined as any location that experiences more than 15 minutes of flooding and 10,000 gallons of ponded volume. This is the same definition used in the Centralville Sewer Separation Revised Preliminary Design Report (CDM Smith, July 2024).

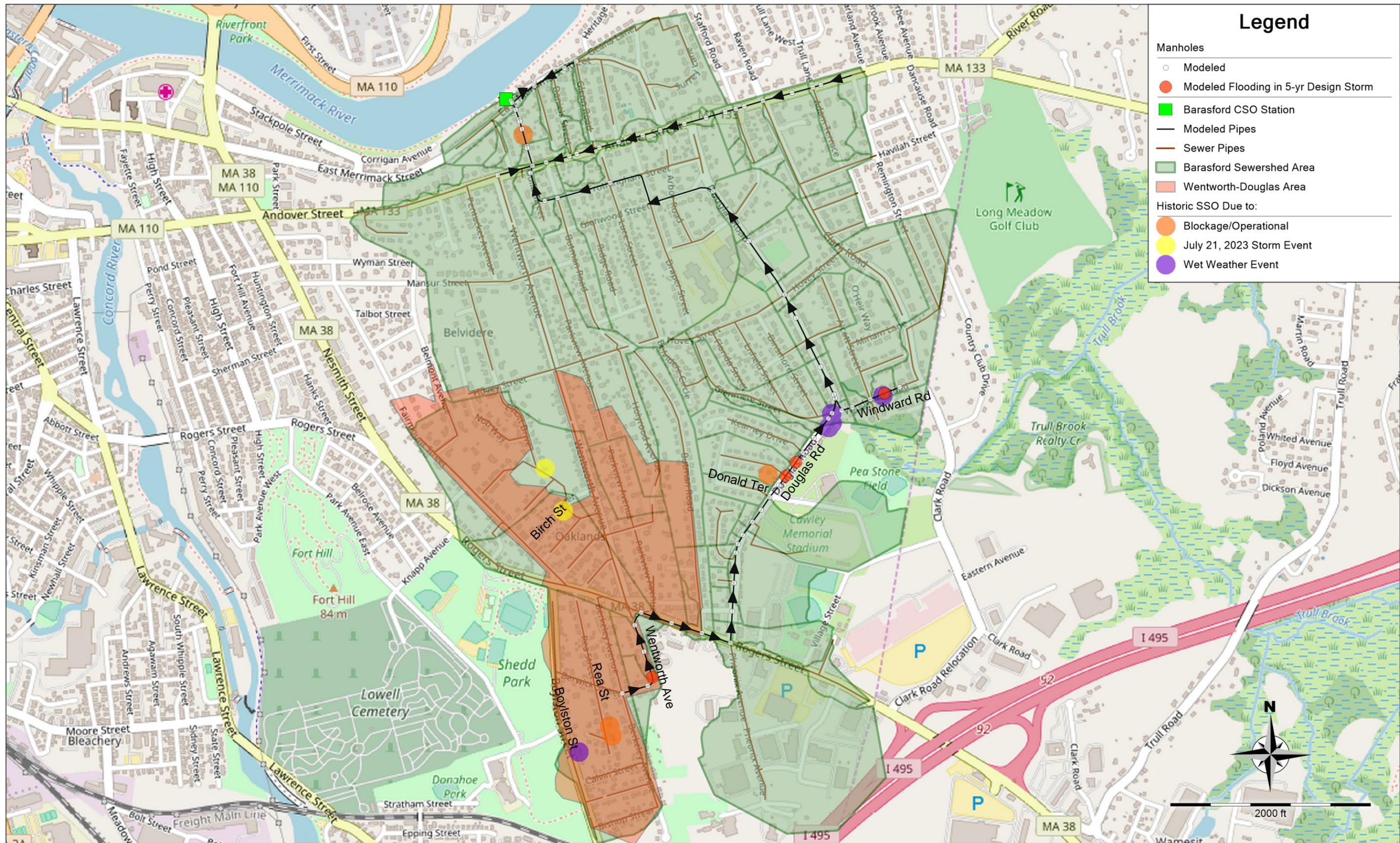


Table 2.24 summarizes the historical SSO events shown in Figure 7.1, which have occurred in this area since January 1, 2014, including the cause of the SSO, wet-weather event statistics where rainfall was the cause, the volume discharged, and properties or receiving waters affected. As summarized in Table 2.24, the majority of recent and recurring SSO events were caused by wet weather surcharging in the sewers along Douglas Road and Windward Road. A model profile of the sewer extending from the upstream end of Douglas Road to Windward Road is shown in **Figure 7.2** to illustrate the surcharge problem in the 5-year design storm under existing conditions. The model profile shows three more manholes flooding on Douglas Road and one more on Windward Road than in Figure 7.1. The simulated flood duration for each of these four manholes is less than 15 minutes, and so they are not highlighted as flooded nodes in Figure 7.1.

Table 2.24 includes discrete historical SSO events that have occurred in locations other than Douglas Road and Windward Road (Boylston Street, Birch Street, Rea Street, Elliott Drive, and Donald Terrace). These isolated events were associated with specific addressable sewer blockages and/or occurred during the July 21, 2023 event, which was characterized as a greater than 20-year, 1-hour storm, or during the separate August 8, 2023 event. The August 8, 2023 storm was a 5-month, 1-hour event based on rainfall observed at the Utility's Warren rainfall gage as presented in Table 2.24, however, this was a summer thunderstorm with variable rainfall across the City. The QPE radar rainfall data used for model calibration, which better represents spatial variability of rainfall that occurs in summer thunderstorms, suggests that this storm was a greater than 5-year event in the Barasford CSO Basin. The SSO that occurred at 174 Boylston Street on July 18, 2017 does not appear to be due to a blockage or operational issue or a particularly intense rainfall event based on available data. However, no other SSOs have been reported on Boylston Street since then, despite the numerous large storm events that have occurred between 2017 and 2024. Additionally, the model shows one manhole flooding for approximately 30 minutes on Wentworth Avenue upstream of Douglas Road in the 5-year design storm.

Based on the analysis of historical and modeled SSOs, the primary area of surcharging in the sewer shed is along Douglas Road and Windward Road downstream of the Wentworth-Douglas Area. There were two alternatives analyzed for addressing these SSOs: a storage tank and sewer separation. Model simulations were completed to analyze these alternatives to address the SSOs in addition to mitigating CSO. SSO model simulations were based on a 5-year storm event and CSO model simulations were based on average annual CSO reduction as outlined in Section 4 and described further in this section.

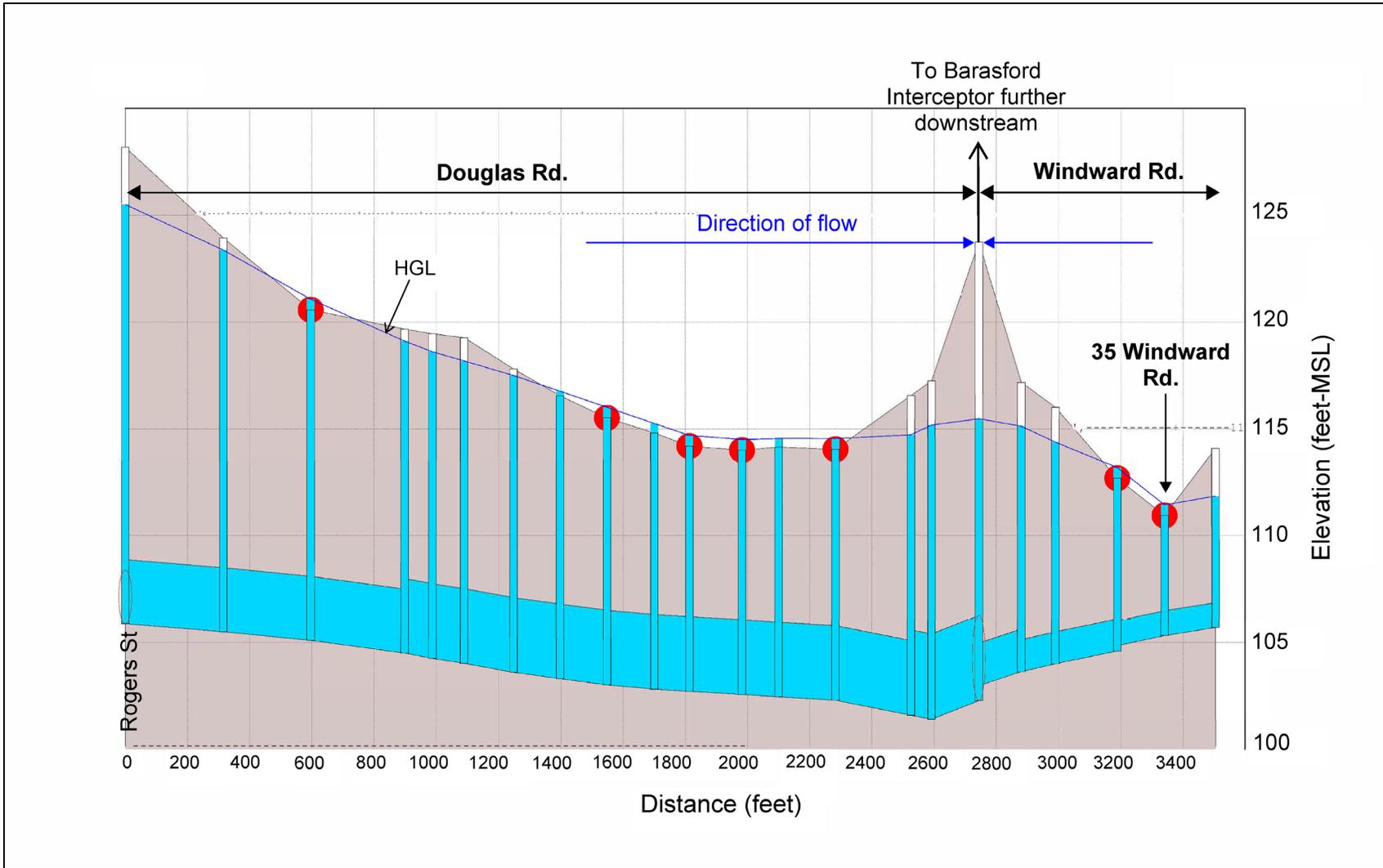


Figure 7.2 Model Profile of Douglas Road and Windward Road Sewers in the 5-Year Design Storm – Existing Conditions

7.2.1.1 Storage

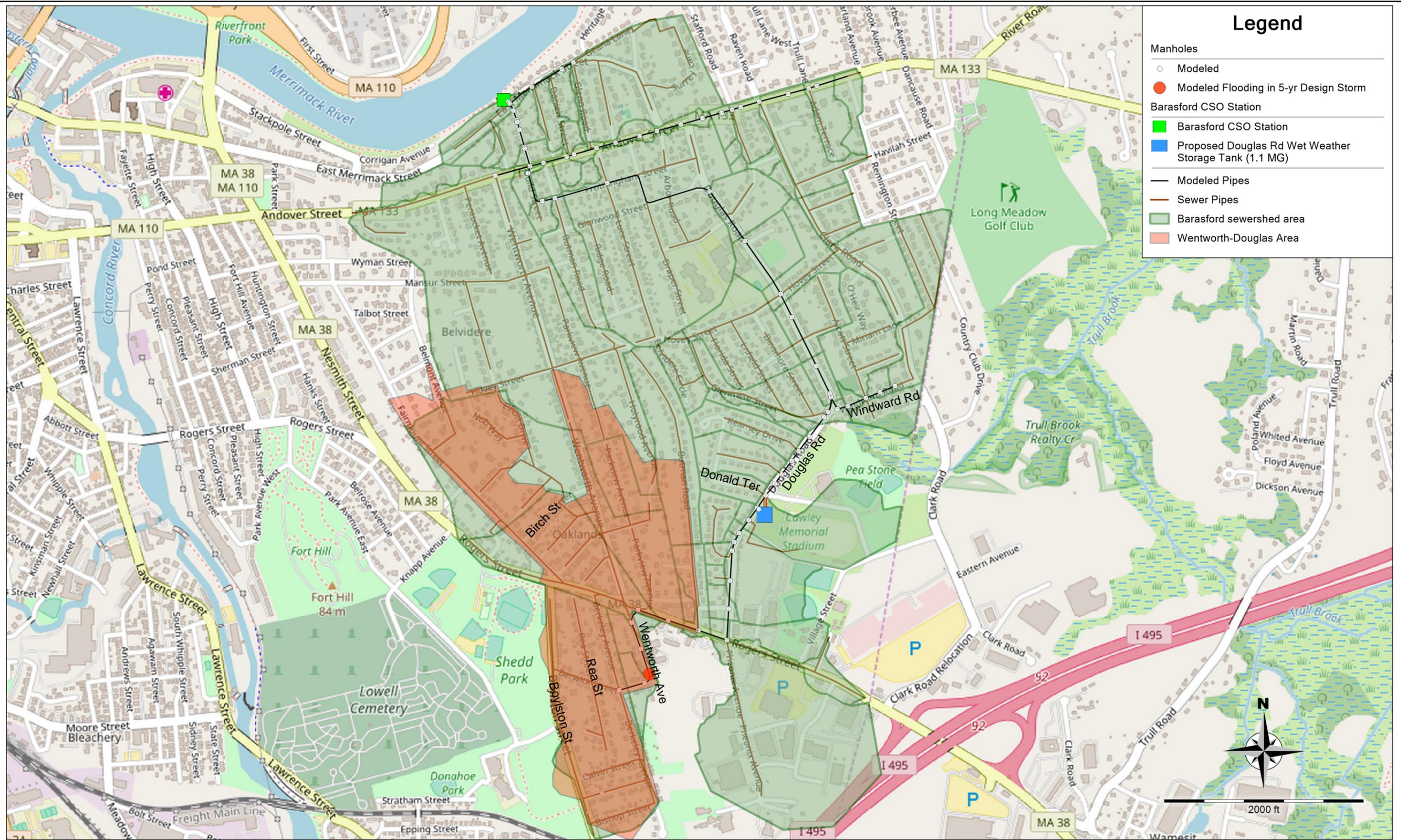
The Utility is proceeding with the construction of the Douglas Road Wet-Weather Storage Tank, which will be installed in the Cawley Stadium parking lot, to address the SSOs along Douglas Road and Windward Road. Wet-weather storage to address the SSO surcharging in this area was originally conceptualized in 2014 by CDM Smith. At that time, a 5 MG storage tank was conceptually sized to be constructed to address the 5-year storm event for street flooding along Douglas Road. Tank sizing was also based on the installation of an additional conveyance pipe from the intersection of Wentworth Avenue and Berwick Street, through the Phoenix Avenue wetlands, to convey additional wet-weather flow to the Douglas Road storage tank site.

In the 2019 Integrated Plan (Hazen), the recommended sizing for the Douglas Road storage tank was downsized to a 2.5 MG tank with design expandability, to initiate mitigating the Douglas Road-Windward Road SSOs in a phased approach. At that time, there was no reported SSOs at the Wentworth Avenue/Berwick Street intersection; the Utility believed that increased sewer maintenance had helped improve conveyance capacity and reduced the potential for SSOs at this location.

The Utility obtained 2021 American Rescue Plan Act (ARPA) funding and began planning for the new storage facility based on available funding. CDM Smith assisted with the early planning for tank sizing using the calibrated Collection System SWMM for just the Douglas Road-Windward Road issues. SWMM analysis indicated that a 1.1 MG storage tank at Cawley Stadium would mitigate SSO discharges on both Douglas Road and Windward Road, up to the 5-year design storm. **Figure 7.3** shows the proposed location of the tank and the SWMM results, indicating there would be no flooded manholes along Douglas and Windward Roads during the 5-year design storm. **Figure 7.4** shows the peak HGL along the Douglas Road and Windward Road sewers during the 5-year design event with a 1.1 MG storage tank in place. The profile shows that modeled peak HGL at 35 Windward Road reaches the rim elevation in the 5-year design storm for 1 to 2 minutes, but this is not typically considered to be actual flooding given the extremely peaky nature of the surcharge event and short duration of time the HGL is at the rim elevation.

The location of the proposed tank is optimal given that it can be constructed in a parking lot directly adjacent to the wet-weather surcharge and SSO problem area upstream of the Barasford CSO Diversion Station. However, SWMM simulations show that the proposed tank only provides minimal reduction of CSO discharges at the Barasford CSO Diversion Station because of its significant hydraulic distance upstream from the station. Separation of the Barasford CSO Basin was considered as an alternative to the tank (Section 7.2.1.2).

During design, the tank designer, Tighe & Bond, recommended the installation of a 1.9 MG tank, which was designed with additional storage volume to address potential water hammer-related issues during larger than 5-year storm events. The proposed Douglas Road Wet-Weather Storage Tank was bid and will soon be under construction at an approximate project cost of \$17 million (construction and engineering). Completion of the Tank is scheduled for December 2026.



Legend

- Manholes
 - Modeled
 - Modeled Flooding in 5-yr Design Storm
- Barasford CSO Station
 - Barasford CSO Station
 - Proposed Douglas Rd Wet Weather Storage Tank (1.1 MG)
- Modeled Pipes
 - Modeled Pipes
 - Sewer Pipes
- Barasford sewershed area
 - Barasford sewershed area
 - Wentworth-Douglas Area



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR
Figure 7.3

Wentworth-Douglas Area and Modeled Sanitary Sewer Overflow Locations in the 5-Year Storm with the Proposed Storage Tank in Place

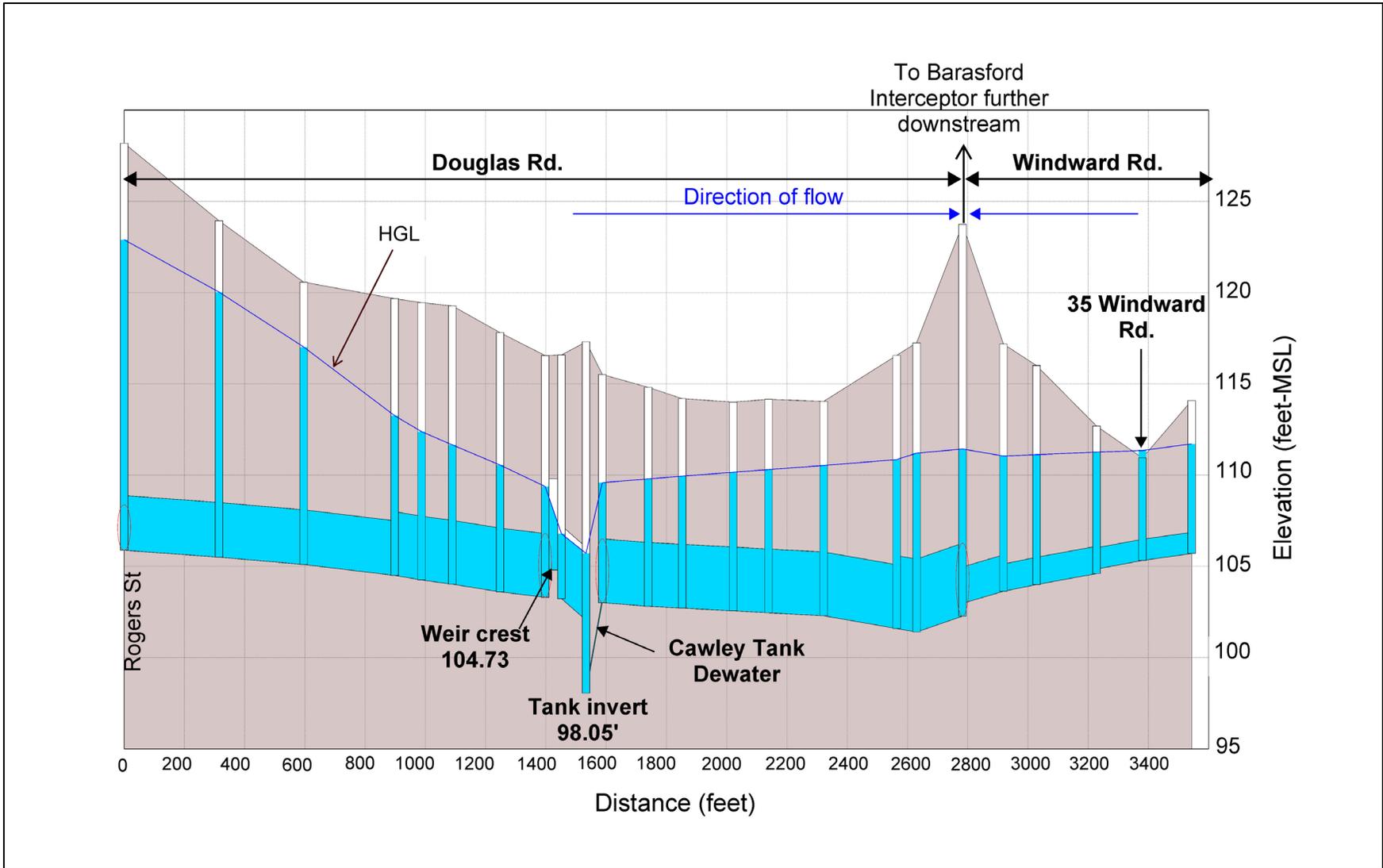


Figure 7.4 Model Profile of Douglas Road and Windward Road Sewers in the 5-Year Design Storm – With Proposed (1.1 MG) Storage Tank in Place

7.2.1.2 Sewer Separation

As an alternative to storage, separation was also considered. To eliminate SSOs on Douglas Road and Windward Road in the 5-year design storm, SWMM simulations indicate that separation of most of the sewer shed upstream of the Barasford CSO Diversion Station (approximately 400 acres) is required at an estimated cost of \$125 million based on the average cost for the Phase 3 Candidate Area separation projects of \$310,000 per acre. This estimate could be significantly higher in certain areas given specific local project challenges. Although sewer separation of the Barasford CSO Basin could mitigate CSOs at the Barasford CSO Diversion Station, it is not a cost-effective strategy for SSO mitigation along Douglas Road and Windward Roads compared to the Douglas Road Wet-Weather Storage Tank (at \$17 million).

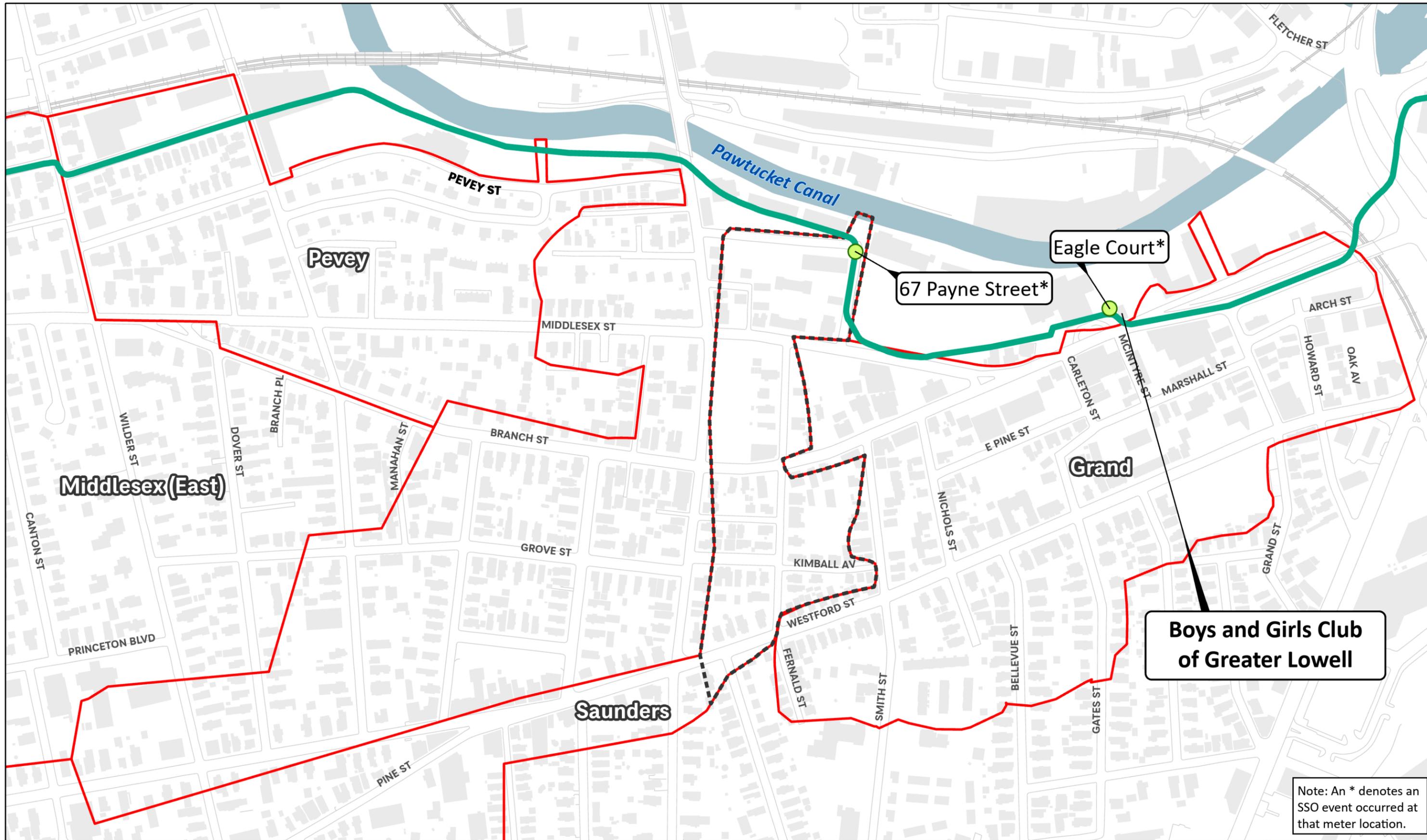
Separation of only the Phase 3 Wentworth-Douglas Area does not eliminate the SSOs on Douglas and Windward Roads in the 5-year design storm. It would help mitigate the isolated SWMM-simulated flooding manhole on Wentworth Avenue-Berwick Street in the 5-year design storm (Figure 7.1).

However, sewer separation is not recommended to address this one location of modeled flooding given that there have not been SSOs reported in this area and the duration of modeled flooding is less than 30 minutes. Additionally, separation of the Wentworth-Douglas Area poses several technical challenges as discussed in Section 6. There is no feasible outfall adjacent to the project area. An outfall to the Phoenix Avenue wetlands would still require dredging of the wetland bottom. Even with this effort, the outfall would still likely be submerged. Alternatives to this outfall location were considered in past studies of this area. One alternative involves construction of more than 6,000 linear feet of a large-diameter drain, running through the wetlands and along Douglas Road, to the Lowell and Tewksbury town line where flow then would be conveyed to and discharged into Trull Brook. Trull Brook winds its way through the Town of Tewksbury where it eventually discharges to the Merrimack River. The stormwater flow impacts to Trull Brook likely would require significant analysis and approval from the Town of Tewksbury.

7.2.2 Pevey Street Area (Boys and Girls Club)

The Pevey Street Area cited in the CD refers to a portion of the Marginal Interceptor (in the Warren CSO Basin) that runs parallel to the Pawtucket Canal between Pevey Street and Eagle Court-Middlesex Street. This SSO area and following key locations in the analysis are shown in **Figure 7.5**. Surcharging along the Marginal Interceptor has resulted in SSOs at Pevey Street, Payne Street, and Eagle Court/Lowell Boys & Girls Club. Section 2 documents the history of recurring SSO problems along this portion of pipe.

Table 2.23 summarizes the historical SSO events which have occurred in this area since January 1, 2014, including the cause of the SSO, wet-weather event statistics where rainfall was the cause, the volume discharged, and properties or receiving waters affected. Locations of the SSO events are shown in Figure 2.21. As summarized in Table 2.23, the majority of recent and recurring SSO events were caused by wet weather surcharging. The reported results along the Marginal Interceptor west of 91 Pevey Street occurred before the construction of the Marginal Sewer Relief Pipe, and there have been no recent reported SSOs in that area even with several large intensity storms occurring since that time. The one exception is a reported SSO at 64 Foster Street on August 8, 2023, the only such report over the last decade at this location. The reported storm intensity on that date using the Warren rainfall gage indicates a 5-month storm as noted in Table 2.23. However, as described in Section 7.2.1, the August 8 storm was an intense summer thunderstorm with localized rainfall. The SWMM modeling effort for



Note: An * denotes an SSO event occurred at that meter location.



Legend

- Active SSO Level Meter
- Marginal Interceptor
- Lower Saunders
- Phase 3 Candidate Areas



Marginal Interceptor surcharge evaluation was therefore focused on the area between Eagle Court and Pevey Street.

The calibrated model was used to determine baseline SSO estimates and projected SSO reduction achieved by separating various Phase 3 Candidate Area projects along the Marginal Interceptor. Initial SWMM simulations showed that only separation of the proposed Grand, Saunders, Middlesex (East), and Pevey Areas would benefit the surcharging along the interceptor.

During the 5-year design storm established by MassDEP for I/I analysis, the Marginal Interceptor did not surcharge to levels that resulted in SSO discharges. Accordingly, the baseline analysis for this area was established using the 5-year synthetic design storm discussed in Section 4. Two locations were chosen to be representative of SSO results along the Marginal Interceptor: 67 Payne Street and Eagle Court. **Table 7.1** presents the results of this SWMM analysis.

Table 7.1 Pevey Street/Boys and Girls Club Area Sanitary Sewer Overflow Reduction Results

Simulation	Acres	Payne Street SSO Location Surcharge Results				Eagle Court (Boys & Girls Club) SSO Location Surcharge Results			
		Surcharge Duration (minute)	Flood Duration (minute)	Flood Volume (MG)	Volume Reduced (MG)	Surcharge Duration (minute)	Flood Duration (minute)	Flood Volume (MG)	Volume Reduced (MG)
Baseline		96	19	0.10	0.10	79	41	1.01	1.01
Single Area Separation Alternatives									
Grand	44	85	14	0.04	0.06	58	19	0.19	0.82
Pevey	31	76	19	0.10	0.00	64	33	0.78	0.24
Middlesex (East)	140	69	17	0.09	0.00	59	31	0.74	0.27
Saunders	100	86	14	0.02	0.08	70	32	0.68	0.33
Grouped Separation Alternatives									
Grand and Pevey	75	67	13	0.04	0.06	46	16	0.15	0.86
Grand and Saunders	144	80	0	0.00	0.10	52	10	0.06	0.95
Grand and Lower Saunders	56	80	0	0.00	0.10	53	11	0.06	0.95
Combination Separation Alternatives									
Grand, Lower Saunders, and Pevey	87	60	0	0.00	0.10	41	8	0.04	0.97

Table 7.1 shows that the most effective SSO mitigation by separating individual projects was achieved by separation of the Grand Area with an SSO volume reduction of 0.82 MG at Eagle Court. Modeled flooding for 19 minutes still exists at this manhole following separation. Accordingly, separation of the Grand Area was simulated in combination with three other separation alternatives: Grand/Pevey, Grand/Saunders, and Grand/Lower Saunders. A combination simulation was then conducted of the

Grand, Lower Saunders and Pevey Areas. Because of the cost and construction challenges outlined in Section 6, and relative SSO benefit on its own, Middlesex (East) was not included in a grouped simulation with Grand.

As discussed in Section 2 and Section 6, the Saunders Area (100 acres) is a unique area because it has a high outlet cross-connection at Hastings Street between two subbasins. The dry-weather flow and most of the wet-weather flow from the combined sewer area upstream of Hastings Street goes to the interceptor on Chelmsford Street (and then is conveyed to the Warren CSO Diversion Station). Only a small portion of wet-weather flow is conveyed by the high outlet connection to Westford Street and to the Marginal Interceptor through the Saunders Area. In addition, there are CBs along Westford Street that contribute flow to the Saunders combined sewer area that could be readily separated and connected to the existing School Street drainage system (Section 7.4.1). Later in this section, the Lower Saunders alternatives are discussed in more detail. Based on the analysis shown in Table 7.1, separating the upper portion of the Saunders Area does not provide any more modeled SSO mitigation.

The information presented in the Table 7.1 shows the following:

- All four individual Candidate Area Sewer Separation Projects provide SSO reduction compared to the baseline condition.
- Separation of just Grand provides a considerably higher reduction in SSO duration and volume compared to the other three areas while also having a smaller acreage required to separate.
- Separating Grand and all of Saunders compared to just Lower Saunders did not provide any measurable benefit at these SSOs. This suggests that separation of just Lower Saunders is more impactful to the resolution of these SSOs. Sewer flows from areas in the upstream portion of Saunders do not significantly affect SSO reduction.
- At Eagle Court, separation of Grand, combined with other projects, can reduce SSO occurrence from more than 40 minutes in the baseline run to 16 minutes or less. Additionally, the flood volume can decrease from 1 MG to 0.15 MG or less depending on the project combination, based on simulation of the 5-year design storm.
- At Payne Street, separation of Grand, combined with other projects can reduce SSO occurrence from nearly 20 minutes and 0.10 MG of flooding to no flooding, based on the simulation of the 5-year design storm.
- Middlesex (East), while not being the lowest SSO reduction separation option, does not show significantly more SSO mitigation than Pevey, which is a much smaller project.
- The combination simulation of Grand/Lower Saunders/Pevey shows the most favorable results of all runs.

In conclusion, Middlesex (East) should not be considered a priority project for reduction of the Pevey Street Area SSO. On a per acre basis, the SSO reduction for Middlesex (East) is less than the other three areas at 0.0019 MG/acre compared to 0.0033 MG/acre for Saunders, 0.0077 MG/acre for Pevey, and 0.019 MG/acre for Grand. The cost of Middlesex (East) is also much higher and project feasibility/constructability is much more difficult. Grand and Lower Saunders together have the highest SSO reduction potential for this area, and both should be viewed as top-priority projects to reduce SSOs

in this area. The Pevey Area should also be considered as a priority project because it would provide incremental SSO benefit. As later discussed in Section 7.3, it also has comparatively higher CSO benefit.

Figure 7.6 provides an illustration of Lower Saunders compared to the full Saunders Candidate Area.

The selection of Lower Saunders as a priority project in the implementation plan requires further consideration of drainpipe sizing. One option is to construct the Lower (downstream) portion of Saunders with adequate pipe sizing to facilitate completing separation in the remainder of the Saunders Area during a future date (i.e., larger pipe now). A second option is to size the Lower Saunders pipes based on the current area being separated (i.e., smaller pipe). While the second option provides a significant cost benefit now, it would likely require installation of larger replacement pipes along the same alignment if and when a future larger separation project was to be implemented throughout Saunders. Figure 7.6 shows the location and sizes of pipes for both options, and **Table 7.2** compares current dollar project costs for sewer separation of Lower Saunders between Option 1 with larger pipe and Option 2 with smaller pipe.

Table 7.2 Lower Saunders Option Cost Comparison

Project	Sewer Separation Cost ¹ (Million \$)
Lower Saunders – Option 1 (large pipe option)	\$10.1
Lower Saunders – Option 2 (small pipe option)	\$6.1

Note:

1 Costs include construction, construction contingency, engineering, and project contingency. Pipe rehabilitation and escalation is not included.

Constructing larger pipes now will allow for separation of the entire Saunders Area in the future. Constructing smaller pipes provides a cost benefit now that could allow for other projects to be prioritized by the Utility. The disadvantage is that if separation of the Upper Saunders Area becomes a requirement in the future, some of the smaller pipes installed solely for Lower Saunders may have to be increased in size to accommodate additional drainage capacity.

This PDR has found that separation of all Saunders does not add any additional SSO benefit, and it does not compare as highly with other Candidate Areas for CSO, so only Lower Saunders is recommended as the current priority. It is expected that any future planning and analysis will arrive at similar conclusions. For these reasons, the prioritized Lower Saunders project will be designed and constructed with the smaller pipe option.

7.3 Combined Sewer Overflow Reduction Potential of the Candidate Separation Areas

Based on the SSO impact analysis, three Phase 3 Candidate Areas (Grand, Lower Saunders, and Pevey) will be prioritized for separation as part of the Phase 3 PDR Implementation Plan. Section 6 discusses the separation plan, construction challenges, and costs for the remaining Phase 3 Candidate Areas.

To help assess the benefits achieved by separation of the remaining Phase 3 Candidate Areas, the calibrated Collection System SWMM was used to determine baseline CSO estimates and projected CSO reduction with separation. Average annual CSO discharge was used as a metric for evaluating CSO reduction based on the representative 5-year period (2005 through 2009). CDM Smith established this representative period approach in previous studies, using a statistical analysis of annual precipitation for Boston Logan Airport hourly precipitation data to represent a typical year.

Table 7.3 presents the results of this analysis based on the downstream CSO Diversion Station most affected by the separation. Twenty-five potential CSO separation projects were simulated using the model. **Figure 7.7** shows all 25 separation projects and the CSO Diversion Station in which results are presented in the table. As discussed in Section 6, the Candidate Areas Tilden 1 and 2 projects were divided into five individual outfall/separation projects with dedicated outfalls. Similarly, the Burnham Candidate Area was also divided into three areas to help phase future separation and to have more easily constructed outfalls. Initially, Saunders was run as a whole area, followed by separate assessment of the Lower and Upper portions once Lower Saunders was identified as an SSO priority project.

The table includes the cost of separation per acre and the cost for incremental annual average volume (MG) of CSO reduction. This is a typical approach to evaluating CSO sewer separation cost-effectiveness. Typically, the cost of sewer separation is compared to the cost of other CSO mitigation strategies (such as CSO storage or treatment technologies) to identify the best plan for CSO control at the downstream CSO discharges. However, in this case, the Phase 3 Candidate Area PDR is only considering sewer separation. Accordingly, the incremental costs per CSO benefit were considered compared to each other and not other potential CSO mitigation alternatives.

Table 7.3 shows that there is a relatively small incremental difference of cost-effectiveness for each cost criteria (cost per gallon or cost per acre) between the individual separation projects. To help with the prioritization, the projects were ranked (Table 7.3).

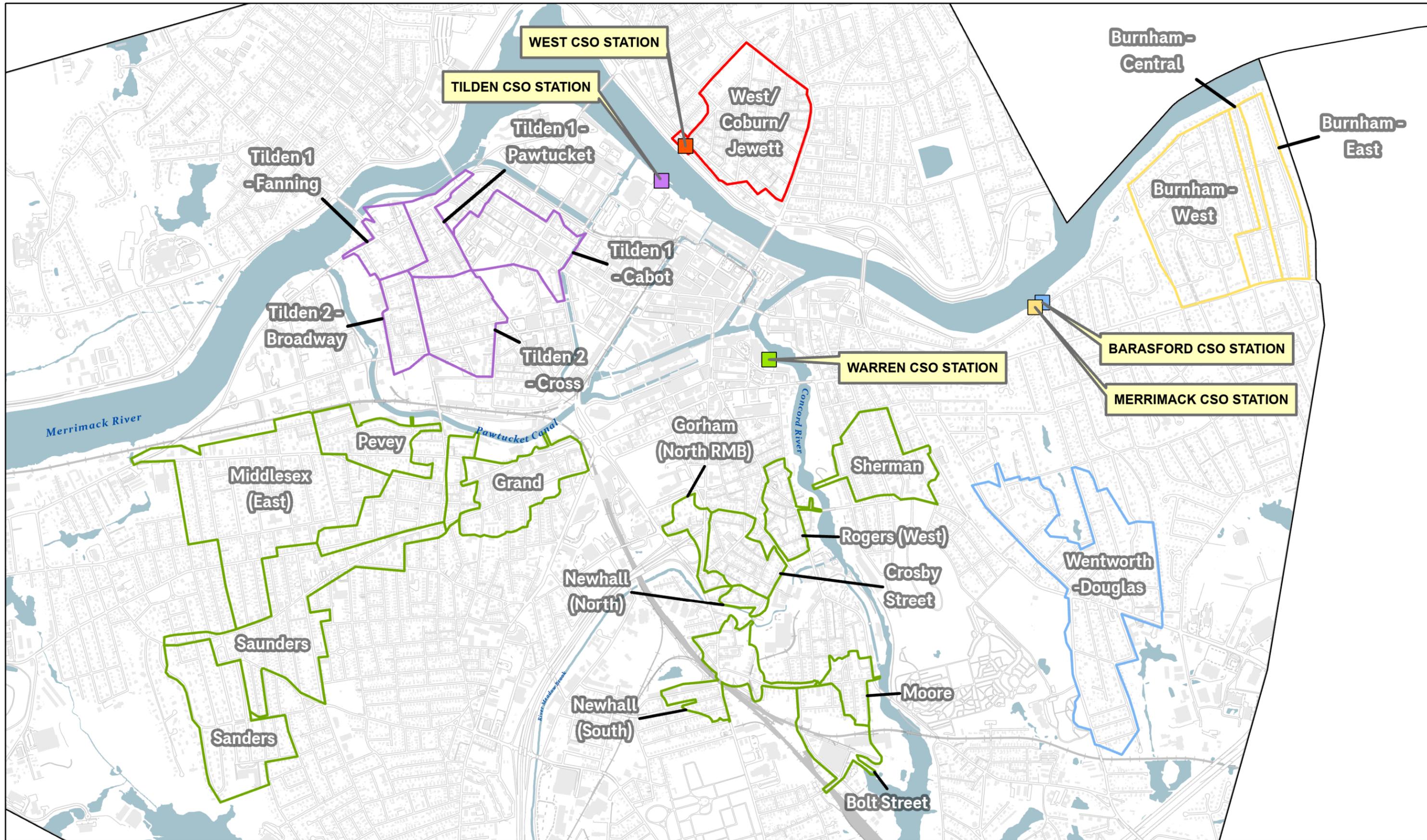
Table 7.3 Combined Sewer Overflow Reduction Results

Separation Areas Arranged by Primary Downstream CSO Diversion Station		Avg Annual CSO Diversion Station Statistics					CSO Reduction Cost Ranking \$/Gal		Acre Cost (\$/Acre)		
		Phase 3 Separation Area	Acres	CSO Diversion Station Affected	Avg. CSO Volume (MG/Yr)	Avg. CSO Volume Reduction (MG/Yr)	Avg. CSO Events (per Yr)	Avg. CSO Events Reduced (per Yr)	Cost (millions) Per MG CSO Removed	Rank	Cost (millions) Per Acre
Warren (Baseline of 61.8 MG, 19 events)										61.8	
Middlesex (East)	140	Warren	53.9	7.9	18	1	\$5.5	22	\$0.291	14	
Pevey	31	Warren	55.3	6.5	18	1	\$1.4	8	\$0.191	5	
Saunders	99	Warren	52.5	9.3	18	1	\$5.6	23	\$0.525	22	
Lower Saunders	12	Warren	59.0	2.8	19	0	\$5.1	21	\$1.200	24	
Upper Saunders	87	Warren	52.1	9.7	18	1	\$3.9	20	\$0.432	19	
Grand	44	Warren	53.1	8.7	17	2	\$1.8	12	\$0.357	16	
Sanders	19	Warren	60	1.8	19	0	\$5.6	23	\$0.534	23	
Newhall (South)	31	Warren	55.3	6.5	18	1	\$1.1	3	\$0.203	7	
Bolt Street	30	Warren	57.9	3.9	18	1	\$2.3	16	\$0.358	17	
Moore	14	Warren	58.8	3.0	19	0	\$1.6	9	\$0.197	6	
Newhall (North)	5	Warren	59.8	2.0	19	0	\$0.6	1	\$0.139	2	
Gorham (North RMB)	13	Warren	56.9	4.9	18	1	\$1.0	2	\$0.173	4	
Crosby Street	27	Warren	56.3	5.5	18	1	\$1.4	6	\$0.216	8	
Rogers (West)	18	Warren	57.9	3.9	19	0	\$1.9	13	\$0.440	20	
Sherman	40	Warren	53.9	7.9	18	1	\$1.3	5	\$0.134	1	
Tilden (Baseline of 19.2MG, 14 events)			19.2			14					
Tilden 1											
Cabot	41	Tilden	11.3	7.9	9	5	\$1.3	4	\$0.229	10	
Fanning	15	Tilden	16.9	2.3	13	1	\$1.7	10	\$0.154	3	
Pawtucket	17	Tilden	15.5	3.7	12	2	\$1.7	11	\$0.296	15	
Tilden 2											
Broadway	19	Tilden	15.7	3.5	13	1	\$1.4	7	\$0.259	12	
Cross	44	Tilden	13	6.2	11	3	\$2.5	17	\$0.380	18	

Separation Areas Arranged by Primary Downstream CSO Diversion Station		Avg Annual CSO Diversion Station Statistics					CSO Reduction Cost Ranking \$/Gal		Acre Cost (\$/Acre)	
		CSO Diversion Station Affected	Avg. CSO Volume (MG/Yr)	Avg. CSO Volume Reduction (MG/Yr)	Avg. CSO Events (per Yr)	Avg. CSO Events Reduced (per Yr)	Cost (millions) Per MG CSO Removed	Rank	Cost (millions) Per Acre	Rank
Phase 3 Separation Area	Acres									
Merrimack (Baseline of 97.7 MG, 25 events)			97.7		25					
Burnham		Merrimack								
Burnham - West	101	Merrimack	90.3	7.4	23	2	\$3.5	19	\$0.260 13	
Burnham - Center	21	Merrimack	95.4	2.3	24	1	\$2.0	14	\$0.221 9	
Burnham - East	41	Merrimack	94.5	3.2	24	1	\$3.2	18	\$0.248 11	
Barasford (Baseline of 40.4 MG, 24 events)			40.4		24					
Wentworth-Douglas	134	Barasford	30.1	9.7	23	1	-.1	-	- -	
West (Baseline of 112.0 MG, 18 events)			112.0		18					
West/Coburn/Jewett	77	West	92.8	17.4	15	3	\$2.3	15	\$0.468 21	

Note:

1 No cost available for Wentworth-Douglas for the reasons noted in Section 6 and Section 7. Therefore, CSO reduction or per acre cost effectiveness was not ranked or evaluated for relative CSO reduction.



Legend

- Diversion Station and CSO Outfall**
- WARREN
 - TILDEN
 - MERRIMACK

- BARASFORD
- WEST

- Phase 3 Candidate Areas**
- WARREN
 - TILDEN
 - MERRIMACK

- BARASFORD
- WEST



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 7.7

Phase 3 Candidate Area CSO Stations

The next step was to take the top 10 of these rankings and make a comparison to see which projects were identified under both criteria (**Table 7.4**).

Table 7.4 Candidate Project Rankings Based on Cost per gallon of Combined Sewer Overflow Removed and Acre Separated

Ranking	Ranked Projects	
	\$/Gallon CSO Removed	\$/Acre Separated
1	Newhall (North)	Sherman
2	Gorham (North RMB)	Newhall (North)
3	Newhall (South)	Tilden 1 – Fanning
4	Tilden 1 – Cabot	Gorham (North RMB)
5	Sherman	Pevey
6	Crosby Street	Moore
7	Tilden 2 – Broadway	Newhall (South)
8	Pevey	Crosby Street
9	Moore	Burnham - Center
10	Tilden 1 – Fanning	Tilden 1 – Cabot

Note: Green highlighting indicates project ranked top 10 in both categories.

As shown highlighted in green in Table 7.4, there are nine Candidate Areas that are ranked in the top 10 in both categories. Of these nine projects, each was assessed further on its individual merits and construction challenges, in a qualitative evaluation, to consider relative priorities using the data presented in Section 6.

Table 7.5 summarizes the assessment process.

Table 7.5 Summary of Assessment Process

Phase 3 Sewer Separation Area	Ranking		Project Comment
	\$/Gallon Removed	\$/Acre	
Newhall (North)	1	2	<ul style="list-style-type: none"> Very small, low-cost project. Potential to combine with Gorham (North RMB) area to address two sewer separation areas in one project.
Gorham (North RMB)	2	4	<ul style="list-style-type: none"> Portion of this Candidate Area is within limits of MassDOT intersection improvement project, which will separate majority of CBs. Three of five remaining CBs could be included in separation of Newhall (North) project.
Newhall (South)	3	7	<ul style="list-style-type: none"> Outfall required for this separation project goes through private property (Markley Group, LLC, formerly Prince Spaghetti Factory), which may present significant issues with project viability as outlined in Section 6. Project requires crossing under a railroad overpass with low clearance, which will require unique construction challenges.
Crosby Street	6	8	<ul style="list-style-type: none"> Warren Interceptor crossing near outfall is a factor in constructability; requires shallow drain with minimal cover that presents a challenge and affects project feasibility.
Tilden 1 – Cabot Street	4	10	<ul style="list-style-type: none"> Of the five Tilden projects, Cabot, and Cross present the highest degree of difficulty construction-wise. Construction requires installation of large-diameter drain at shallow depth along streets with significant horizontal and vertical utility congestion. These tight corridors will likely result in other costly utility offsets/replacements as more survey becomes available in future design phases.
Sherman	5	1	<ul style="list-style-type: none"> Some portions of this area have been separated; full separation would likely require upsizing existing drains or alternative pipe routing. Aside from existing drainage, this is a straightforward constructable project.
Tilden 1 – Fanning Street	10	3	<ul style="list-style-type: none"> At the outfall there is a long run of proposed drainage that runs through a private property, which may present significant issues with project viability. There are alignment options to combine portions of this area with other Tilden outfalls, but the value and CSO benefit of those options will need to be evaluated further.
Pevey	8	5	<ul style="list-style-type: none"> Pevey is a relatively straightforward constructable project. Primary construction consideration is crossing over Marginal Interceptor with shallow pipe and flat slopes near outfall. SSO benefit at Boys & Girls Club.
Moore	9	6	<ul style="list-style-type: none"> This is a relatively small, straightforward, constructable project.
Tilden 2 – Broadway	7	13	<ul style="list-style-type: none"> This is a relatively small, straightforward, constructable project.

Note: Green indicates project ranked in top 10 of both categories.

Four of the nine projects include construction or land acquisition challenges, which present a higher degree of difficulty to construct. Those four projects are Newhall (South), Crosby Street, Tilden 1 – Cabot Street, and Tilden 1 – Fanning Street. Despite comparing highly among all Candidate Areas in the two cost rankings, they do not grade the highest within the subset of this assessment, so they are not recommended as priority projects.

Sherman, Moore, and Tilden 2 – Broadway are all viable projects that should be considered favorable sewer separation projects for future consideration based on constructability, cost, and CSO reduction value.

Newhall (North) and Gorham (North RMB) are two, small, sewer separation projects. It is recommended that given the planned MassDOT work in Gorham (North RMB), the remaining CBs in this area be included as part of a future Newhall (North) sewer separation project.

Pevey also provides great value in both cost categories assessed and presents as a constructable project. Considering this project shows value from a cost perspective, CSO reduction perspective, and SSO reduction, as discussed in Section 7.2.2, this project is recommended as a priority sewer separation project.

Overall prioritization and adoption in the Phase 3 Candidate Area PDR recommended implementation plan is discussed in Section 8.

7.4 Additional Separation Projects to be Included in the Phase 3 Program

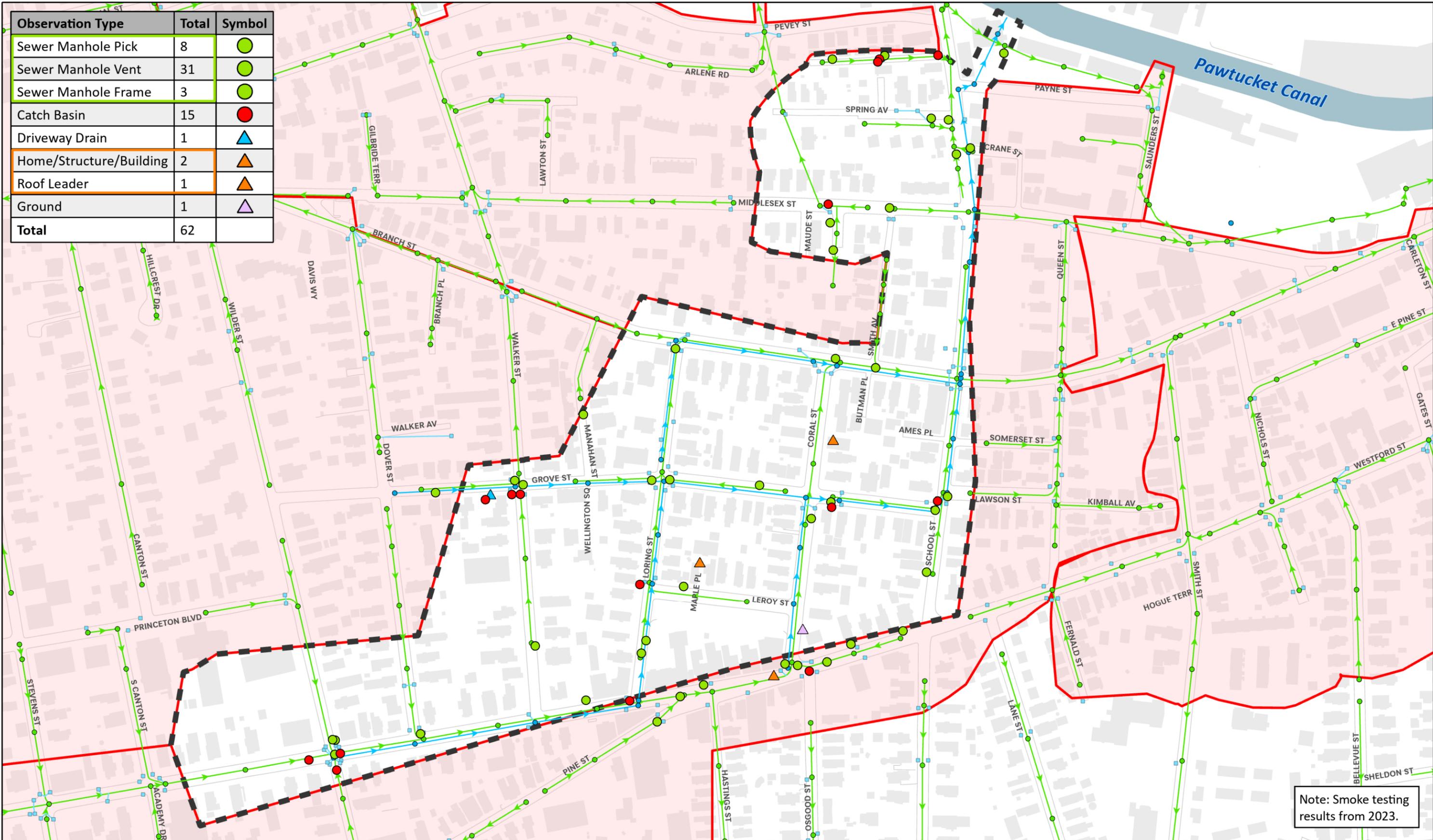
During the development of this PDR, other potential projects were identified by the Utility, that were not within the scope of the Phase 3 Candidate Areas. These additional projects provide benefit to the Utility in fulfilling cost effective CSO and SSO reduction goals.

7.4.1 School Street Drainage Area

The School Street area is bordered by the Pevey, Saunders and Grand Areas and has an existing drainpipe network with a dedicated outfall to the Pawtucket Canal. During field investigations performed for this PDR, as discussed in Section 3, smoke testing was conducted in the adjacent sanitary sewer system to identify any potential inflow sources. Smoke testing results showed that a total of 15 CBs in this area are still connected to the sewer system. Because this sanitary sewer system in the School Street area drains to the Marginal Interceptor, the Utility elected to remove these inflow sources as part of the Phase 3 PDR work. Smoke testing also indicated that there could be three private sources of inflow that require further investigation to determine whether these sources also could be readily disconnected from the sewer system.

Figure 7.8 depicts potential inflow sources identified during smoke testing.

Observation Type	Total	Symbol
Sewer Manhole Pick	8	●
Sewer Manhole Vent	31	●
Sewer Manhole Frame	3	●
Catch Basin	15	●
Driveway Drain	1	▲
Home/Structure/Building	2	▲
Roof Leader	1	▲
Ground	1	▲
Total	62	



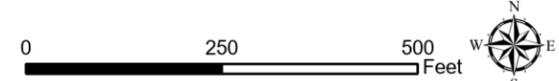
Note: Smoke testing results from 2023.



Legend

- Smoke Testing Results
- Smoke from Sewer Manhole Pick, Vent Hole, or Frame
 - Smoke from Catch Basin
 - ▲ Smoke from Driveway Drain
 - ▲ Smoke from Home/Structure/Building/Roof Leader/etc.
 - ▲ Smoke from Ground
- Observation Type
- Sewer Manhole
 - Drain Manhole
 - Catch Basin
 - Sewer Gravity Main
 - Sewer Force Main
 - Drain Pipe
 - Catch Basin Lateral

- Phase 3 Candidate Areas
- School Street Area



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 7.8

Smoke Testing Results: School Street Area

The three potential sources of private inflow (smoke source from building and roof leaders) should be investigated further using building inspection to determine the best method of separation.

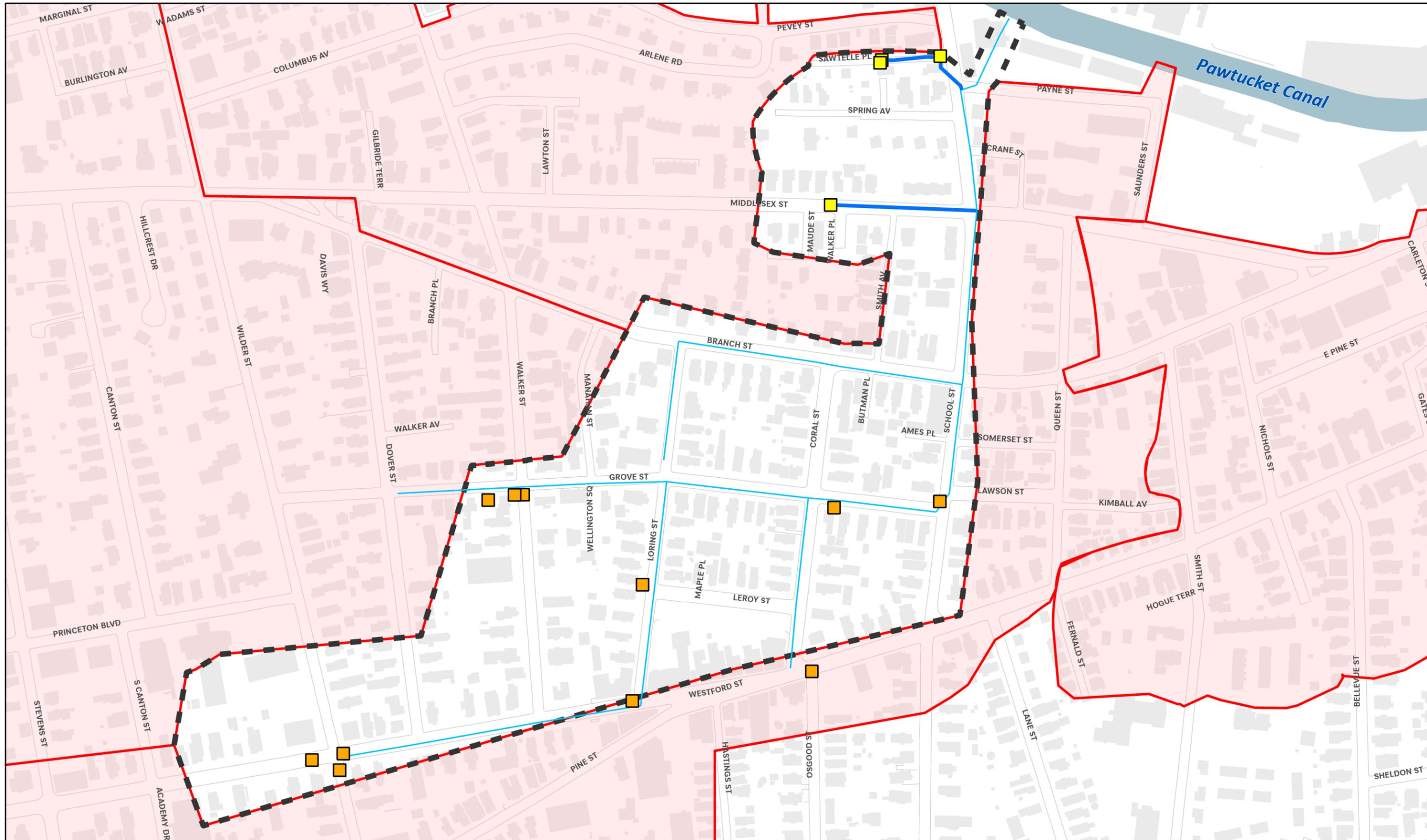
Eleven of the 15 CBs potentially connected to the sewer in this area have adjacent drainpipes within the street. Further field investigations will need to be completed to determine if these CBs were not properly connected to the new drains in School Street and need redirection, or if there are cross connections to the old system that need to be located and properly abandoned.

There were four additional CBs identified in the area where new drains were not extended. To separate these four remaining CBs, approximately 300 feet of 12-inch drain on Sawtelle Place and 200 feet of 12-inch drain on Middlesex Street would need to be installed.

Given the uncertainty of extent of work needed to separate the CBs, a range of work could be required. A less costly requirement would be that CBs adjacent to the existing drainage are already connected and only need their old, previously abandoned connections to the sewer properly plugged, and CBs not adjacent to existing drainage need new drain extensions and laterals. A greater need would involve rerouting CB laterals to the drain, where available, and installing a new manhole to avoid blind ties. Additionally, new drain extensions would be constructed where drainage is not present to connect the remaining CBs. For planning purposes, the Utility should assume an opinion of probable project cost of \$1,860,000.

Aside from drain work needed, there are other system improvements that should be considered in this area. There were 39 sewer manholes identified with pick or vent holes and three other sewer manholes that had smoke emitting from the frame, indicating a potential source for inflow. The Utility should consider replacing those manhole frame and covers with new structures that would be more watertight. There was also one driveway drain at 116 Grove Street that should be separated. These costs are included in the CSS rehabilitation costs presented in Section 8.

Figure 7.9 shows the recommended work required to separate the remaining School Street area.



Legend

Phase 3A School Street

- Proposed Drain
- Proposed Catch Basin Separation to New Drain
- Proposed Catch Basin Connection to Existing Drain

- Existing Drain
- Phase 3 Candidate Areas
- School Street Area



Lowell, Massachusetts
Phase 3 Candidate Area
Sewer Separation PDR

Figure 7.9

School Street Separation - Catch Basin Reconnection

7.4.2 Inland Street

The Utility previously considered Inland Street sewer separation. During progression of the prior separation designs in that area, the Utility decided to avoid this street because it would require disturbing many large trees and root systems near the required proposed drain alignments. The trees preventing sewer separation along this street have recently been removed and the Utility will now include this street as a priority for separation so they can complete sewer separation in the area. The previous separation design left a stub for a new drain connection and capacity to receive flow from the four CBs along this street. The project requires approximately 630 linear feet of new drain and the replacement of all four CBs. This work has an opinion of probable project cost of \$680,000. **Figure 7.10** shows the work required to separate Inland Street.

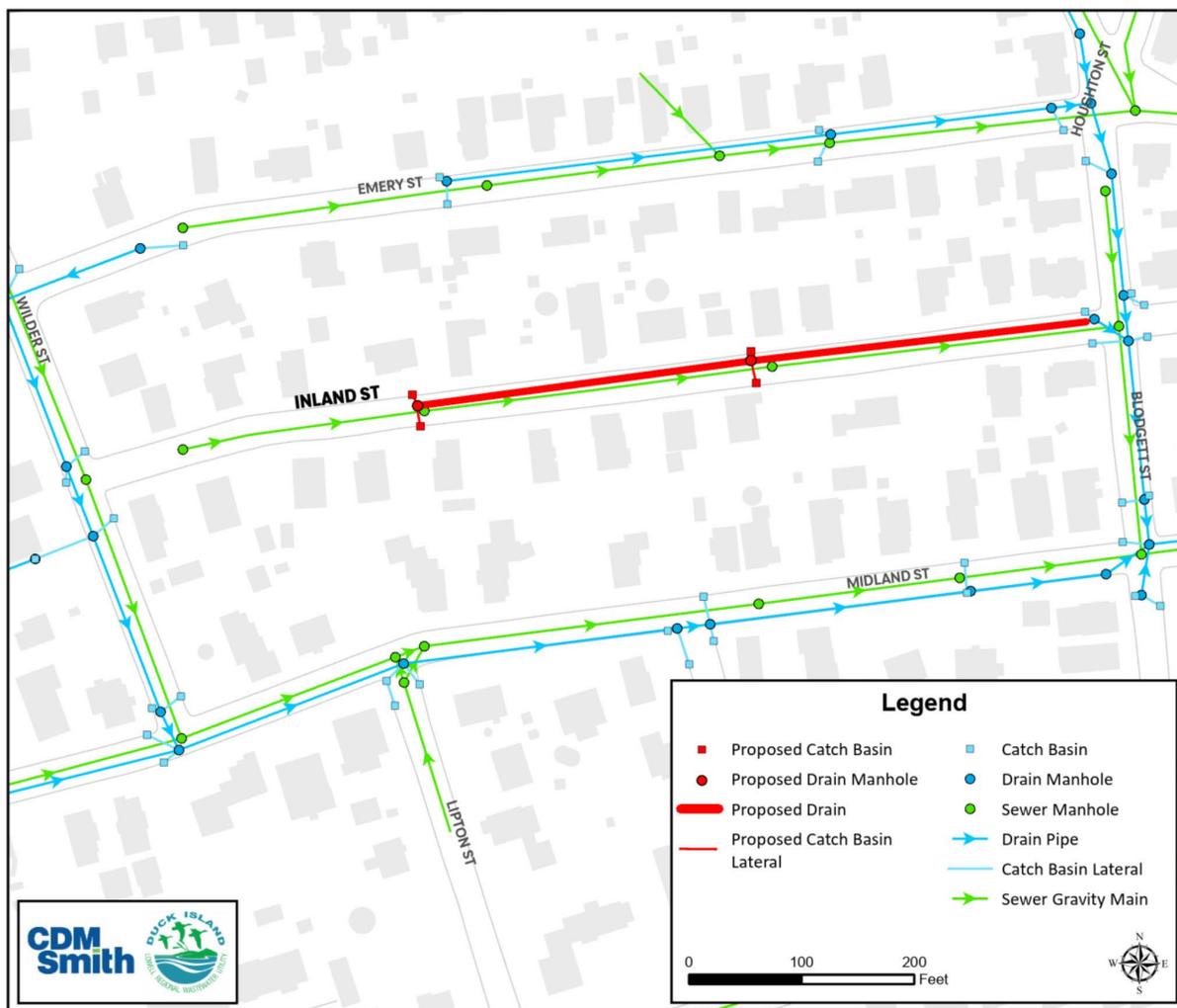


Figure 7.10 Inland Street Sewer Separation



8.0 Recommended Plan

8.1 Introduction

The recommended plan for the Phase 3 Candidate Area Sewer Separation Program is based on a SWMM analysis of wet-weather benefits, the development of separation plans with new drains and outfalls for each area (with an estimate of project costs), identification of design and construction challenges, and an evaluation of the relative priority of each Phase 3 Candidate Area.

The Utility had two objectives for the development of its priorities for Phase 3:

- Reduction or elimination of chronic SSOs identified in the CD.
- Reduction of CSO discharges from CSO Diversion Stations (downstream of each Phase 3 Candidate Area) integrated with the Utility's long-term CSO planning goals.

The CD does not have specific projects or schedules identified for the recommended Phase 3 Program. This report and its recommendations will establish the Phase 3 Program upon approval by the regulatory agencies. The CD also requires completion of a LTCP by the end of 2034. It is intended that the Phase 3 Program be completed at the end of 2032 so that the LTCP flow metering program can be used to identify the actual CSO reduction benefits achieved by all the sewer separation work in the CD Compliance Program.

8.2 Current Consent Decree Compliance Program Projects

The Utility is currently undertaking several extensive programs to achieve compliance with the CD and the Duck Island NPDES Permit that require significant expenditures over the next 10 years.

These include the following:

- The Centralville Area Sewer Separation program that will consist of the installation of more than 40,000 feet (8 miles) of new drains, sewers, and water mains, and two new large-diameter drain outfalls to the Merrimack River. This program includes two CD completion deadlines of December 2027 and December 2031. The overall program is estimated at a project cost of almost \$158 million over 8 years.
- Construction of improvements to Duck Island (\$27 million) will address nutrient limits in the effluent discharges and will revitalize existing infrastructure, especially related to solids dewatering and primary tank equipment renewals. This construction will help to maximize wet-weather treatment capabilities at Duck Island. This project will be completed in 2027.
- Construction of the Douglas Road Wet-Weather Flow Storage Tank will be completed by the end of 2026 and is estimated to cost \$17 million.
- Compliance with CD-derived initiatives for the Utility's CMOM program, I/I reduction program, MS4 Stormwater, and LTCP is estimated to cost \$36 million.

In total, the Utility has committed \$238 million over 10 years for CD compliance, not including implementation of the Phase 3 Candidate Area Separation Program recommended in this PDR.

8.3 Implementation Plan Challenges

In addition to the significant capital and implementation costs and the sewer rate impact for project funding of the current CD Compliance Program identified in Section 8.2, the Utility has other program implementation challenges that were considered in the development of the Phase 3 Candidate Area recommendations, including:

- Assess the feasibility of overseeing these numerous projects relative to Utility engineering staff availability and time to provide coordination and oversight of multiple concurrent construction contracts.
- Evaluate program benefits of staggering the start of construction projects within the same local urban and densely developed areas/neighborhoods to help manage and mitigate construction impacts.
- Provide adequate time for the significant design and permitting efforts required for pipeline projects of this magnitude, including pre-design efforts such as survey, geotechnical investigation, and evaluation of sewer pipe requiring rehabilitation.
- Integrate public outreach and coordination while ensuring appropriate public input is solicited, allowing for the resolution of sewer system and street flooding issues in a reasonable and practical approach.
- Assess the impact of traffic detours and alternative routing given the narrow, congested roads, considering traffic flow patterns, the presence of schools and bus routes, parking constraints, and the presence of hospitals requiring emergency accessibility.
- Adopt staggered construction schedules to maximize the receipt of multiple competitive bids, considering bonding and project execution capacity required for general contractors to perform this work, while allowing for the manufacture and timely delivery of large-diameter pipes to minimize impacts on construction implementation schedules in a tight and resource-constrained economy.
- Consider winter shutdown periods and the potential impact these shutdowns will have on the overall project schedule.
- Coordinate with DCR for Article 97 conversions, if needed, and other permitting work associated with the outfalls.
- Coordinate with City roadway paving projects and other planned utility improvements/upgrades that are scheduled for the next few years.
- Develop project timelines for project costs incurred so the Utility can take steps to maintain adequate funding to meet project obligations throughout the construction program.
- Attain State Revolving Fund (SRF) requirements and deadlines to maximize available SRF funding.
- Consider the heavy financial burden on sewer users in the City, as the planned sewer separation projects represent significant per annum rate increases.

These challenges have been considered in developing the recommended implementation plan and schedule for Phase 3.

8.4 Phase 3 Preliminary Design Report Recommendations and Sewer Separation Prioritization

The Utility's goals for the Phase 3 Candidate Area Sewer Separation Program are the mitigation of SSOs and CSO reduction.

8.4.1 Sanitary Sewer Overflow Mitigation

The Utility will target SSO mitigation first for system improvements implementation as part of the recommended Phase 3 Program. As discussed in the previous sections, in many cases, the Utility has a program in place to install temporary meters to monitor sewer flow depths after reports of apparent SSOs or street flooding to identify the system cause. The 2024 CMOM CAP (submitted on December 19, 2024) identifies seven general system locations that have experienced repeated surcharge events that have resulted in either SSOs or street flooding, and are included by reference in the CD. The Utility reviewed each of the surcharge areas and used the flow meters to determine the problems and make recommendations to address these issues. Based on this, the CMOM CAP identified two key areas of system surcharge that are resulting in chronic SSOs:

- Windward and Douglas Road Area
- Marginal Interceptor (reflected in surcharge reports at the Pevey Street, Payne Street, and at the Boys & Girls Club of Lowell (also referenced as Eagle Court locations)).

8.4.1.1 Douglas Road Wet-Weather Flow Storage Tank

In Spring 2025, the City will commence the construction of the 1.9 MG wet-weather flow storage tank off Douglas Road in the Cawley Stadium parking lot. This tank is designed to address system surcharging along Douglas Road and Windward Road (located in the Barasford CSO Basin) for storm events up to the 25-year return frequency event. This tank is designed for a higher design standard to attenuate the hydraulics involved with a passive operated system and system surcharge impacts. This tank will have limited benefits to CSO discharge reduction at the Barasford Diversion Station because of its location within the CSS. The tank is at a low elevation in the sewer system far upstream and away from the CSO Diversion Station. The long-term CSO mitigation plan for this basin will be analyzed during the development of the 2034 LTCP later in the CD implementation period. Accordingly, it was not necessary to prioritize the Wentworth-Douglas Phase 3 Candidate Area for sewer separation in this PDR to address the SSOs in the Windward Road and Douglas Road Area.

The cost of the Douglas Road Wet-Weather Storage Tank is about \$17 million, including engineering services during construction.

8.4.1.2 Marginal Interceptor Surcharging

As discussed in Section 7, the Marginal Interceptor sewer surcharges should be resolved by implementing three Phase 3 Candidate Area sewer separation projects—Grand, Lower Saunders, and Pevey. The surcharges from excess wet-weather flow along this interceptor have caused reported SSO discharges from manholes along the Marginal Interceptor, including Pevey Street, Payne Street, and

Eagle Court. Sewer separation of these three areas will reduce at least 87 acres of CSS, and SSO discharges will be mitigated to the 5-year synthetic storm event (which is more conservative than the Massachusetts 5-year event for SSO planning).

Section 7 details the recommended projects, which are summarized in the following paragraphs. Construction challenges within the three project areas are similar given the dense development and variety of large underground utilities, which will conflict with the shallow but large diameter drainpipes. The outfall pipes for each separation project must cross the existing Marginal Interceptor to discharge to the Pawtucket Canal. Each new outfall (unless the existing outfalls can be used for the Lower Saunders and Pevey Separation Projects, to be established in final design) will require coordination with Boott Hydropower, which owns and operates the canals, and DCR, who owns the land along the canal. This will require an Article 97 land conversion from parkland to municipal use.

- The Grand Separation Project comprises the separation of 44 acres of combined sewer area by the installation of 7,000 linear feet of proposed drainpipe (ranging from 12 inches in diameter to 60 inches in diameter), with a new proposed outfall discharge to the Pawtucket Canal, near the Boys & Girls Club. The outfall pipe is currently shown along a City easement, but it may require additional easements or land acquisitions to facilitate the pipe construction. The remaining work is on City streets. Note that the School Street Drain Separation and Inland Street Drain are independent projects to be included as part of the Grand Separation Project.
- The Lower Saunders Separation Project comprises the separation of 12 acres of combined sewer area by the installation of 2,000 linear feet of proposed drainpipe (ranging from 12 inches in diameter to 30 inches in diameter). A new outfall discharge to the Pawtucket Canal will be required on private property, including an easement or land acquisition. The remaining work is on City streets.
- The Pevey Separation Project area comprises the separation of 31 acres of combined sewer area by the installation of 5,100 linear feet of proposed drainpipe (ranging from 12 inches in diameter to 3-foot-high by 4-foot-wide box culvert). The outfall pipe is currently shown along a private property and will require an easement or land acquisition.

The total cost of these three projects to resolve the Marginal Interceptor surcharging is \$58.2 million. In Section 7, the annual CSO volume reduction achieved by separating the combined sewer systems in these three project areas is about 18 MG at the Warren CSO Diversion Station.

8.4.2 Combined Sewer Overflow Reduction

The 17 Candidate Areas (excluding Wentworth-Douglas) were considered for their relative CSO reduction potential under the 25 separation projects simulated in Section 7 to identify cost-effective sewer separation projects that could potentially be implemented for the Phase 3 Program. This evaluation to determine cost-effective sewer separation projects was completed by comparing each project to the other Candidate Areas. A more robust determination of cost-effective sewer separation will be completed in the 2034 LTCP, which will evaluate sewer separation compared to other CSO control/mitigation technologies, to identify a long-term system-wide CSO control plan strategy in compliance with the State CSO Policy and the USEPA LTCP Guidelines. Many times, in the development of an LTCP, the system-wide analysis can identify conveyance improvements to centralized storage or

treatment facilities that are more cost-effective than individual sub-area or full-basin sewer separation projects.

Table 7.3 identifies a ranking of each candidate sewer separation project to review the cost per annual CSO volume removed (potential cost-effective CSO removal individually for the Utility's goal of CSO reduction) and the cost per acre of separation (which Candidate Areas might have more effective sewer separation value added). Subsequent Tables 7.4 and 7.5 provide top ranked projects and a priority list of potential projects that could be included in the Phase 3 Program.

Based on this list, and as presented in Section 8.4.1, the Utility selected the Grand, Lower Saunders, and Pevey Sewer Separation Projects as cost-effective, feasible, and future projects that would be considered integral to future long-term CSO control planning. It also would address chronic SSO surcharging.

8.5 Recommended Phase 3 Preliminary Design Report Projects

Based on the system-wide implementation challenges described, the Utility elected to proceed with the Grand, Lower Saunders, and Pevey Phase 3 Candidate Area Separation Projects, based on the current Utility commitment for compliance with the CD.

These projects and their phasing have been identified as follows:

- Phase 3A – Grand Separation Project (including School Street Drain Separation and Inland Street Drain) with construction to be completed by December 2029
- Phase 3B – Lower Saunders Separation Project, with construction to be completed by 2031
- Phase 3C – Pevey Separation Project, with construction to be completed by 2032

Phasing of this Phase 3 Candidate Area separation work was developed to minimize and balance disruptions in the very densely developed area adjacent to the Marginal Interceptor and to balance overall CD Compliance Program spending. Conceptual design plans and profiles for the Grand, Lower Saunders, and Pevey Areas are presented in **Appendix E**.

Figure 8.1 shows the delineation of the three phases of work and the proposed construction schedule. Under Phase 3A, the Utility will also complete separation of the existing School Street drainage system (see Figure 7.9) as described in Section 7. In addition, Phase 3A will also include installation of the Inland Street drain (see Figure 7.10) as described in Section 7.

Table 8.1 presents the Opinion of Probable Construction Cost (OPCC) for each phase of work.

Table 8.1 Cost Breakdown

Description	Phase 3 Sewer Separation Program			
	Phase 3A Grand ¹	Phase 3B Lower Saunders	Phase 3C Pevey	Total
	(Costs in Million \$)			
Construction Cost	\$13.5	\$5.2	\$8.2	\$26.9
CSS ² and Lateral ³ Rehabilitation Allowance	\$5.5	\$2.3	\$2.8	\$10.6
Engineering (20 percent)	\$3.8	\$1.5	\$2.2	\$7.5
Project Contingency (35 percent)	\$6.7	\$2.6	\$3.9	\$13.2
Total Cost	\$29.5	\$11.6	\$17.1	\$58.2

Notes:

1. Phase 3A Grand Sewer Separation includes completion of separation in the School Street Drainage System and the installation of the Inland Street Drain.
2. CSS rehabilitation includes sewer pipe (lining all sewers 1950 and older) and manhole rehabilitation.
3. Lateral rehabilitation assumes lateral lining for the first 20 feet of sewer lateral, one lateral per parcel.

8.6 Phase 3 Preliminary Design Report Implementation Schedule

Figure 8.2 shows the costs and implementation schedule for all Utility CD compliance work. There are no CD milestones for the Phase 3 Sewer Separation Projects, but these will be included upon approval of this Phase 3 Candidate Area Sewer Separation PDR. As shown in this figure and discussed in Section 8.2, the Utility is committed to \$238 million over the next 10 years to complete its CD compliance work, including:

- Sewer Separation of the Centralville Area CSS
- Duck Island WWTP Wet-Weather/Capacity Improvements
- Douglas Road Wet-Weather Storage Tank
- Various CD Compliance Programs Involving CMOM, I/I Reduction, MS4 Compliance, and the LTCP

The value of this work already represents a heavy financial burden on the sewer users in the City and represents significant per annum rate increases. Accordingly, the Utility plans to take a balanced approach to the selection of additional sewer separation projects to be incorporated into the Phase 3 PDR implementation plan by identifying those projects necessary to address chronic SSO discharges and direct public health issues.

These projects (Centralville Sewer Separation Program and the Recommended Phase 3 Candidate Area Separation Program) represent in total a commitment of about \$216 million to separate about 480 acres of combined sewer area in the City (and the removal of three surface water inflow sources of overland flow from nearly 200 acres in Dracut). This represents a 16 percent reduction in the City's CSS.

Figure 8.2 CD Compliance Program Schedule

	Estimated Cost (millions)	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Collection System Maintenance Improvements												
CMOM Program Updates	\$5.0	■	■	■	■	■	■	■	■	■	■	■
Infiltration/Inflow Program												
I/I Reduction Projects in Sanitary System	\$22.0	■	■	■	■	■	■	■	■	■	■	■
Centralville Sewer Separation Program												
Phase 1 - Mainline Conduit and Outfalls	\$57.5	■	■	■	■	■						
Phase 2A - Ennell/Lakeview Area	\$37.0		■	■	■	■	■	■				
Phase 2B - Collector Drains	\$63.4			■	■	■	■	■	■	■		
Subtotal	\$157.9											
Duck Island WWTP Wet-Weather/Capacity Improvements												
Construction	\$27.0		■	■	■	■						
2034 Long Term Control Plan												
LTCP	\$3.0									■	■	■
Stormwater Compliance Program												
IDDE/Phosphorus/Field Support	\$6.0	■	■	■	■	■	■	■	■	■	■	■
Phase 3 PDR Program (SSO Mitigation)												
Douglas Road Wet-Weather Storage Tank	\$17.0		■	■	■							
Phase 3A - Grand (School St.and Inland St.)	\$29.5		■	■	■	■	■	■				
Phase 3B - Lower Saunders	\$11.6				■	■	■	■	■	■		
Phase 3C - Pevey	\$17.1					■	■	■	■	■	■	
Subtotal	\$75.2											
TOTAL	\$296.1	\$8.2	\$48.9	\$57.5	\$48.6	\$35.6	\$37.8	\$22.3	\$22.2	\$6.7	\$4.3	\$4.0

Separation of this combined sewer system area is projected to reduce CSO discharges from the current annual average discharge of 385 MG to 278 MG (a 28 percent reduction).

It is expected that at the end of the CD compliance schedule in 2034 that the Utility will submit a new CSO LTCP. This document will comprehensively evaluate sewer separation for the entire CSS as a strategy to reduce CSO discharges and compare these costs to other appropriate CSO control strategies and technologies (in compliance with the USEPA Guidance for LTCP, 1995, and various updates through new and revised national CSO policies). Sewer separation may not eliminate all public and private inflow in this heavily urban environment, and this remaining inflow may still require additional satellite storage or treatment facilities to achieve higher levels of control than the 3-month frequency. Accordingly, an LTCP will allow the Utility to evaluate a range of robust strategies to identify the cost-effective system-wide strategies for the City, without excessive financial burdens. Implementation of the recommendations in the Phase 3 PDR establishes a completion date of the end of 2032 for Phase 3C, so the LTCP flow metering program can be used to identify the actual CSO reduction benefits achieved by all the sewer separation work in the CD Compliance Program.

As discussed in Section 8.3, it is not practical for the Utility to implement significant larger programs for system improvements at the current time. These sewer separation programs require significant Citywide department coordination, road utility reconstruction, and an extensive public outreach. The burden of these projects affects residents, property owners, businesses, and commuters into the City. To prevent massive disruption in the City, a coordinated and balanced effort is essential. This is crucial given the significant amount of money and redevelopment efforts being made to draw visitors and employers into the City for revitalization. Accordingly, the Utility believes the selection of these high-priority projects for the Phase 3 PDR reflects this careful and thoughtful balance between social disruption and system improvement to address water quality goals.

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