DECEMBER 2023, REVISED JULY 2024

Centralville Sewer Separation Revised Preliminary Design Report

(Humphrey's Brook Revised PDR)

Volume 1 of 2

Prepared for:

Lowell Regional Wastewater Utility

CENTRALVILLE SEWER SEPARATION
REVISED PRELIMNARY DESIGN REPORT
(REVISED CENTRALVILLE PDR)

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.

[signature]

Aaron Fox
Executive Director
Lowell Regional Wastewater Utility

7/31/2024
Date

CDM Smith

July 31, 2024

Mr. Aaron Fox, Executive Director
Lowell Regional Wastewater Utility
451 First Street Boulevard, Route 110
Lowell, Massachusetts 01850

Subject: Revised 2024 Centralville Sewer Separation Preliminary Design Report (Revised PDR)
2024 Consent Decree Paragraph 10 Requirement

Dear Mr. Fox:

On December 29, 2023, CDM Smith submitted the Centralville Sewer Separation Preliminary Design Report (PDR) to the Lowell Regional Wastewater Utility (LRWWU), and the Federal and State regulatory agencies, in accordance with draft Consent Decree (CD) Paragraph 10.

The 2023 PDR provided an evaluation of the Centralville area to develop an engineering approach to separate the combined sewer system serving this neighborhood. Sewer separation of this area will reduce combined sewer overflow (CSO) discharges from LRWWU's collection system. The engineering work included an assessment of the system based on field investigations, extensive computer hydraulic modeling to establish pipe conveyance requirements based on a range of design storms, and the development of 30 percent design drawings (included in Volume 2 of the PDR) that were used to assess pipe route, potential utility conflicts, and construction challenges associated with the proposed separation plan.

Sewer separation of the Humphrey's Brook/Billings Brook Drainage Area (2000 HB PDR Area) is particularly complex due to several factors unique to this drainage area, including:

Topography that transitions sharply from steep slopes in the upper reaches of the basin to flat grades in the lower reaches of the basin, creating the need for large conduits in the lower reaches of the area to convey flow to the river with little slope,

The 96-inch diameter North Bank Interceptor, which runs along the bank of the Merrimack River, severely limiting access for a large new drainage pipe to the river,

The earthen levee, which is part of Lowell's Flood Damage Reduction (FDR) project constructed for flood protection purposes, and VFW Highway (MADOT roadway on top of the levee) along the bank of the Merrimack River, creating construction and permitting complications for any new pipeline to the river,

The West Pump Station, which was constructed for flood protection purposes, and the need to maintain the primary functionality of this station (flood protection) under any recommended sewer separation plan,

- The variability of water levels in the Merrimack River, as high-water levels can create a hydraulic constraint for the discharge of a new drainage pipe to the river.

Several new drain outfall alternatives were evaluated to address the complication of a gravity stormwater discharge into the Merrimack River during river flood conditions. One concept, connecting the new drain to the West Pump Station outfall, was investigated, but it was found to be impractical for the entire drainage area. Accordingly, the PDR developed two other outfall alternatives that would instead convey most of the flow from a new drainage system to dedicated drainage outfalls, with only a small portion of flow from the new drainage system conveyed to the West Pump Station/Outfall (or a new third outfall). These route alternatives provided several benefits to mitigate construction challenges, utility conflicts, and costs. One of these alternatives allowed for the potential future sewer separation of Sewer Area 40, located adjacent to the Humphrey's Brook Drainage Area in the Centralville neighborhood; a new area that was not previously considered in the CD for sewer separation.

These two drain pipe route alternatives were presented in the 2023 PDR but a final decision regarding the selected alternative was extended given the many unique aspects of this project. The 2023 PDR recommended that additional engineering activities continue to advance the design and allow for final selection of a discharge alternative. The additional analysis provided an opportunity to obtain feedback from the regulatory agencies so that these comments could be incorporated into a recommended plan.

Since submission of the 2023 PDR, additional effort was completed to calibrate the CSO model (to identify CSO reduction benefits); to meet with the U.S. Army Corps of Engineers (USACE) and the Federal Emergency Management Act (FEMA) agencies to discuss construction approaches for pipe installation through the earthen levee and to maintain the functionality of the FDR; to meet with various agency heads at the Department of Conservation and Recreation to start the process of obtaining designated state parklands (for the outfalls) via the Commonwealth of Massachusetts Article 97 and Public Land Protection Act (2023) process; and to continue the process of collecting additional topographic survey and subsurface borings to further advance the design.

Concurrently, the Massachusetts Department of Environmental Protection (MassDEP) issued comments to the 2023 PDR in a letter dated March 5, 2024 (with concurrence from the U.S. Environmental Protection Agency, USEPA). LRWWU and CDM Smith met with MassDEP and USEPA on May 10, 2024 to discuss LRWWU's initial responses to the MassDEP comments; to discuss the SWMM calibration of the Centralville combined sewer area; CSO discharge reduction benefits with Centralville separation; and to discuss the challenges of separating the Jewett/Coburn/Hampshire Street subarea of the Humphrey's Brook Drainage Area (near the West Pump Station).

Based on this discussion, MassDEP and USEPA provided positive feedback on LRWWU's recommended plan that incorporates the separation plan for Humphrey's Brook area as follows:

- Proceed with the Phase 1 design and construction of the Centralville main line drain pipe with a new outfall at Bunker Hill Avenue;

Complete separation of Sewer Area 40 as a future Centralville Phase 2 project with a new outfall at Aiken Street, along with separation of the remaining Humphrey's Brook combined sewer area (with the exception of bullet below); and

Incorporate future separation of Jewett/Coburn/Hampshire Street area as part of the future Phase 3 PDR (due on December 31, 2024) for prioritization.

LRWWU appreciates the MassDEP comments received in the March 5, 2024. The 2023 PDR was revised (to be referred to as the Revised 2024 PDR) to incorporate the response to these comments (and our discussion with the agencies) to develop a phased recommended plan. The following presents the MassDEP comments (**in bold**) and LRWWU's response (*in italics*) with references to sections of the Revised 2024 PDR that provides further detail to each comment, where applicable.

1. **The PDR indicated that the City deploys level monitors in the sewer system at some locations to provide real-time information on system surcharging. The City should include a map showing the locations of the level monitors***.*

   Response*: Figure 2-11 shows the SSO level Sensor locations in Centralville near 34 Coburn Street and 776 Lakeview Ave.*

2. **The PDR mentions potential "green solutions" without any detail on locations where use of green infrastructure could be effective. The Final PDR should include and assessment for incorporating these elements into the design plan. It appears there may be some city-owned sites in the project area that may hold potential for such projects.**

   Response*: The City is committed to incorporating green infrastructure into the sewer separation projects. The potential for green infrastructure will be assessed during each of the future pipeline design phases. At that time, more information (such as survey, borings, identification of available city property, etc.) will be available to determine the most effective locations for green infrastructure, if applicable.*

3. **The PDR includes a figure showing measured versus modeled Humphrey's Brook flows (fig. 4-3) while, as noted In the PDR, no consistent bias is clear, and there are some substantial discrepancies in the measured versus modeled flows which raises some concerns. The Final PDR should include a discussion of the model calibration, and use of 2023 flow data, which has been cited as a potential issue.**

   Response: *The Collection System SWWM calibration was completed and presented to MassDEP/USEPA at the May 10, 2024 meeting. Figure 4-3, noted in the comment above, was removed from Section 4 in the Revised PDR and a summary of the SWMM calibration is included in Volume 2 of the Revised PDR.*

4. **Estimate of CSO abatement: The central goal of the sewer separation work is to mitigate CSO discharges from the City's combined sewer system. The Final PDR must include an estimate of the projected CSO abatement benefits to be achieved upon completion of the Centralville Sewer**

Separation work. Where some of these benefits can be achieved incrementally, those benefits should be described in the Final PDR, with the work phased to optimize water quality benefits.

Response*: CSO reduction potential with the proposed sewer separation was discussed during the May 10, 2024 meeting and are included in Section 7 (Table 7.4 shows the incremental benefits of the sewer separation areas).*

5. **Upper Jewett/Hampshire Street area:**

   a. **CDM should indicate if use of a regulator structure to divert (surcharged) flows from a potential new drain system to the existing combined sewer was considered as a means to address any risk of street flooding, which is expressed as a major concern. This could further maximize sewer separation in the project area and reduce risk of street flooding.**

      Response*: LRWWU appreciates the MassDEP suggestion to approve and permit the construction of a diversion structure of drain flow into the sewer system so that this excess flow (to avoid street flooding) can be discharged to the Merrimack River via the West Pump Station during high river levels. As we discussed, separation of the Jewett/Coburn/Hampshire area will be considered in the Phase 3 PDR and the Revised Centralville PDR was modified accordingly.*

   b. ***The City is recommending exclusion of this 32-acre area from the sewer separation work and has indicated that a design including a new stormwater outfall on Aiken Street will afford the opportunity for an even larger area to be separated (Area 40), which could offset the impact of this exclusion. However, it does not appear that the City is committing to the Area 40 sewer separation work, deferring any recommendations in that Area until the successive Phase 3 Sewer Separation PDR, which is more focused in scope on the City's combined sewer system south of the River.***

      Response*: As discussed during the May meeting, SWMM simulations show an equivalent CSO reduction benefit for separation of the Jewett/Coburn/Hampshire Street area and Sewer Area 40. Based on our discussion, the Revised PDR was modified to incorporate the separation of Sewer Area 40, and the Aiken Street outfall, into the Centralville Phase 2 Sewer Separation program. Sewer separation of the Jewett/Coburn/Hampshire area will be considered in the Phase 3 PDR.*

   c. **The PDR has no estimate of the incremental increase in CSO activations and volumes, which may occur by excluding the Upper Jewett/Hampshire Street area. This information needs to be provided.**

      Response*: See responses above for Comments 5a and 5b.*

d. **For the PDR to be approvable by MassDEP, it must either include a plan to separate the 32 acres in the Upper Jewett/Hampshire Street area (by making modifications to the current plan to divert surcharged flows to the existing combined sewer, if feasible) or a commitment to complete Area**

40 sewer separation work as part of the Centralville Sewer Separation project (i.e., not delay it to Phase 3 Sewer Separation).

***Response**: See the response to Comment 5b.*

6. **The cost estimate carries $20-$27 million for sewer separation in area 40, depending on which of the two alternatives is selected. CDM should clarify if this represents partial or full sewer separation in that area.**

   ***Response**: See the response to Comment 5b. LRWWU is committed to fully separating Sewer Area 40 in the Centralville Phase 2 program as discussed in this Revised PDR.*

7. **Final Recommended Sewer Separation Plan and Schedule: The Final PDR must include a listing and schedule of design and construction work, identifying all key deadlines to complete the recommended work in accordance with the provisions of the Consent Decree. That listing must include, at a minimum:**
   a. **The scope and plan to complete work to incorporate infiltration/inflow removal, including private inflow removal, into the design of the sewer separation work;**
   b. **Completion dates and sequencing for the permitting, design and construction work; and,**
   c. **Cost estimates for each phase of the work.**

   ***Response**: Section 8 of the Revised PDR includes an updated implementation schedule with cost estimates with each phase of work as required to meet the CD deadlines.*

We believe that this 2024 Revised PDR addresses the March 2024 MassDEP/USEPA comments to the 2023 PDR and provides an approvable implementation plan to completing a cost-effective, technically sound approach, to separate major portions of the Centralville area in compliance with the intent of the CD. We remain available to discuss the contents of the report further as the City and/or regulators require.

Sincerely,

Michael J. Walsh, P.E.
Senior Vice President
CDM Smith Inc.

cc: Evan Walsh, Lowell Regional Wastewater Utility

Contents

Figures

Tables

Appendices (Volume 2)

Acronyms and Abbreviations

ACP	Asbestos Cement Pipe
ADR	Automated Defect Recognition
AI	Artificial Intelligence
AO	Administrative Orders
ARI	Average Recurrence Intervals
AUL	Activity and Use Limitations
BVW	Bordering Vegetated Wetland
CB	Catch Basin
CCTV	Closed-Circuit Television
cfs	Cubic Feet per Second
CIPP	Cured-in-Place-Pipe Lining
City	City of Lowell, Massachusetts
CMP	Corrugated Metal Pipe
CMR	Code of Massachusetts Regulations
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DCR	Department of Recreation and Conservation
Duck Island	Duck Island Wastewater Treatment Facility
DPW	Department of Public Works
EEA	Executive Office of Energy and Environmental Affairs
EJ	Environmental Justice
ENF	Environmental Notification Form
EENF	Expanded Environmental Notification Form
FEMA	Federal Emergency Management Agency
FDR	Flood Damage Reduction System
FIRM	Flood Insurance Rate Map
fps	Feet per Second

GIS	Geographic Information System
GMPS	Inland Water/Green Mountain Pipeline Services
gpd/in-mile	Gallons per Day per Inch-Mile
GP	General Permit
GPM	Gallons per Minute
GPS	Global Positioning Satellite
HB	Humphrey's Brook
HGL	Hydraulic Gradeline
I/I	Infiltration /Inflow
ICP	Integrated Capital Plan
LCD	Lowell City Datum
LoF	Likelihood of Failure
LOMR	Letter of Map Revision
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
MCP	Massachusetts Contingency Plan
MEPA	Massachusetts Environmental Protection Act
mgd	Million Gallons per Day
M.G.L.	Massachusetts General Law
MHC	Massachusetts Historical Commission
MHD	Massachusetts Highway Department
MS4	Municipal Separate Storm Sewer System
MTBM	Micro Tunnel Boring Machine
NAD	North American Datum

NASSCO	National Association of Sewer Service Companies
NAVD	North American Vertical Datum
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOAA	National Oceanographic and Atmospheric Administration
NOI	Notice of Intent
NPC	Notice of Project Change
NPDES	National Pollution Discharge Elimination System
O&M	Operations and Maintenance
OB	Observation Well
OOC	Order of Conditions
OPCC	Opinion of Probable Construction Cost
OSHA	Occupational Safety and Health Administration
PACP	Pipeline Assessment Certification Program
PDR	Preliminary Design Report
PID	Photoionization Detector
PLPA	Public Land Preservation Act
PM	Particulate Matter
PNF	Project Notification Form
PVC	Poly Vinyl Chloride
RAO	Response Action Outcome Statement
RCP	Reinforced Concrete Pipe
RDA	Request for Determination of Applicability
RTN	Regional Tracking Numbers
SRF	State Revolving Loan Fund
SSES	Sewer System Evaluation Survey
SSO	Sanitary Sewer Overflow
SV	Self-Verification
SWMM	Stormwater Management Model
USACE	United States Army Corps of Engineers

USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Utility	Lowell Regional Wastewater Utility
VCP	Vitrified Clay Pipe
WWTF	Wastewater Treatment Facility

1.0 Introduction

1.1 Background

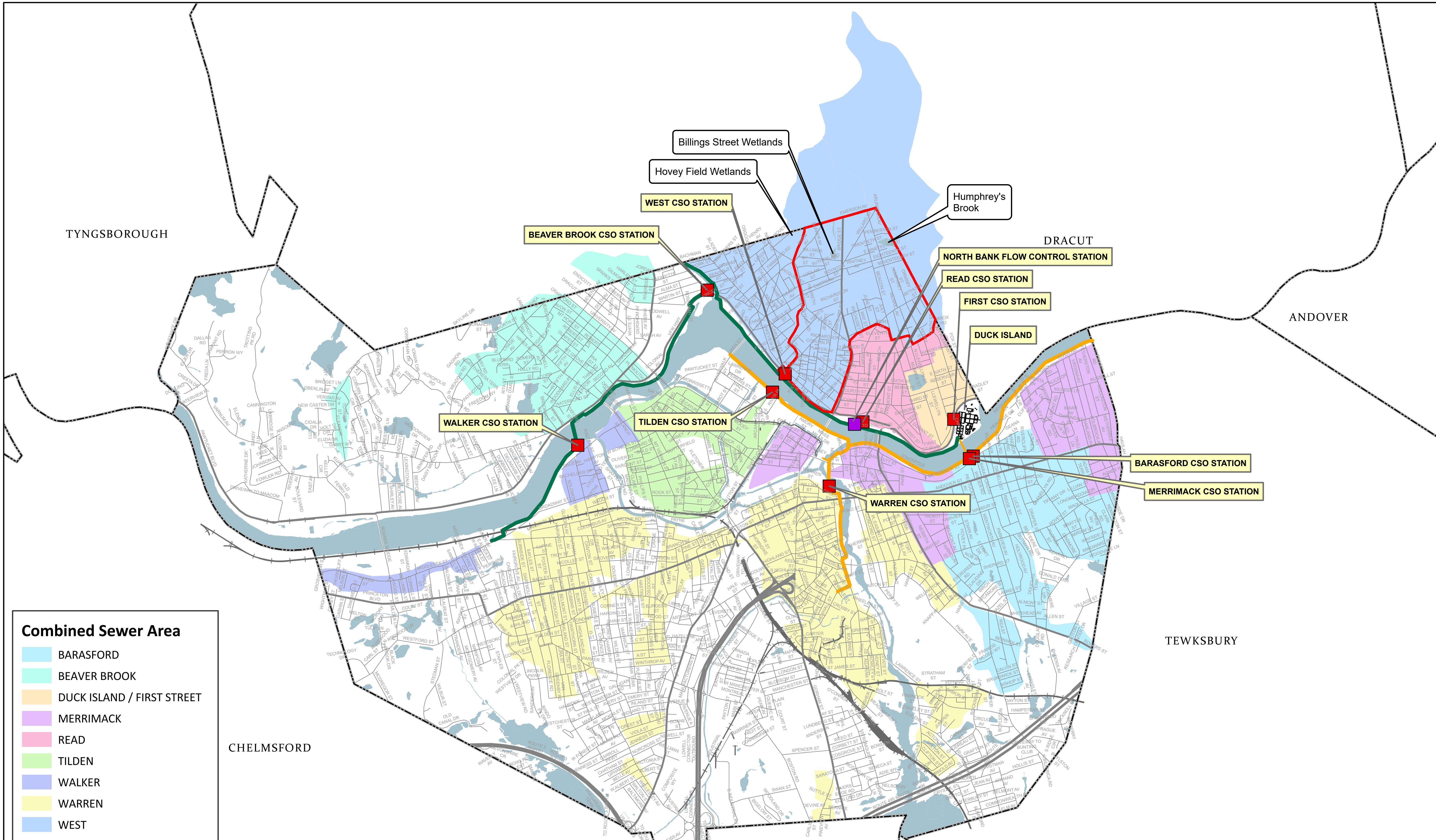
The City of Lowell, Massachusetts (City) has a combined sewer system (CSS) like many older cities in the northeast United States. The CSS was originally designed to convey both sanitary wastewater (residential, commercial, and industrial flow) and stormwater flow within a single pipe in the street. During 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 the Duck Island Wastewater Treatment Facility (Duck Island) and sewer and drainage collection system facilities in the City.

LRWWU has nine permitted outfalls where untreated CSOs discharge from the combined sewer system during rain storms. The CSOs discharge to Beaver Brook (Beaver Brook Station #007-SDS#2), the Concord River (Warren Station #020-SDS#6), and the 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, Merrimack Station #030(2)). **Figure 1.1** shows Lowell's combined sewer and sanitary sewer systems.

This Centralville Sewer Separation Preliminary Design Report (Centralville PDR – December 31, 2023; Revised July 31, 2024) focuses on a portion of the tributary basin contributing combined sewer flow to the West Station, which includes the CSO Diversion Structure, West Station Outfall and the West Pump Station. Dry weather flow and portions of wet weather flow received at this station are conveyed to Duck Island via a direct connection to the North Bank Interceptor System; excess wet weather flow is diverted at the CSO Diversion Structure away from the North Bank Interceptor System into the West Station Outfall as either gravity discharge or into the West Pump Station, as a pumped discharge via the West Station Outfall, during significant rain events.

The West Station is an integral part of the City of Lowell's Flood Damage Reduction System (FDR System), installed in the late 1930s by the U.S. Army Corps of Engineers (USACE), to protect low lying areas of the City from Merrimack River Floodwaters. The pump station operates, in unison with a system of earthen levees and concrete I-walls, to pump out wet weather sewer flow into the Merrimack River during periods of high river conditions to avoid property flooding.

The tributary combined sewer basin addressed in this report is referred to as the Centralville CSS, which includes the Humphrey's Brook Area (as identified in the 2000 Humphrey's Brook Area Combined Sewer Separation Project Preliminary Design Report, discussed in Section 1.2, and referenced hereinafter as the 2000 HB PDR) and Sewer Area 40. Humphrey's Brook is an unnamed surface water system with overland drainage running through the Town of Dracut into Lowell's CSS at Humphreys Street in Lowell (at the Dracut border). The moniker for the brook was generated based on the prior evaluation report where CSO planning efforts focused on eliminating Humphrey's Brook flow from the sewer system to reduce CSO discharges using a new separate main drain conduit with a new discharge to the Merrimack River.



Legend

- North Bank Interceptor
- South Bank Interceptor
- Diversion Station and CSO Outfall
- North Bank Flow Control Station
- 2000 HB PDR Area

0 1,000 2,000 4,000 Feet

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 1.1
Existing Combined Sewer System

During prior system assessments, two additional surface drainage inflow sources (from Dracut) were also identified and added to the list for removal from the sewer system - the Billings Street Wetlands at Billing Street and a stream from Dracut that enters the Lowell CSS near Hovey Field (Hovey Field Wetlands). These CSS inflow locations are shown on Figure 1.1, along with the boundaries of the Dracut tributary drainage area, which encompasses approximately 450 acres outside the City limits.

1.2 Project History

Under the Clean Water Act (CWA) of 1986, municipalities nationwide must take steps to reduce or eliminate CSO discharges to receiving streams to improve water quality. In response, the United States Environmental Protection Agency (USEPA) issued a series of interim CSO control policies and adopted a final 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. The Massachusetts Department of Environmental Protection (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 combined sewer systems must submit a Long-Term Control Plan (LTCP) that identifies a program to abate CSO discharges.

In 1988, the USEPA alleged that the City was discharging pollutants into waters of the United States from CSO outfalls and certain unauthorized discharge points in its wastewater collection system in violation of the National Pollutant Discharge Elimination System (NPDES) permit and Section 301 (a) of the CWA. Accordingly, the United States, the Commonwealth of Massachusetts, and the City entered into a Consent Decree (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, since the original 1988 Consent Decree, including the 1990 CSO Facilities Plan and the (1998) 2002 Revised Draft Long-Term CSO Control Plan. These planning documents was developed to address changing federal and state CSO control regulations, policies, and provide updated planning approaches; update the existing Stormwater Management Model (SWMM) hydraulic model of the CSS for system evaluation; identify and quantify progress on implementation of past CSO abatement measures; assess the benefits achieved by these implemented measures; and to 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 City’s CSS.

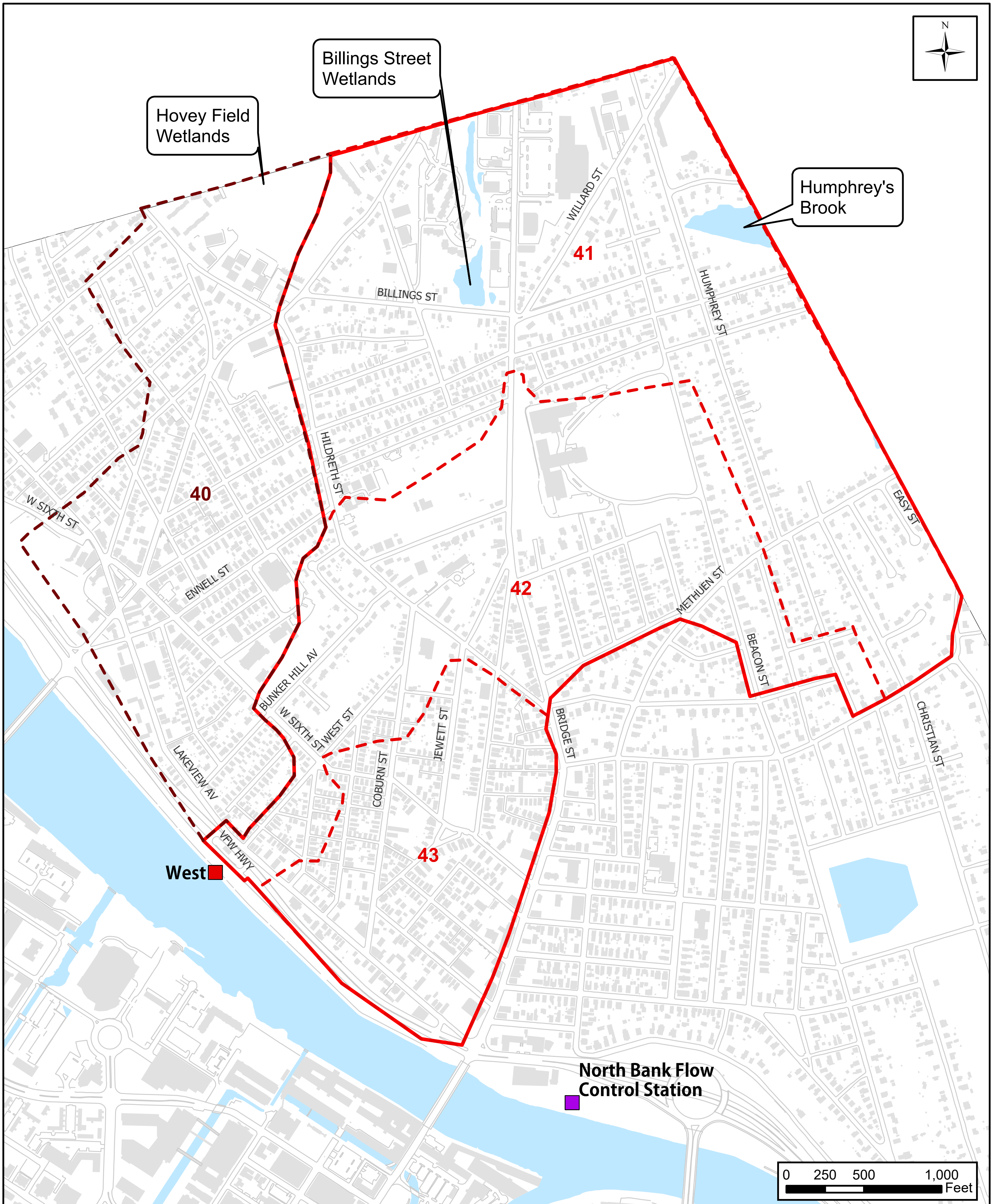
The USEPA issued Administrative Orders (AOs) at the conclusion of each of the LTCPs, and several in the interim periods, to facilitate additional planning and capital improvements to reduce uncontrolled CSO discharges from Lowell’s CSS. Capital improvements included Duck Island improvements to maximize and provide reliable treatment of wet weather flows reaching Duck Island, sewer separation of key areas of the system including the Warren CSO Basin, implementation of real-time instrumentation and control to facilitate the use of in-line interceptor pipeline storage (including the construction of the North Bank Flow Control Station), and a sewer system rehabilitation program.

The potential to separate the Humphrey's Brook Basin was initially considered in the 1990 CSO Facilities Plan but it was not determined to be a high priority. As part of the development of the 2002 Revised Draft LTCP, CDM Smith (formerly CDM) completed a report entitled Conceptual Sewer Separation Plan for Selected Areas (June 1998). This report presented an initial evaluation of the City's CSS to identify drainage areas where the existing collection system could be readily separated (due to the proximity of nearby drainage channels) or where sewer separation could eliminate significant inflow sources such as streams and brooks entering the CSS. Based on the analyses, CDM Smith (formerly CDM) selected seven (7) key drainage areas and developed conceptual sewer separation plans, showing the potential routes of a new drainage piping system for each drainage area. These 7 drainage areas were also subject to excessive street flooding where sewer separation could reduce the street flooding potential and reduce CSO discharges.

Based on the 1998 Conceptual Sewer Separation Plan for Selected Areas, the City engaged CDM Smith (formerly CDM) to complete the 2000 HB PDR, which focused on separation of Sewer Areas 41, 42, and 43 as shown in **Figure 1.2**. Initial costs and construction challenges were identified for the sewer separation of the basin in this report and a comparison was made to other CSO control strategies in the 2002 Revised Draft LTCP. Based on this assessment, and negotiations with USEPA and MassDEP, the City received an AO (Docket 03-22) from the USEPA that required implementation of a different set of system improvements as CSO control priorities in a compliance schedule including:

- Modifications to Duck Island to improve wet weather treatment capacity;
- Modifications to four CSO diversion stations (Read, Tilden, Merrimack, and Warren) to increase the use of in-line interceptor storage and reduce CSO discharges; and
- Completion of the Warren Street CSO Drainage Basin Sewer Separation Preliminary Design and implementation of its recommendations.

In June 2022, the regulatory agencies, along with the U.S. Department of Justice and the Commonwealth of Massachusetts Department of Justice, began negotiations to develop a new Consent Decree (CD) with violation findings (NPDES permit, Section 301(a) of the Clean Water Act, and provisions of the 2003 Small MS4 General Permit) and remedial measures to address these violations. Negotiations continued through 2022 and 2023. The CD was fully executed and filed with the US District Court on May 17, 2024 (Case: 1:24-cv-1290-DJC, Document 13, .



Legend

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

Sewer Area

- 40
- 41, 42, 43
- 2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 1.2

Centralville Sewer Separation PDR Area

Based on this CD, under Section VI. Remedial Measure (Paragraph 10), the City must:

> *On or before December 31, 2023, the City shall submit to EPA and MassDEP for review and approval a Preliminary Design Report and Sewer Separation Implementation Schedule for the Humphrey's Brook/Billings Brook drainage area ("Humphrey's Brook PDR)." The Humphrey's Brook PDR shall 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 with the goal of sequencing the work to achieve the greatest CSO reduction benefits; and identify major technical and permitting issues. The Humphrey's Brook PDR shall include cost estimates for the recommended work, and shall specifically incorporate the following provisions:*
>
> *a. Conceptual design plans which will result in the separation of the sewer and storm drain system throughout the Humphrey's Brook/Billing's Brook drainage area;*
>
> *b. Phasing of the sewer separation work to achieve:*
>
> *i. Removal of Humphrey's Brook flows from the City's combined sewer system, including surface flows from the Town of Dracut, by December 31, 2027; and*
>
> *ii. Separation of the sewer and storm drain system in the Humphrey's Brook/Billing's Brook drainage area by December 31, 2031.*
>
> *c. Engineering design plans for each phase of the work shall be approved by MassDEP prior to commencing construction.*

The Centralville Sewer Separation Preliminary Design Report (Humphrey's Brook PDR), Volumes 1 and 2 (CDM Smith, December 2023) was submitted to MassDEP and USEPA on December 29, 2023, thereby meeting the Consent Decree schedule. In correspondence dated March 5, 2024, MassDEP provided the Utility with comments on the PDR (MassDEP March 5, 2024 letter included in Volume 2). This 2024 Centralville Sewer Separation Revised PDR addresses MassDEP's comments. The City responses to the comments were also presented by the City and CDM Smith to MassDEP and USEPA in a meeting held on May 10, 2024. An important revision to the 2023 PDR is the inclusion of Sewer Area 40 as part of the Centraville area evaluated for sewer separation. The inclusion of this area extends the boundary of the study area outside the original HB PDR area, as shown on Figure 1.2. The Revised PDR outlines the recommended phased implementation plan for sewer separation of the Centralville area. Specific responses to the MassDEP comments of March 5, 2024 are included in the transmittal letter to this Revised PDR.

It is important to note that the project has been a priority for the City for many years but due to the significant cost and construction challenges, separation of the Humphrey's Brook Basin has been deferred while more cost-effective CSO control and sewer separation projects were implemented. During Consent Decree negotiations, separation of the Humphrey's Brook Basin CSS was adopted as one of the renewed priorities based on system surcharging and street flooding in several areas of the basin. This is a similar approach that the City has undertaken in its previous sewer separation projects, i.e., to provide property owners with a solution to reduce the impact of excessive rainstorms in the City.

1.3 Purpose

The purpose of this report is to provide an updated preliminary design of the proposed sewer separation of the existing Centralville area identified in the 2000 HB PDR area (Sewer Areas 41, 42, and 43 in the CD), plus a new preliminary design of Sewer 40, which now addresses more of the Centralville area. All these areas drain to the West CSO Station and separation of the respective combined sewer areas will result in CSO reduction at the station. Figure 1.2 shows the boundaries of Sewer Area 40, 41, 42 and 43.

This report includes the development of preliminary design plans and profiles of all proposed new drain piping to fully assess pipe connectivity, potential underground utility conflicts, outfall locations, update implementation/construction costs, and to further consider permitting and construction challenges (based on past City sewer separation projects).

System operations have changed since the initial 2000 HB PDR including the re-activation of the West Pump Station and recognition of the adjacent earthen levee system along the Merrimack River as an important function of the City's FDR Project. In addition, this report is intended to utilize new system flow metering (obtained in 2023 as part of the concurrent Infiltration/Inflow (I/I) Analysis Plan) to update the SWMM model for analysis of CSO benefits achieved by separation of the combined sewer area tributary to the West Station and CSO Outfall. The report includes the identification of the Phase 1 and Phase 2 Humphrey's Brook project components to meet Consent Decree Paragraphs 10.b.i and 10.b.ii, presented above.

1.4 Study Area

Figure 1.2 shows the boundaries of the Revised PDR study area. Humphrey's Brook and the Billings Street Wetland inflow sources connect through Sewer Area 41 on the upstream side of the basin. Another Dracut inflow source, Hovey Field Wetlands, enters the sewer system in Sewer Area 40.

The study focuses on a majority of the Centralville neighborhood of the City north of the Merrimack River. Approximately 490 acres of the Revised PDR area are located within the city limits.

The Centralville study area is characterized by steep hills in the north and east portions of the basin, which descend into the flatter catchment area just north of the VFW Highway. Land use is primarily one- and two-family homes and small multifamily properties in the mid- to north portions of the neighborhood, while more densely developed areas with multi-story apartment buildings and small commercial businesses are in the southern portion of the basin.

1.5 Approach

The preliminary design is intended to identify the most feasible and cost-effective alternative for new piping systems to remove the Humphrey's Brook, Billings Street Wetlands, and Hovey Field Wetlands inflow from the CSS and provide for eventual sewer separation of the adjoining collection system in the drainage area. This report summarizes the extensive field investigations, preliminary design drawing development, hydraulic evaluation, and alternatives analyses conducted to complete and enhance the preliminary design for sewer separation of this area.

Preliminary engineering for the project consisted of the following activities:

- Collection of available information, mapping, and reports related to the ongoing assessment and conceptual design of the separation work for the Humphrey's Brook Basin;
- Completion of field investigations to evaluate potential pipeline routes, existing utilities, 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, 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 drain pipes;
- Development and use of a hydraulic SWMM of a new drain system and the surface input of the Humphrey's Brook/Billings Street Wetlands/Hovey Field Wetlands area, using flow data, to develop a drain pipe network optimized for hydraulic conditions and pipe slopes;
- Re-development and calibration of the existing combined sewer SWMM model to provide simulations of CSO benefits that may be achieved by the phased separation program;
- Identification of permitting issues and environmental impacts along the proposed routes;
- Completion of initial subsurface investigations to identify potential bearing soil and environmental issues, if any, along with bedrock depths;
- Field survey to support the evaluation of alternatives and development of design drawings;
- Evaluation of pipe route alternatives to minimize project costs and surface disturbances during construction;
- Preparation of plan and profile drawings to identify critical elevation conflicts with existing underground utilities;
- Estimation of most probable construction and projects costs for the recommended alternative plans;
- Development of a comprehensive preliminary design report to summarize the findings and provide recommendations along with an implementation schedule; and
- Development of a preliminary design report to summarize the findings.

2.0 Existing System

2.1 General

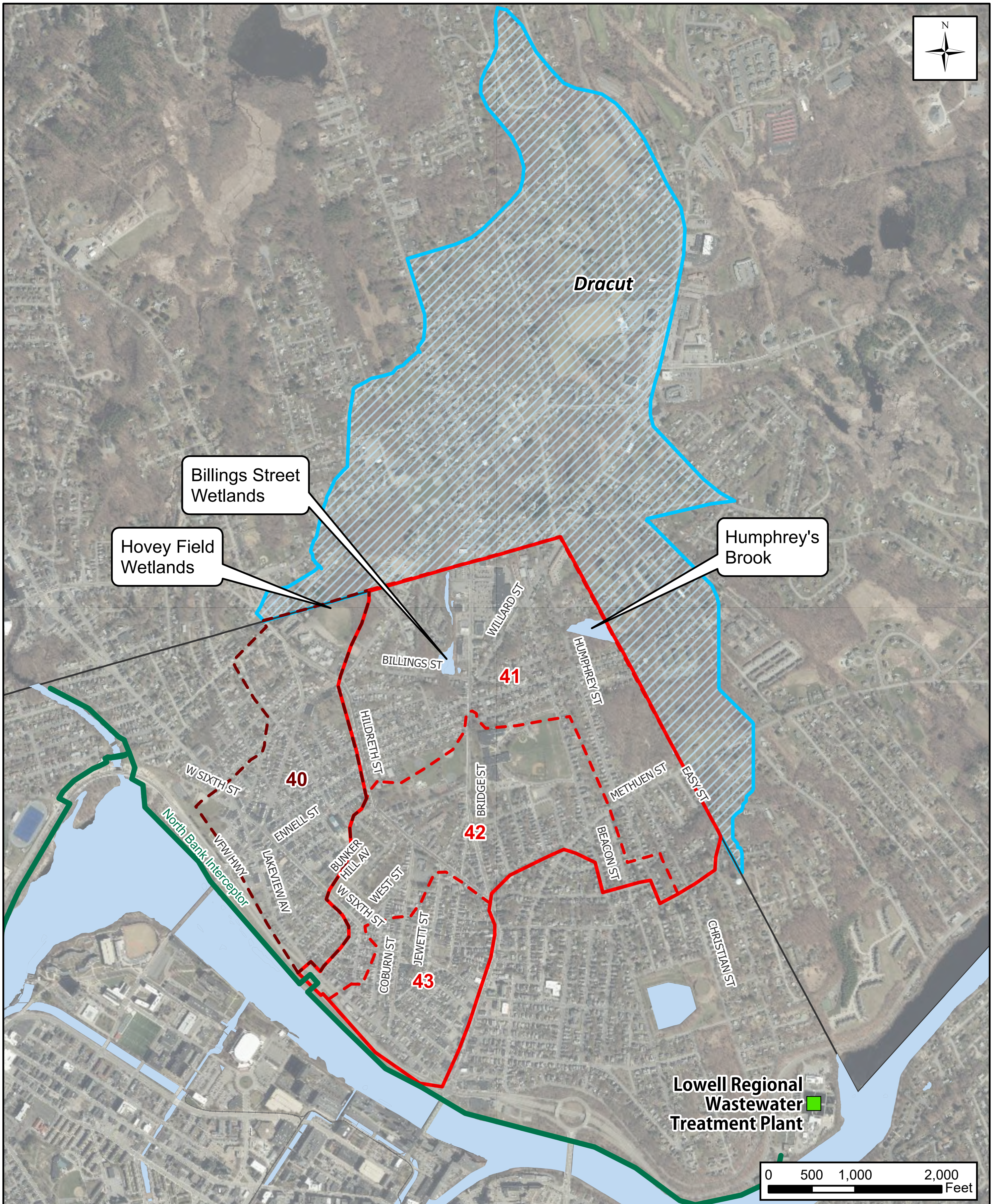
An understanding of the existing CSS is important to develop and evaluate piping alternatives that will effectively separate the 2000 HB PDR Area and Sewer Area 40. This requires an assessment of the condition of the existing pipe network, including a review of structural pipe integrity, reliability, and operation of the collection system, and a review of available records and anecdotal information regarding system problems (such as sewer back-ups, street flooding, etc.).

An analysis of the existing pipe network is also necessary to identify current conveyance capacity. The level of service provided by the existing combined system (i.e., the capacity to convey a certain sized storm event) should be maintained or improved through the installation of new pipes to separate the existing system. This is considered in Section 4 Hydraulic Modeling of the Drainage System and Section 6 Development of Alternatives.

Figure 2.1 shows the Centralville study area, which is comprised of Sewer Areas 41, 42, and 43, which were included in the 2000 HB PDR Area and Sewer Area 40, which was included in the Revised PDR. All areas are comprised of a combined sewer system that collects stormwater and wastewater flow from nearly 490 acres in Lowell and conveys it by gravity to the West CSO Station and then to the 96-inch diameter North Bank Interceptor that runs along the Merrimack River.

Dracut has a sanitary sewer system that enters Lowell's sewer system at many points at the boundary between the two communities into Centralville. More importantly, Dracut has separated drainage systems that also contribute runoff to the LRWWU sewer system at three key locations as shown on Figure 2.1 - Humphrey's Brook at Humphrey Street, the Billings Street Wetlands at Billings Street, and Hovey Field Wetlands that enter Lowell at Hovey Field near Hildreth Street. The Dracut surface flow covers about 450 acres. However, it is important to note that the surface water in Dracut is composed of a series of wetlands and hydrologic flow conditions that tend to dampen peak flow. As a result, the net runoff generated by the Dracut portion of the area tributary to the Lowell system is much smaller per acre than the runoff generated by the City's combined sewer system.

Figure 1.1 showed the interceptor system, which conveys flow from west to east along both banks of the Merrimack River to the Duck Island Wastewater Treatment Facility, located on the north bank side of the Merrimack River. The plant has a design capacity of 32 MGD for dry-weather flow and a wet-weather treatment capacity of up to 112 MGD, with a bypass of the secondary aeration/biological treatment process. All flows are chlorinated before discharge to the Merrimack River.



Legend

- Lowell Regional Wastewater Treatment Plant
- North Bank Interceptor
- Dracut Surface Water Tributary Area

Sewer Area
- 40
- 41, 42, 43
- 2000 HB PDR Area

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DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR

Figure 2.1
Centralville Project Area

2.2 Topography

Figure 2.2 shows the existing topography and key features of the Centralville study area. The terrain includes steep hills in the north and east with the ridge running along Beacon Street. This ridge serves as a divide of the Methuen Street area, a portion of which flows east towards Dracut; the remainder of the street and study area flows to the west. The Methuen Street area combined sewer flow follows a circuitous path flow east into Dracut, then north up to Humphrey's Brook, where it enters the sewer collection system at Humphrey Street and drains southwest.

The main sewer conduit, shown in purple in Figure 2.2, predominantly follows along the old streambed from Humphrey's Brook to the Merrimack River. The high elevations along the Beacon Street ridge rapidly descend north and west toward the main collector line as sewer flow is conveyed by gravity (following topography) downstream into the western and southern regions of the system. Generally, the western and southern regions approaching the Merrimack River are much flatter. Flow from the main collector continues southwest through this flat, lower elevation area, toward West Street/VFW Highway and then the North Bank Interceptor at the West CSO Diversion Structure. VFW Highway (constructed in the 1960s) is located on an earthen levee system originally constructed by the US Army Corps of Engineers in the 1940s.

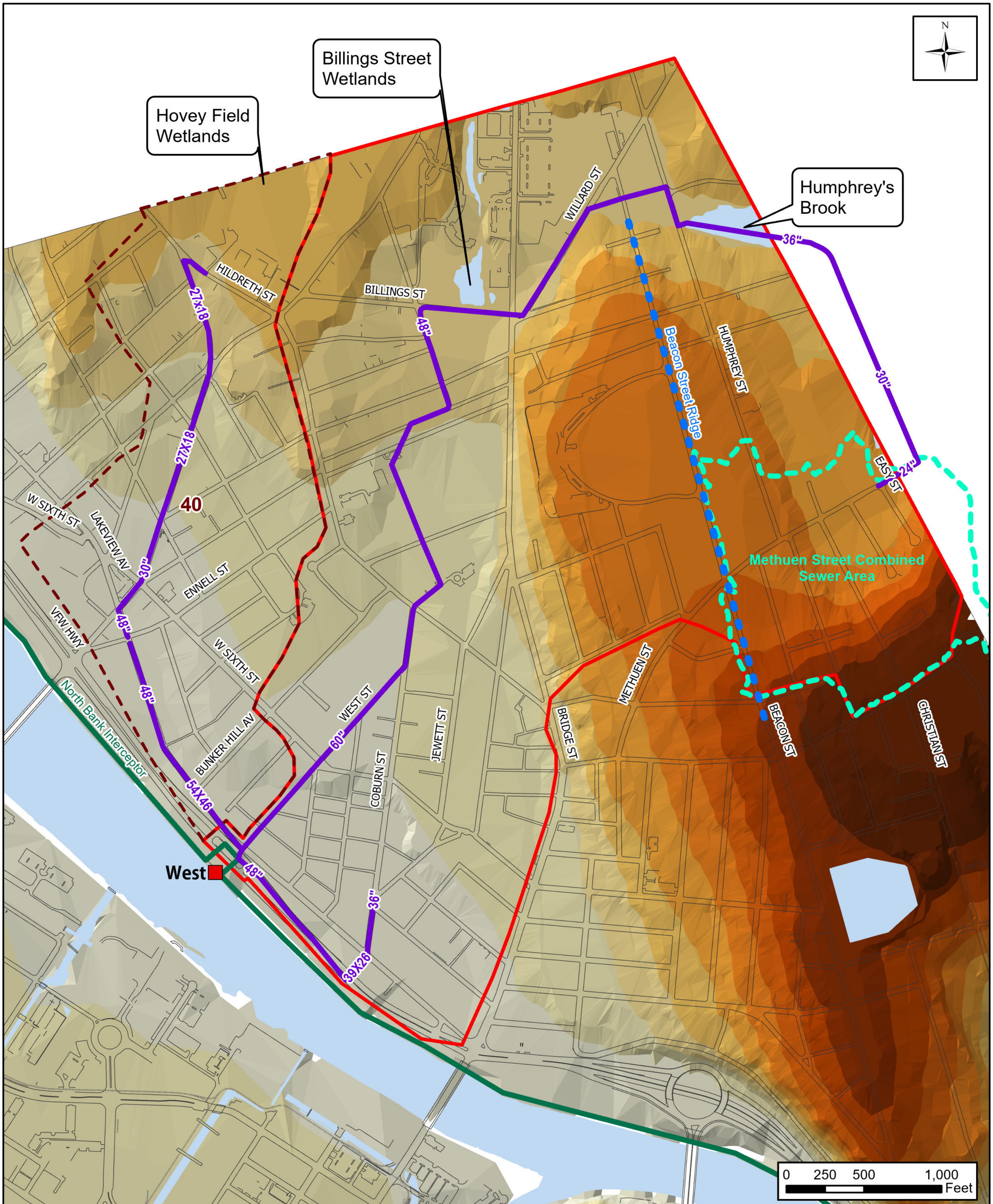
These topographical features are a significant factor in the design of new gravity wastewater or stormwater collection systems in Lowell as the new pipes should follow this topography to avoid deep and expensive excavations. Pipes in the upper portion of the study area with steep terrain can have steeper pipe slopes, which can decrease new pipe sizes in these areas. In the lower parts of the basin near the river, the pipe slopes are flatter to match terrain to minimize pipe burial depth and to eventually connect the drain outlet to the river above the river bottom. Flatter pipe slopes increase the pipe sizes for the same conveyance capacity.

2.3 Combined Sewer System

2.3.1 Overview

Figure 2.3 shows the existing CSS in the Centralville study area. Based on the Utility's GIS records, the existing combined sewer system in the 2000 HB PDR Area (Sewer Areas 41, 42 and 43) is comprised of approximately 60,000 linear feet of sewer pipe ranging in size from 8-inch to 60-inch diameter pipe and non-circular brick pipe. Sewer Area 40 contains an additional 22,000 linear feet of sewer pipe. This sewer collection system conveys sanitary sewage, surface runoff collected by the City's catch basins, and other sources of public and private infiltration and inflow (I/I) to the North Bank Interceptor. Infiltration, typically from groundwater, enters the system through the aging City sewers and potentially through private property sewer laterals. Private inflow enters the City's sewer via catch basins or yard drains, roof drain/downspout connections, or basement drains or open sewer cleanouts.

There are three major surface water sources, primarily from Dracut, that discharge to the CSS: Humphrey's Brook, Billings Street Wetlands and Hovey Field Wetlands. There is a short segment of drain on Easy Street that has a separate outfall pipe. There are also three areas with stormwater drain systems that recombine to the sewer system - Christian Street, McPherson Park, and Robinson Middle School/McAuliffe Elementary School.



Legend

Elevation (ft)
Max: 300
Min: 61

Diversion Station and CSO Outfall

Main Sewer Conduit

North Bank Interceptor

Methuen Street Combined Sewer Area

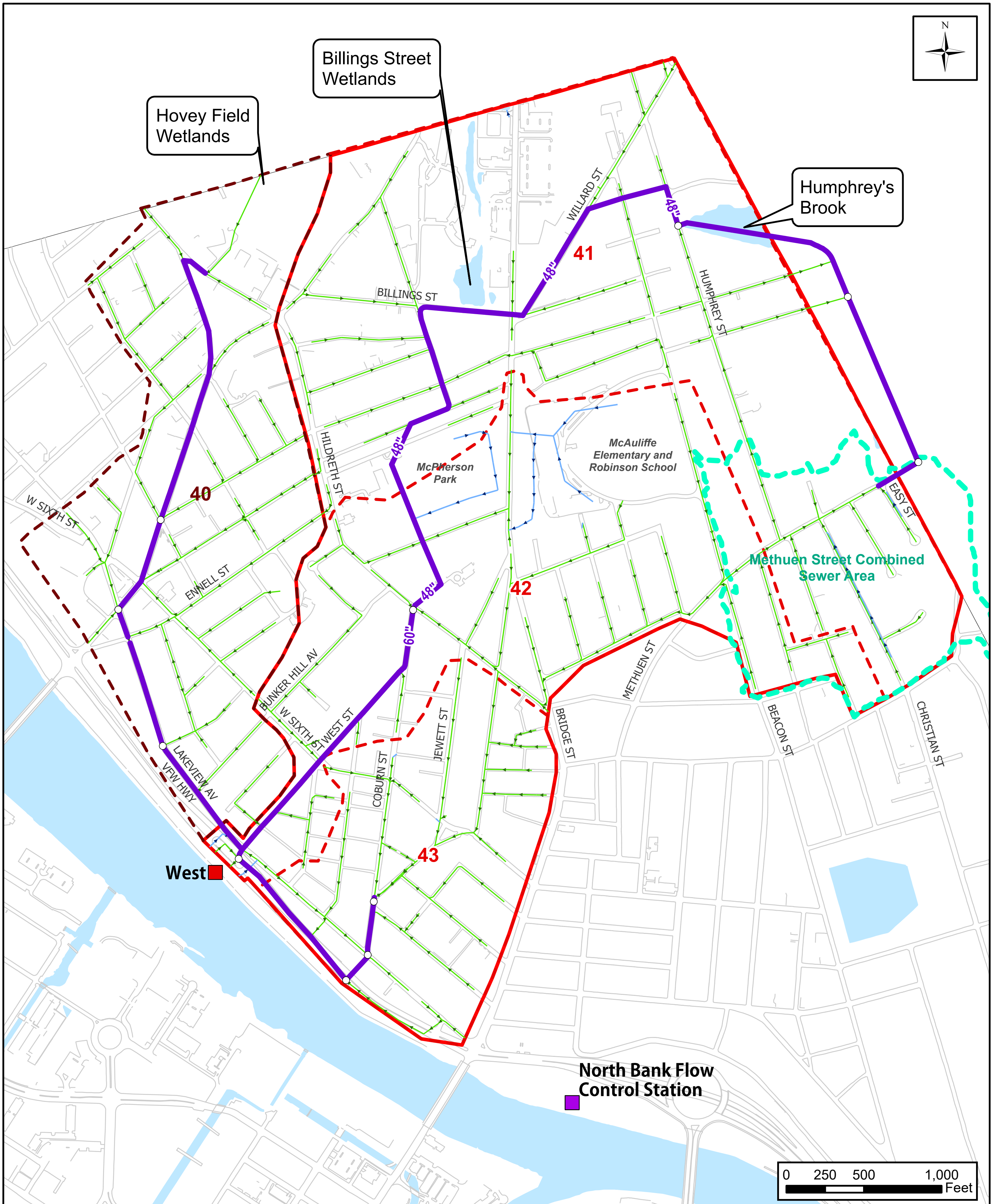
Sewer Area 40

2000 HB PDR Area

Lowell, Massachusetts
Centralville Sewer Separation
Revised PDR

Figure 2.2

Topography and Existing System



Legend

- Diversion Station and CSO Outfall
- North Bank Flow Control Station
- Pipe Diameter Change
- Main Drain Conduit
- Sewer Gravity Main
- Existing Drain
- Methuen Street Combined

Sewer Area
- 40
- 41, 42, 43
- 2000 HB PDR Area

CDM Smith

DUCK ISLAND — LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts
Centralville Sewer Separation
Revised PDR
Figure 2.3
Combined Sewer System

There are nearly 300 LRWWU catch basins in the 2000 HB PDR Area and approximately 80 catch basins in Sewer Area 40 that collect surface water runoff from City streets.

2.3.2 Main Conduit

As shown in Figure 2.3, the existing combined sewer in the Centralville study area is served by a main collector sewer that begins at the inlet for Humphrey's Brook (on Humphrey Street) and flows downstream to the West Station.

Figure 2.4 Humphrey's Brook

The Humphrey's Brook inlet structure is composed of a stone headwall as shown on **Figure 2.4**. The inlet structure directs Humphrey's Brook through a short segment of 36-inch pipe into a manhole on the 48-inch combined sewer in Humphrey Street. That Humphrey Street 48-inch brick sewer also collects wastewater flow from the 36-inch sewer originating from the Methuen Street Area. The 48-inch combined sewer runs north along Humphrey Street before cutting cross-country to the west to connect with Willard Street. The 48-inch line then runs southwest down Willard Street, crosses Bridge Street, and enters Billings Street.

Figure 2.5 Billings Street Wetlands

The Billings Street Wetlands flows into the sewer through a concrete inlet control structure located on the north side of Billings Street. Flow enters the structure via openings on each side and a grate on top and is connected to the existing 48-inch brick sewer. **Figure 2.5** shows the Billings Street Wetlands and inlet structure. The main conduit continues along several streets and a cross-country segment through McPherson Park before eventually connecting with a 60-inch combined sewer line at the intersection of Coburn Street and Hildreth Street. The 60-inch brick conduit then continues down Coburn and West Street, where it connects to the 96-inch North Bank Interceptor at the West Street CSO Diversion Structure.

Sewer Area 43 flows are conveyed by a second larger collector pipe beginning at the intersection of Coburn Street and Jewett Street as a 36-inch pipe that immediately transitions to a 39-inch by 26-inch brick sewer. The alignment continues south along Coburn Street where it then crosses Lakeview Avenue and travels cross country to the VFW highway where it connects to the West Station.

Figure 2.3 also shows the Methuen Street combined sewer area. As mentioned above, this area drains to the northeast because of its topography into Dracut. This local combined sewer system collects flow from nine streets in the eastern section of the project area. The flow then travels further east on

Methuen Street into Dracut where it turns north and runs cross country before discharging into the Humphrey's Brook sewer adjacent to the Humphrey's Brook inlet point.

Area 40 flows are conveyed to the West Station beginning on Hildreth Street at the northern end of this basin. Surface flow from the Hovey Field Wetlands enters a pipe that proceeds under Hovey Field and connects to the sewer on Hildreth Street. **Figure 2.6** shows the Hovey Field inlet for Dracut flow. The Hovey Field inlet is a 24-inch diameter connection pipe to the 27-inch by 18-inch brick sewer on Hildreth Street just east of Essex Street. The collector combined sewer follows Hildreth Street north for a short segment, runs south on Essex Street to Aiken Avenue, and then follows Lakeview Avenue where it combines with the 60-inch West Street pipe and connects to the West CSO Diversion Structure. The brick sewer increases along this run up to a 54-inch by 46-inch brick sewer.

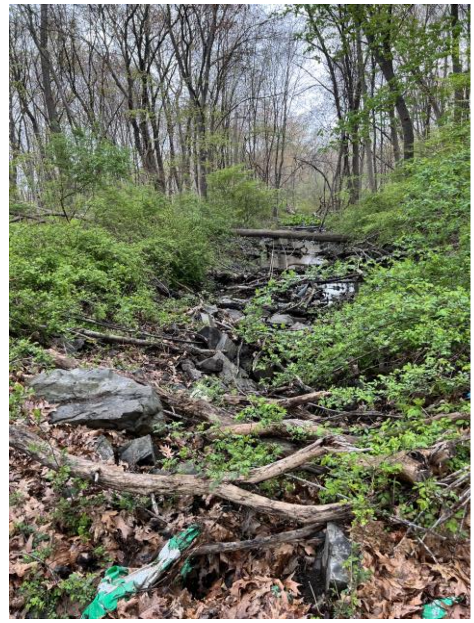


Figure 2.6 Hovey Field

The remaining Centralville study area is comprised of 8-inch to 36-inch collector sewers that extend out from the mainline conduits described above.

2.3.3 System Characterization

Table 2.1 provides a summary of the pipe material breakdown for the Centralville area. Pipe materials include vitrified clay pipe (VCP), cast iron, concrete, and brick. About 22 percent of the pipes in these two systems is comprised of pipe equal to or larger than 24-inch diameter pipe. Most of the pipe larger than 24 inches in diameter is brick pipe.

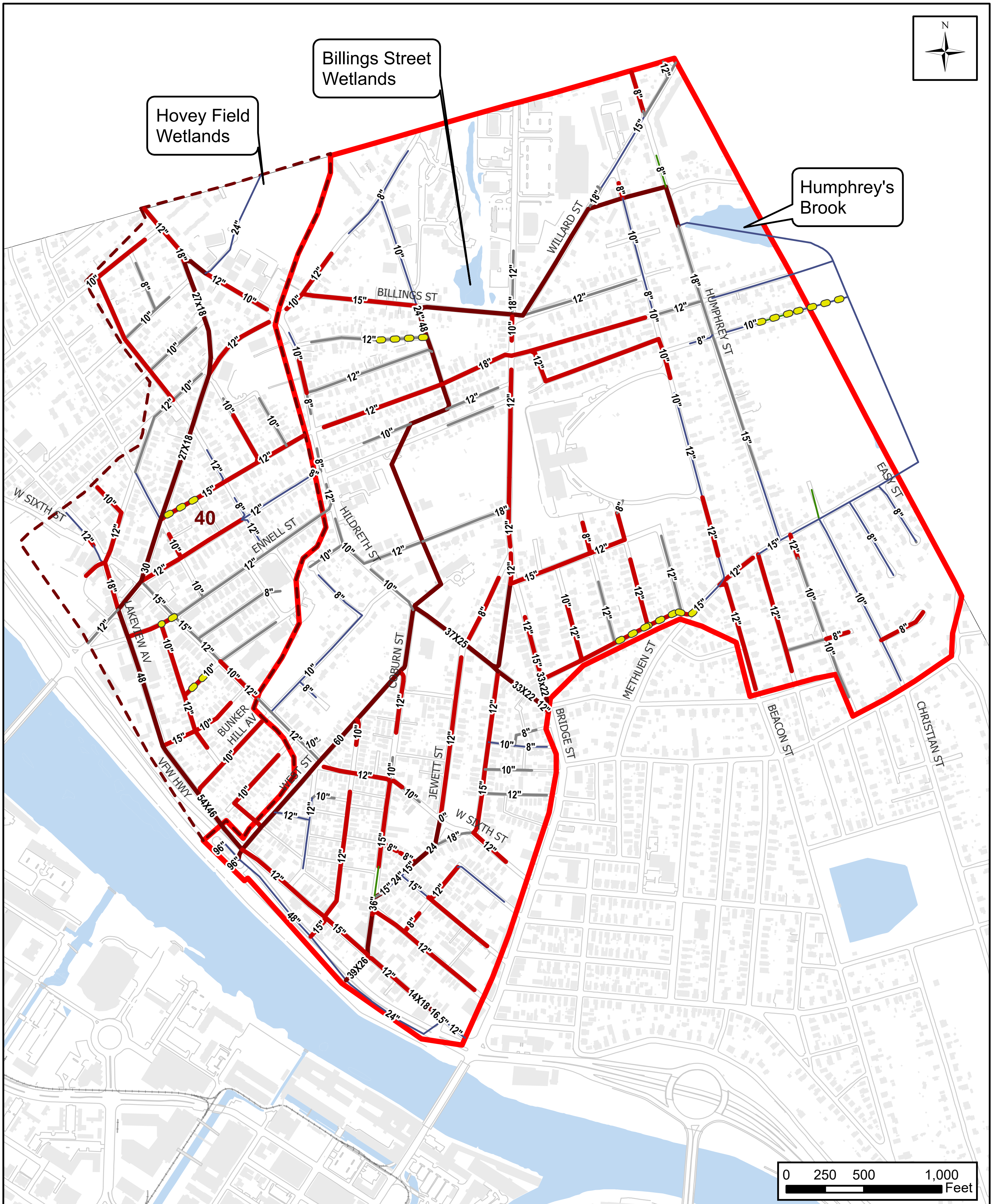
Of the pipe in the Centralville area that is smaller than 24 inches, approximately 37 percent (32,000 linear feet) is comprised of VCP. This pipe material has exhibited problematic early failures in other sewer systems and may be at the end of their useful material life and/or may be sources of excessive infiltration. Accordingly, the City may want to examine these pipe segments and consider holistic replacement and/or installation of a Cured-in-Place-Pipe Lining (CIPP) liner to protect the pipe during construction and extend its useful life. More discussion on rehabilitation will be introduced in Section 3.

Figure 2.7 provides a plan depiction of the pipe materials in these sewer areas.

Figure 2.8 shows the existing pipe age distribution in the Centralville area. Much of the existing piping system was built in the late 1800s and early 1900s; a significant majority of the pipes are over 73 years old (approximately 90 percent). These pipes are nearing the end of their useful life (especially considering the additional time required to replace or to rehabilitate this pipe). **Section 3** considers the age of the system further along with the pipe material in developing a system rehabilitation plan.

Table 2.1 Centralville Pipe Material Summary

Pipe Diameter	Pipe Material (LF)						Total LF
	VCP	PVC	Conc	Brick	CIP	UNK	
Unknown	1,041		136	926	43	494	**2,639**
8-inch	1,901	406	2,792			595	**5,694**
10-inch	864	251	5,032			3,550	**9,697**
12-inch	13,547		2,115			5,721	**21,383**
14x18				125			**125**
15-inch	3,713	201	1,979	46		1,312	**7,250**
16.5-inch			55				**55**
18-inch	1,110					1,922	**3,032**
24-inch			1,921	403		90	**2,415**
30"			1,157				**1,157**
33x22				520			**520**
36-inch			1,336				**1,336**
37x25				689			**689**
39x26				217			**217**
48-inch			1,047	4,552			**5,599**
54x46				209			**209**
60-inch				2,011			**2,011**
96-inch			280				**280**
2000 HB PDR Area Total							**64,309**
Unknown	931						**931**
8-inch			165			474	**639**
10-inch	3,132					1,725	**4,856**
12-inch	4,318		1,655			3,086	**9,060**
15-inch	1,125					564	**1,689**
18-inch	393						**393**
24-inch			744				**744**
27x18				1,918			**1,918**
30-inch				650			**650**
48-inch				924			**924**
54x46				633			**633**
Sewer Subarea 40 Total							**22,436**



Legend

Sewer Gravity Main

Material

- VCP
- Brick
- CIP
- PVC
- CONC
- UNK
- CIPP Lined Pipe
- Sewer Area 40
- 2000 HB PDR Area

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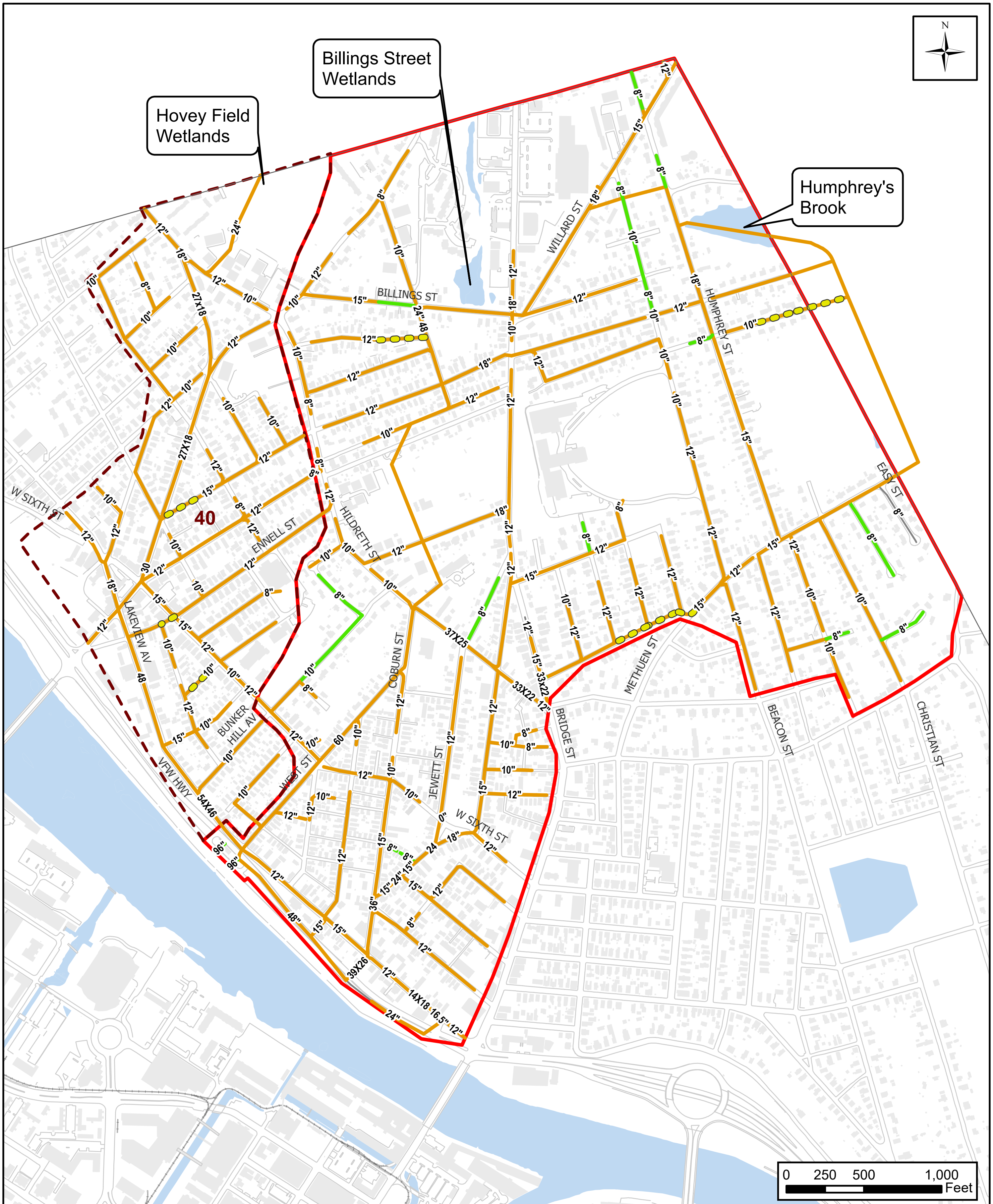
Lowell, Massachusetts
Centralville Sewer Separation
Revised PDR

Figure 2.7

Pipe Material



Legend

Sewer Gravity Main

Date Installed

- 1951 - 2021 (2 - 72 Years Old)
- 1836 - 1950 (73 - 187 Years Old)
- Unknown Age

CIPP Lined Pipe

Sewer Area

- 40

2000 HB PDR Area

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Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 2.8

Pipe Age

2.3.4 West Station CSO Diversion Structure and West Pump Station

The West Station identified on **Figure 2.9** shows a location plan of the components that include the West Pump Station and CSO Diversion Structure in the median of the VFW Highway, and the West Station Outfall that discharges to the Merrimack River.

The West (Flood) Pump Station was originally constructed by the U.S. Army Corps of Engineers (USACE) after significant river flooding occurred in the City during the 1936 storm. The flood improvements included an earthen levee and concrete I-wall system to protect the low-lying Centralville area just to the north of the pump station. The pump station was designed to discharge combined sewer flow from the Centralville area into the Merrimack River. The pump station includes a gravity and a pumped head discharge of sewer flow via the same outfall.

In the 1970s, the Duck Island and the North Bank Interceptor were constructed, along with the West CSO Diversion Station. Flow from the 96-inch diameter North Bank Interceptor and flow from Centralville (including the Humphrey's Brook drainage area in Dracut) are conveyed into the diversion structure. Dry-weather flow and a portion of the wet-weather flow is passed through this structure into the lower segments of the North Bank Interceptor. Excess wet weather flow is diverted to the gravity CSO outfall via a CSO diversion sluice gate in the structure; the sluice gate is remotely and automatically actuated. If river levels are high, greater than 54.0 Water Surface Elevation according to the USGS Gage Datum, the West Pump Station could be activated. **Figure 2.10** shows a schematic of the flow path around these facilities.

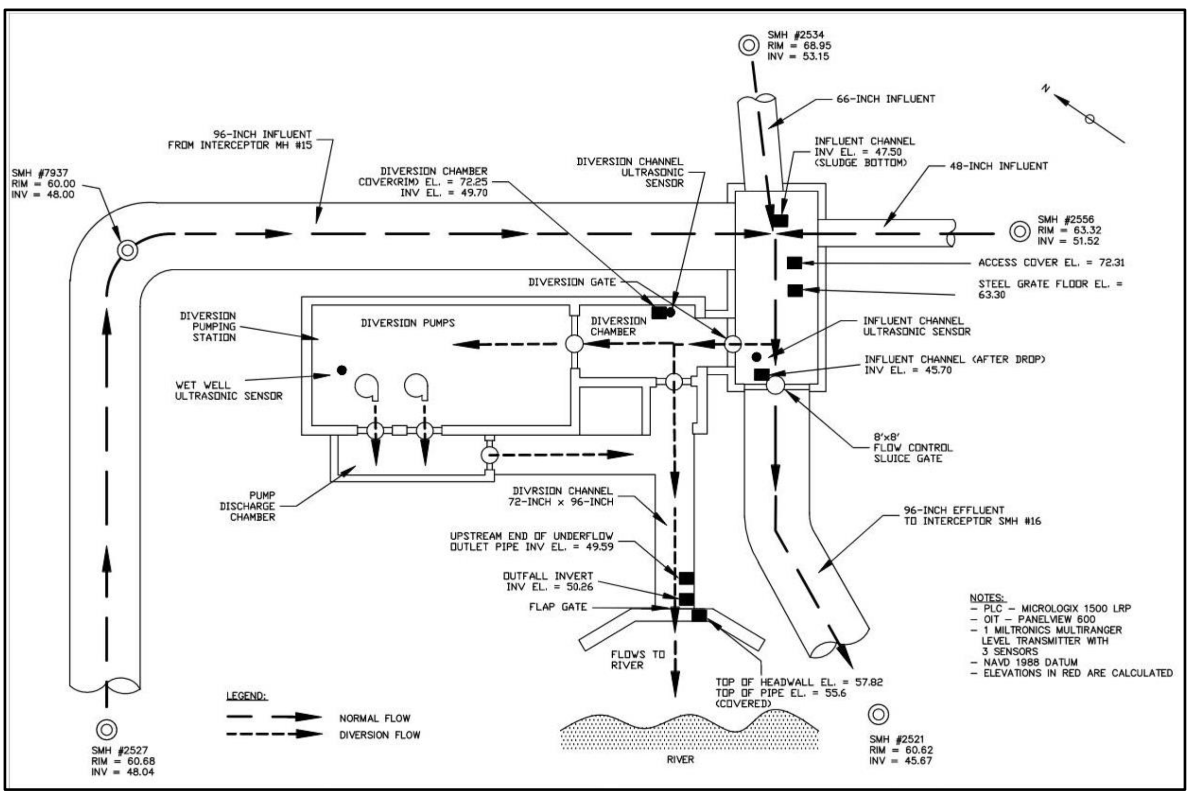


Figure 2.10 Flow Schematic for the West Pump Station and CSO Diversion Structure

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 2.9
West Station CSO Diversion Structure and West Pump Station

The West Pump Station was inoperable for several decades. During an inspection by USACE in 2007, several deficiencies were noted regarding the inoperable state of the West Pump Station. Studies were completed to determine the improvements necessary to reactivate the station including an assessment of the effective pump capacity required to meet the Federal Emergency Management Agency (FEMA) standards for flood protection and re-certification of the Flood Insurance Risk Maps for this low lying area upstream of the station.

It was determined that rehabilitation of the pump station was the most cost-effective approach to return the station to its functional status and that the effective station capacity should be 60 MGD. Station Improvements were completed in 2018.

In addition to the station, a new structure was added to the North Bank Interceptor, downstream of the West Station near the Read CSO Station, to allow LRWWU to use inline interceptor pipeline storage using an automated inline flow control sluice. Currently, the flow control gate at the North Bank Flow Control Station is operated to store flow in the 96-inch interceptor pipe. Flow depth will increase during inline storage use at the CSO Diversion Structure. When flow depths exceed certain limits, the CSO Diversion Structure sluice gate will open to discharge excess wet weather flow as CSO to the gravity outfall or to the West Pump Station.

2.4 System Surcharge and Street Flooding Conditions

2.4.1 Overview

It is important to understand the current level of system surcharging and street flooding in the study area to implement system improvements that could mitigate these conditions.

Street and/or basement flooding commonly occurs in combined sewer systems as a result of:

- Limited capacity of the existing combined system to handle wet-weather flows,
- Limited capacity of catch basins to allow flow into existing piping,
- Existing topography (low-lying areas), and
- High groundwater.

Depending on the intensity of a given storm, the existing combined system may surcharge and cause flooding in low-lying areas. Surcharging occurs when the capacity of a given piping system is exceeded, causing the hydraulic grade line (HGL) of the system to rise above the crown of a given pipe. The height of the HGL can be readily observed at drain or sewer manholes along the surcharged section. Under surcharged conditions, combined systems often flood basements and low-lying homes.

Several sources of information were used to identify and document existing adverse system conditions. These included reported street flooding conditions after historic and recent storm events, the Commonwealth of Massachusetts Sanitary Sewer Overflow (SSO) Notification Forms, temporary level sensor data, staff discussions, and the online Sewer Issues and Street Flooding Survey. This survey was recently deployed on LRWWU's website to solicit and catalogue public input on a variety of sewer/collection system related issues for this study and the ongoing Phase 3 Sewer Separation

Preliminary Design Report. Public input received for the Centralville study area will be considered during future design phases.

Figure 2.11 shows a summary of these wet weather issues.

2.4.2 Street and Property Flooding

Historically, parts of the Centralville Area have experienced flooding during storm events. **Figure 2.12** and **Figure 2.13** show recent examples of street flooding in 2023.

Figure 2.12 Flooding at Stanley Street and Blinkhorn Avenue during a Summer 2023 storm

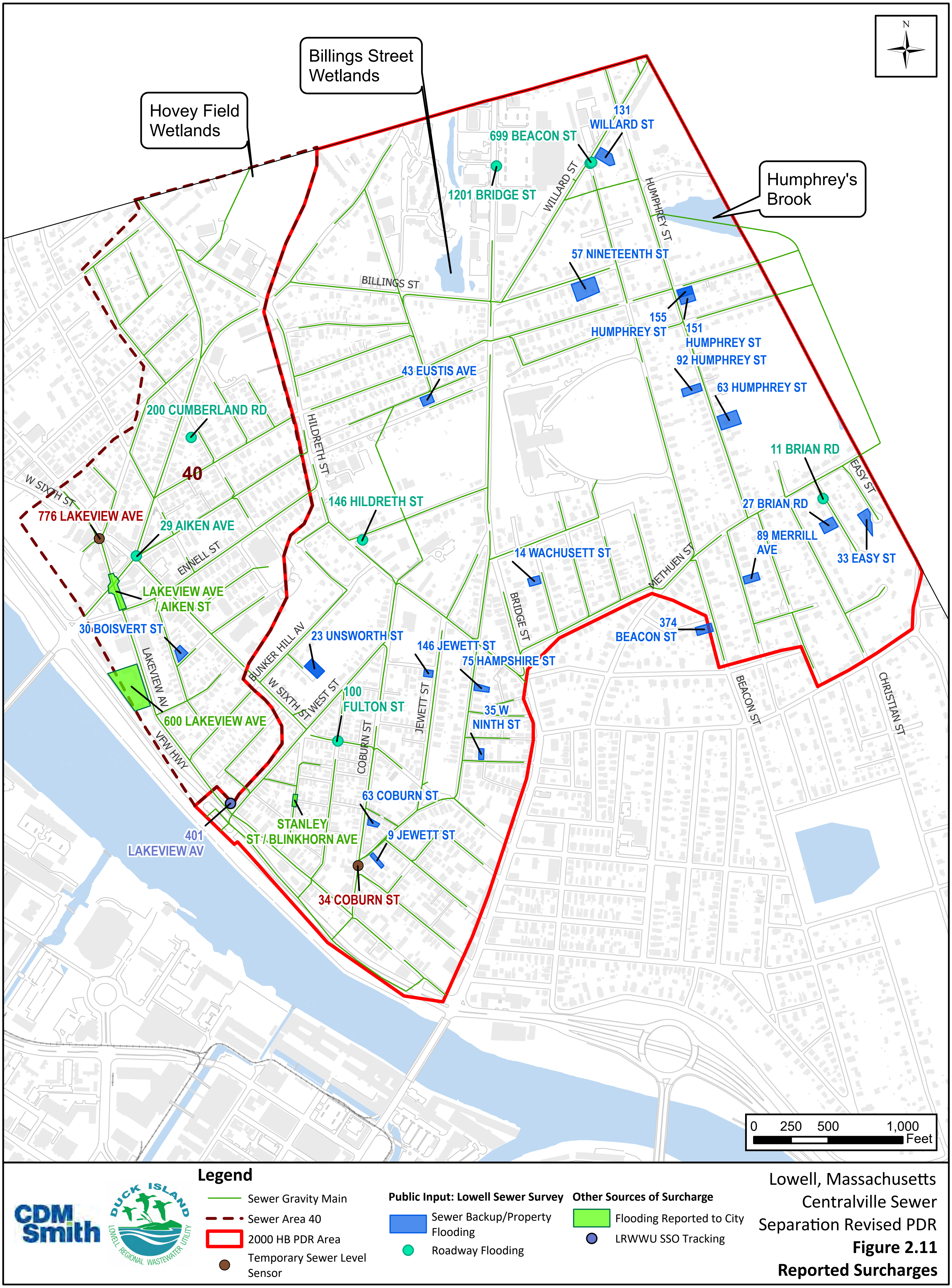
Figure 2.13 Flooding at Lakeview Avenue and Aiken Street during a Summer 2023

2.4.3 SSO Notification Forms

In a CSS if there is a discharge of sanitary sewer or combined flow to the surface, especially to a surface water, it must be reported to MassDEP via the SSO Notification Forms. The Utility can be alerted to an SSO event by level monitors installed at key locations of known sewer surcharges, property owners reporting a discharge by phone, and/or by Civic Plus notifications submitted by residents.

After a notification of the condition, the Utility makes a field inspection to assess the situation and cleanup the area, and then submits the SSO notification form to MassDEP.

Figure 2.11 shows a summary of the wet-weather related SSOs that occurred in the study area for 2023.



Lowell, Massachusetts
Centralville Sewer
Separation Revised PDR
Figure 2.11
Reported Surcharges

In 2023, the vast majority of the 49 SSO events in Lowell occurred via surcharged combined system manholes. However, there was only one SSO event within the Centralville area; this occurred at 401 Lakeview Ave, where a sanitary sewer manhole surcharged in the street.

2.4.4 Public Input

The Utility has created an online Sewer and Street Flooding Issues Survey, available in English, Spanish, Portuguese, and Khmer (https://www.lowellma.gov/637/Wastewater-Utility), to actively solicit input on adverse sewer system conditions within the City. Figure 2.14 shows the first page of this online survey. Residents, visitors, and property owners in Lowell have been notified of the availability of this survey via mailings, public notifications, newspaper articles, website notifications, and electronic media postings.

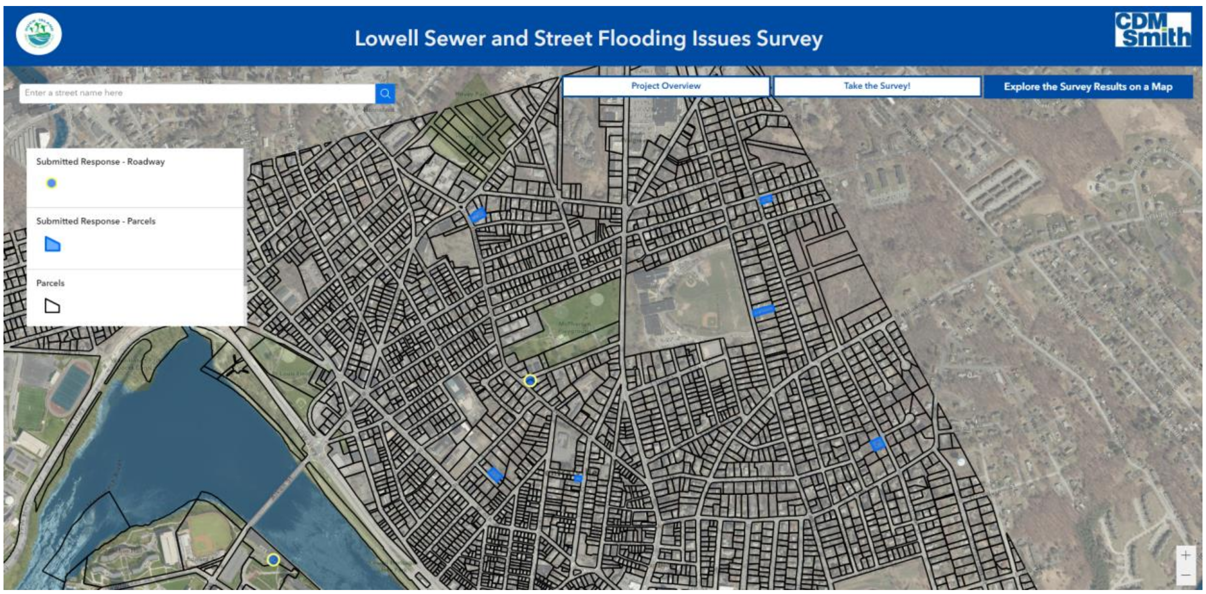


Figure 2.14 Online Lowell Survey

The survey allows the public to provide valuable first-hand experience on how the existing combined sewer system operates and the data collected through this survey will be beneficial in prioritizing future system improvement projects. The survey includes questions on the presence of sump pumps in buildings, historical basement flooding, and adjacent street flooding. It provides a platform for residents, property owners, and visitors to report on issues in the City.

At the time of the December 2023 Centralville PDR, seven responses had been received in the Humphrey's Brook study area. Figure 2.11 shows locations where flooding was reported.

- Flooding has been observed at McPherson Playground on Richardson Street (reported by 146 Hildreth Street),
- Sewer backup and leakage are reported at 155 Humphrey Street,
- 146 Jewett Street reports flooding on the property that started in 2023, that prevents parking, and
- 23 Unsworth Street reports that there is sewer flooding on the property.

Three additional responses were received from residents who reported no issues at 315 Hildreth Street, 503 Beacon Street, and 320 Christian Street.

This on-line survey continues to be available to City residents. At the time of this Centralville Revised PDR (July 2024), approximately 66 responses were received in the Centralville area with 28 reporting a flooding or backup issue (10 additional in Area 40 with 4 reported as having issues). The City continues to review and consider these responses. As appropriate, this information will be incorporated into future sewer separation implementation projects if system improvements are necessary.

2.5 Utility Replacement Needs

The existing combined sewer system in the Centralville area is primarily located along the centerline of the street. Most streets also contain a water main on one side of the combined sewer and a gas main on the other. To accommodate some of the larger lateral drains, either a gas or water main will need to be relocated to develop a dedicated corridor for the new pipe. These relocations will be identified as part of the final design process. Based on experience, conflicts with electric conduit and telephone duct relocations are usually avoided because of the long lead time to coordinate and complete relocation of these utilities.

Many of the existing water mains in the Centralville area are older cast iron, which may be susceptible to damage during construction due to vibration or excavation if too close to the work. On a case by case basis, cast iron water mains that will not be relocated could be replaced with a new ductile iron water main or lined with a structural liner (if practical). LRWWU will work with the Lowell Regional Water Utility to identify water main replacement needs for the project and overall City infrastructure renewal.

Gas mains may also need to be relocated or replaced to accommodate new work. In many cases, the gas utility (National Grid) may be responsible for the gas main work, especially to replace older, cast iron gas mains, which are typically removed by the gas company as part of their infrastructural renewal to minimize leaks. National Grid will be contacted during design to coordinate the infrastructure renewal needs prior to construction because the gas main relocations are typically completed first. To the extent practical, the work will avoid the relocation of high pressure and large diameter gas mains to minimize construction challenges.

3.0 System Rehabilitation Needs

3.1 Introduction

Aging wastewater collection system infrastructure is a challenge for municipalities. Historically, many municipalities operated with a run-to-failure management approach that caused assets to deteriorate faster and resulted 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 over $1.5 million annually spent on collection system maintenance and refurbishment programs. Activities under this program include regularly cleaning sewers (average of 10,000 linear feet over the last 5 years), identifying and monitoring problem areas (through methods such as CCTV inspections and SSO reporting), repairing failing sewers, pump station inspections, and implementation of infiltration/inflow (I/I) studies and a Sewer System Evaluation Survey (SSES) program.

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

- 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, and
- New construction in close vicinity to aging combined sewer pipes.

These factors are magnified in an area like the Centralville study area where, as discussed in Section 2, most of the pipe was installed before 1950. Pipes of that age are reaching the end of their useful life and the pipe material used in these older installations are prone to settlement (causing joint issues), cracking/fracturing, and broken and collapsed pipe segments. The City has a significant quantity of brick sewers that also present issues such as missing brick and walls that can contribute to groundwater infiltration and external pipe circumference voids that can lead to street collapses.

There are two reasons for LRWWU to address this aging pipe issue – one is to rehabilitate or replace the aging pipes before they fail and the second is to eliminate sources of extraneous flow that can pour into sewer defects. The Consent Decree 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.

The prerequisite for system rehabilitation is a comprehensive condition assessment of the piping system. The condition assessment provides the background to evaluate the existing system, characterize the defects and severity, and identify other deficiencies. Once the condition assessment is complete, system rehabilitation needs should be evaluated against available rehabilitation technologies to determine the best approach for infrastructure renewal. This section addresses the condition assessment and rehabilitation needs for the existing combined sewer system.

3.2 Condition Assessment

3.2.1 Introduction

Extraneous flow (i.e., flow not discharged by residents or businesses) 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 include rivers, brooks, and streams. Lowell continues to investigate its interceptor system for sources of extraneous flow due to the proximity of the interceptors to the river and the range of river depths along the river banks relative to the interceptor. 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 (CBs) or from private sources such as roof leader (gutters), yard/ driveway drains, or foundation drains that are connected to the sewer system. Some buildings may also 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. These extraneous flows can substantially reduce the dry and wet weather capacity of the existing system.

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

In addition, for this project, new sewers and/or drains will have to 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 resulting from vibration from machinery or pipes being unsupported near excavated trenches. Accordingly, the condition of the existing pipe, and its need for rehabilitation/replacement, should be assessed before construction begins.

Comprehensive field investigations were performed on the existing combined sewer system (CSS) in the 2000 HB PDR Area to develop a representative picture of overall system conditions. CDM Smith, with the support of Wright-Pierce, completed these investigations, which included closed-circuit television (CCTV) inspection and review of the CSS, manhole inspections, smoke testing, and windshield/desktop surveys to look for potential building sources of inflow for the purpose of identifying needed repairs and rehabilitation. Field investigations were not performed in Sewer Area 40 during this study; however, they will be conducted as part of any future design efforts.

3.2.2 Television Inspections

CCTV of the CSS was performed by Inland Water/Green Mountain Pipeline Services (GMPS) as a subcontractor to Wright-Pierce during Spring and Summer of 2023. Specific pipe sections were selected for inspection based on size, age, material, and location within the system. CCTV inspections were performed for approximately 25,000 linear feet of pipe. LRWWU provided an additional 2,500 linear feet of pipe CCTV, which was completed over the last 5 years.

Inland Water/GMPS performed 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 travels through the pipe to identify structural and maintenance defects such as fractures, breaks, deformation, sedimentation/debris, infiltration, and lateral locations. The video from the inspection and defect codes are recorded and used to generate an inspection report for each pipe segment.

Once an inspection report is 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. It should be noted that NASSCO LoF ratings are more heavily weighted on structural defects compared to maintenance and operation defects which infiltration codes fall under. Wright-Pierce used a sewer asset rehabilitation software using the LoF ratings and defect types to generate preliminary recommendations for each pipe segment. The program recommendations were then reviewed to confirm or revise the results and recommendations.

LRWWU also provided historical CCTV inspection that they completed over the last five years. The LRWWU videos did not have an inspection report or NASSCO coding, so Wright-Pierce engaged Sewer AI 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 50 percent of the total (CSS) piping was examined during this program.

3.2.3 Manhole Inspections

Manhole inspections were performed by Wright-Pierce in the Summer of 2023 to assess the structural condition of the manholes and identify potential visible sources of I/I. Manhole inspections were completed on 243 manholes using the NASSCO Manhole Assessment Certification Program (MACP) Level 1 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 was on the integrity of the manhole and not the confirmation of pipe inverts, materials, 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 with the zoom camera capability the upstream and downstream pipes. 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). Based on the MACP Level 1 inspection, each component was given a condition rating of sound or defective. Manholes with a defective condition rating were then evaluated to determine if rehabilitation is required.

Nearly 70 percent of the manholes were found to be in good overall condition with no further action needed. The remaining 30 percent of manholes were found to need either lining or point repairs, but no manholes were identified to require a full replacement.

3.2.4 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 as 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 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.

Wright-Pierce performed the smoke testing program for the 2000 HB PDR Area in the Summer of 2023. Smoke testing is conducted by isolating pipes and using a blower to fill the sewer system with non-toxic smoke. The inspector then observes the area for locations where smoke is present. Results of the smoke testing program are summarized in **Table 3.1.**

Table 3.1 Smoke Test Results

Source	Count
Driveway Drain	3
Home/Structure/Building	24
Ground	6
Yard Drain	1
Other	3
Total	**37**

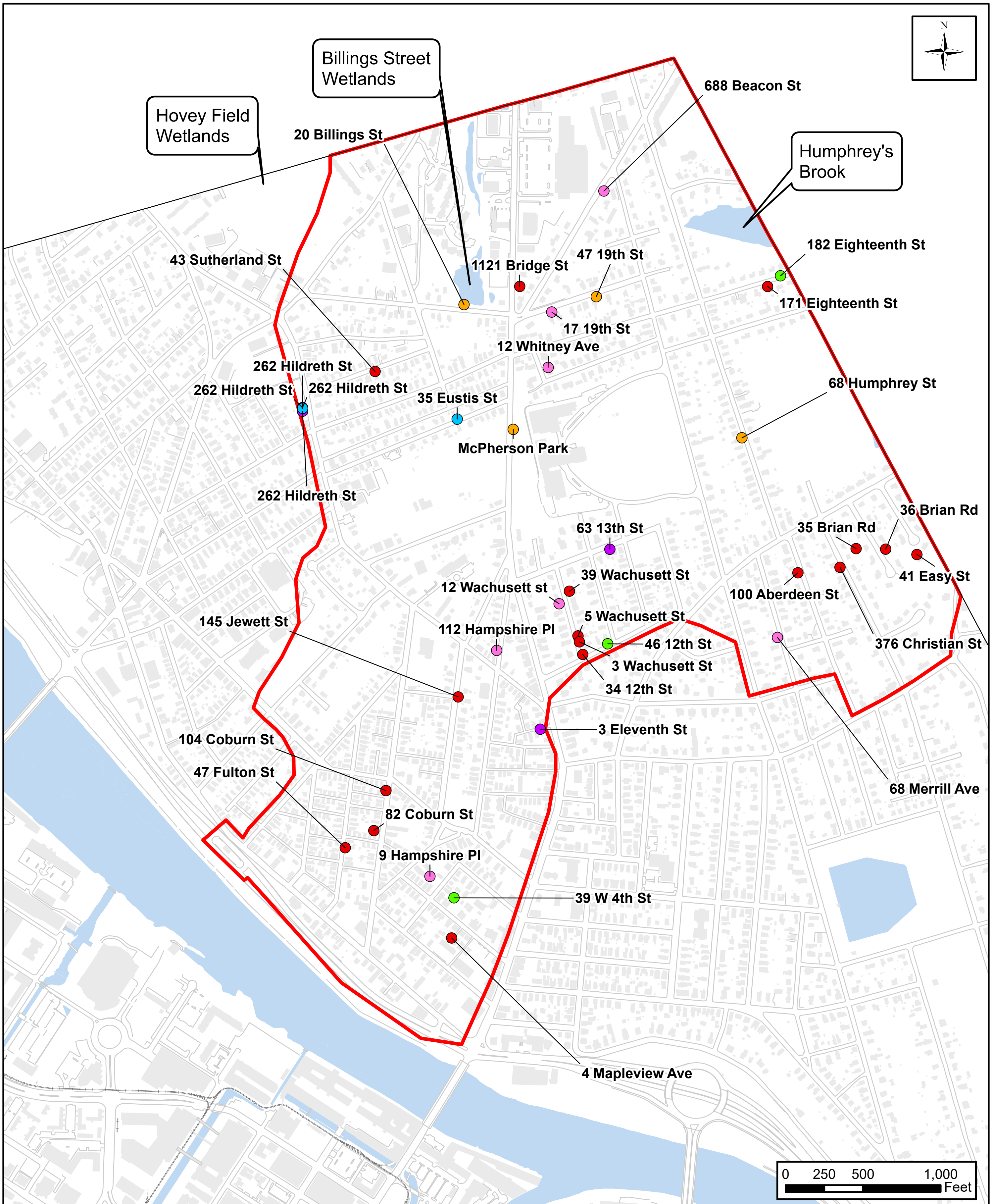
In general, a relatively low number of potential private inflow connections were discovered and these sources were widely distributed. Only 37 sources of smoke not sourced from a catch basin, manhole, or sewer cleanout were identified. Of those 37, only four were directly linked to a confirmed source (driveway/yard) drain. The remaining 33 locations will require further investigation to determine the source such as conducting building inspections or dye testing.

Figure 3.1 shows the results of the smoke testing program.

3.2.5 Desktop/Windshield Survey for Potential Inflow Sources

To complement the smoke testing program, a windshield survey/desktop analysis was also completed. Initially, the City's GIS and photogrammetry were used to identify flat building roofs. This was followed by a field visit during September 2023 to examine each of the buildings with flat roofs to identify visible external roof drains or scuppers that direct roof runoff to the ground or pipes into the ground. During this field program, additional buildings were identified with potential flat roofs that were not picked up in the desktop analysis.

Figure 3.2 shows the location of over 50 buildings with flat roofs having no visible roof drain or scupper within the entire Centralville study area. It is suspected that these flat roofs have internal building drains that could connect to the sewer service. During final design and/or construction, building inspections and dye testing will be completed to identify if extraneous flow connections to the sewer system can be cost effectively disconnected.



Legend

Preliminary Recommendation
- Building inspection
- CCTV lateral inspection
- Redirect source as stormwater flow
- Dye test
- Property owner to repair
- No action (Assumed dry P-trap)

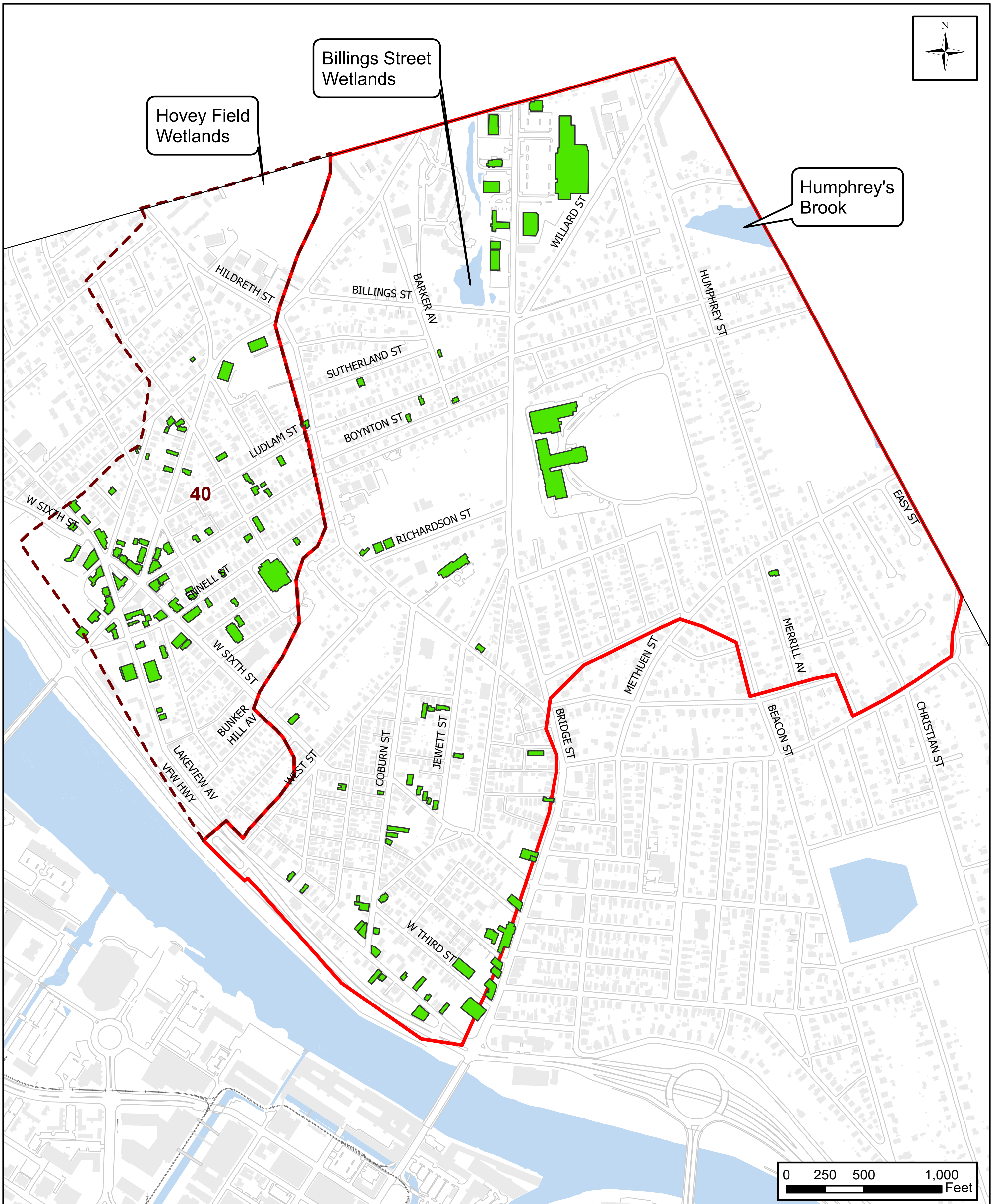
2000 HB PDR Area

CDM Smith

Duck Island Lowell Regional Wastewater Utility

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR

Figure 3.1
Smoke Testing Program



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Flat Roof

2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 3.2

Potential Inflow Sources from Flat Roofs

3.3 Trenchless System Rehabilitation Approaches

3.3.1 Overview

While open cut excavation and complete pipe segment replacement is always an option, rehabilitation of existing sewer pipes, manholes, and service laterals is increasingly being accomplished with trenchless methods. Trenchless rehabilitation methods can be used to reduce I/I and extend the service life of the pipe and 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, and
- Environmental disturbance minimized.

It is important to note that the pipe and manhole inspections were evaluated based on NASCCO standards, which are focused on the structural condition and potential failure of the pipe. The Utility is currently developing an I/I Analysis Report that will utilize 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 will help to mitigate extraneous flow entering the system through some of the defects noted in the NASCCO grading.

3.3.2 Sewer Pipe Rehabilitation

For this project, a cured-in-place pipe (CIPP) will likely be the preferred method of pipe rehabilitation. CIPP liners can be used both for structural and non-structural (for the purpose of 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 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 due to 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. It should be noted that 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 segments, 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 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. In Lowell, the city 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 main. This could create a challenge when navigating any rehabilitation work on private sewer laterals.

The following methods are available for sewer lateral rehabilitation:

- Removal and replacement,
- CIPP lining,
- Chemical grouting, and
- Pipe bursting.

3.3.4.1 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 maintenance of sewer laterals from the source to the mainline. Sewer lateral replacement is recommended when the structural condition of the pipe has failed, or 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.

3.3.4.2 Cured-in-Place Pipe (CIPP) Lateral Lining

The most common type of liner used for lateral rehabilitation is CIPP (cured-in-place pipe). 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. However, newer lining technologies can rehabilitate most of the service lateral from the main line 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, as the completed liner will fully restore the structural integrity of a damaged pipe.

3.3.4.3 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 that 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 the rehabilitation of the lateral, as this will minimize any damage to the liner.

Service connection and lateral liners are cured-in-place 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 3.3**).

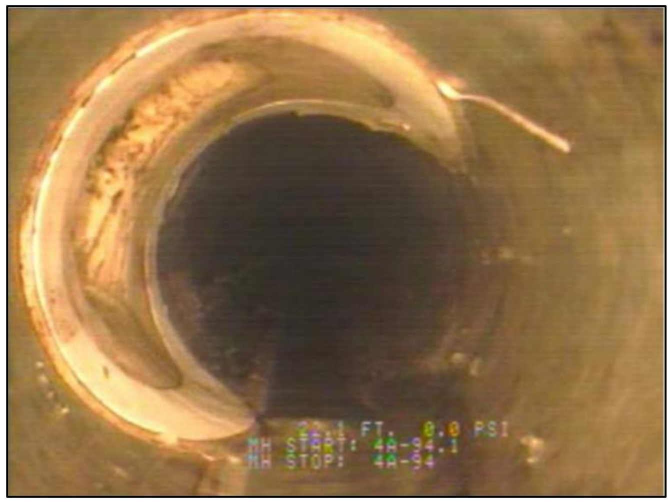


Figure 3.3 Brim Style liner

A brim (top hat) liner forms a ring around the penetration for the lateral then extends from 6 inches to 2 feet up the lateral.

In situations where the mainline has not been lined, a technique known as a full wrap liner is typically used (**Figure 3.4**).

Figure 3.4 Full Wrap Liner

A full wrap lines a short section of the mainline before and after a lateral and then extends up into the lateral, 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 3.5**).

Anytime a lateral connection is rehabilitated, it needs to be sealed. This is done 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 five to twenty years.

Figure 3.5 Shifted Service Connection/ Lateral

3.3.5 Manhole Rehabilitation

Infiltration into manholes generally occurs due to 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 ultimately structural deterioration.

Inflow into a manhole can occur during storm events as the rainwater from the surface may enter the manhole through the cover, frame, or frame seal. Typical defects may include:

- 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 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 prior to 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.

3.4 Conclusions

3.4.1 Pipeline Recommendations

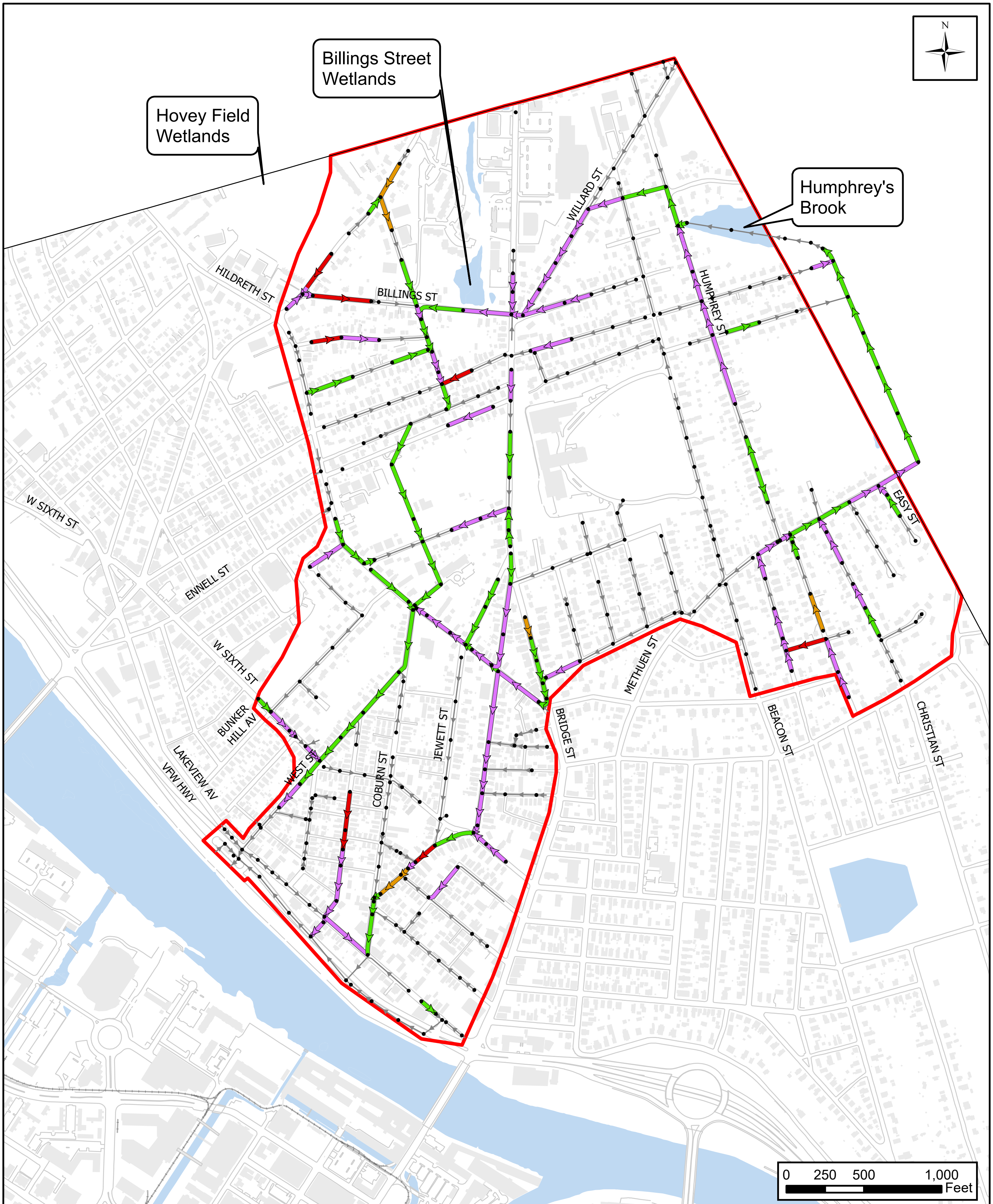
The results of the CCTV inspection program discussed in Section 3.2.2 resulted in recommendations for approximately 28,000 linear feet of sewer pipe within the 2000 HB PDR Area. As pipe failures were identified, Lowell completed immediate repairs (one example is 18th Street). Four categories of repairs were recommended. The results can be found in **Table 3.2** and are shown on **Figure 3.6.**

Table 3.2 Summary of Revised Preliminary Rehabilitation Recommendations

Preliminary Rehabilitation Recommendation	Pipe Length (LF)
No Action Required	11,879
Line	12,980
Point Repair	1,108 (11 pipes)
Replace	1,862
Total	27,830

These recommendations represent pipes selected for this field program as a representative study. Of the pipes inspected, 46.6 percent were recommended for lining rehabilitation. The program also suggests that a smaller percentage of the system is in need of full replacement or excavated discrete repairs. The recommendations from the prior television inspection program can be projected to determine the pipeline rehabilitation needed over the entire Centralville study area.

It is important to understand that these recommendations are based on the current condition of the pipes within the system and as time passes they will continue to degrade. Roughly 90 percent of the pipes in the Centralville study area are older than 1950, or more than 73 years old. 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 the wastewater collection system are typically estimated to be 50 to 100 years old. Based on the age of the system, many of these pipes are at or nearing the end of their useful life. As part of infrastructure renewal for the Humphrey's Brook area, 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. This same approach should also be applied to other areas that were not inspected as part of this study.



Legend

Sewer Gravity Main

Preliminary Recommendation

- Replace
- Point Repair
- Line
- No Action
- No CCTV Performed
- Sewer Manhole
- 2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 3.6

Preliminary Recommendations Based on CCTV Inspections

Construction costs for pipe rehabilitation were estimated using a unit cost by pipe diameter provided by Wright Pierce. Recommendations from the television inspection program were used as a baseline for the estimate. As previously stated, that baseline was projected out over the system to develop a comprehensive cost. Lining of all pipes older than 1950 (which included all pipes recommended from inspection) was also considered.

Rehabilitation costs are presented in **Table 3.3** for a range of options:

- The second column presents the cost for lining just the pipes reviewed and recommended as part of the CCTV program in the 2000 HB PDR area,
- The third column presents the lining cost projected for the entire separation area, assuming that the rate of rehabilitation required for the pipes inspected thus far will be consistent in the entire Centralville study area,
- The fourth column presents the cost to line all pipes installed prior to 1950 in the entire Centralville study area.

As a budgetary cost approach, it is suggested that the Utility consider that all pipes installed prior to 1950 (the fourth column) be lined as this option achieves infrastructure renewal and significantly extends the life of existing sewer collection system. Accordingly, the total cost for pipe lining in the Centralville area is projected to be $22.3 million. The extent of actual pipe rehabilitation necessary for infrastructure renewal will be considered during final design.

Table 3.3 Cured-in-Place Lining Projected Construction Costs

	CCTV Recommended Lining (21.0%)	Projected Cost Extended for Full Area (46.6%)	Line all Pipes installed prior to 1950
2000 HB PDR Area	$4,562,000	$8,200,000	$16,200,000
Area 40	N/A	$3,000,000	$6,100,000

Notes: Costs in November 2023 dollars (ENR 13,510.57)

3.4.2 Manhole Recommendations

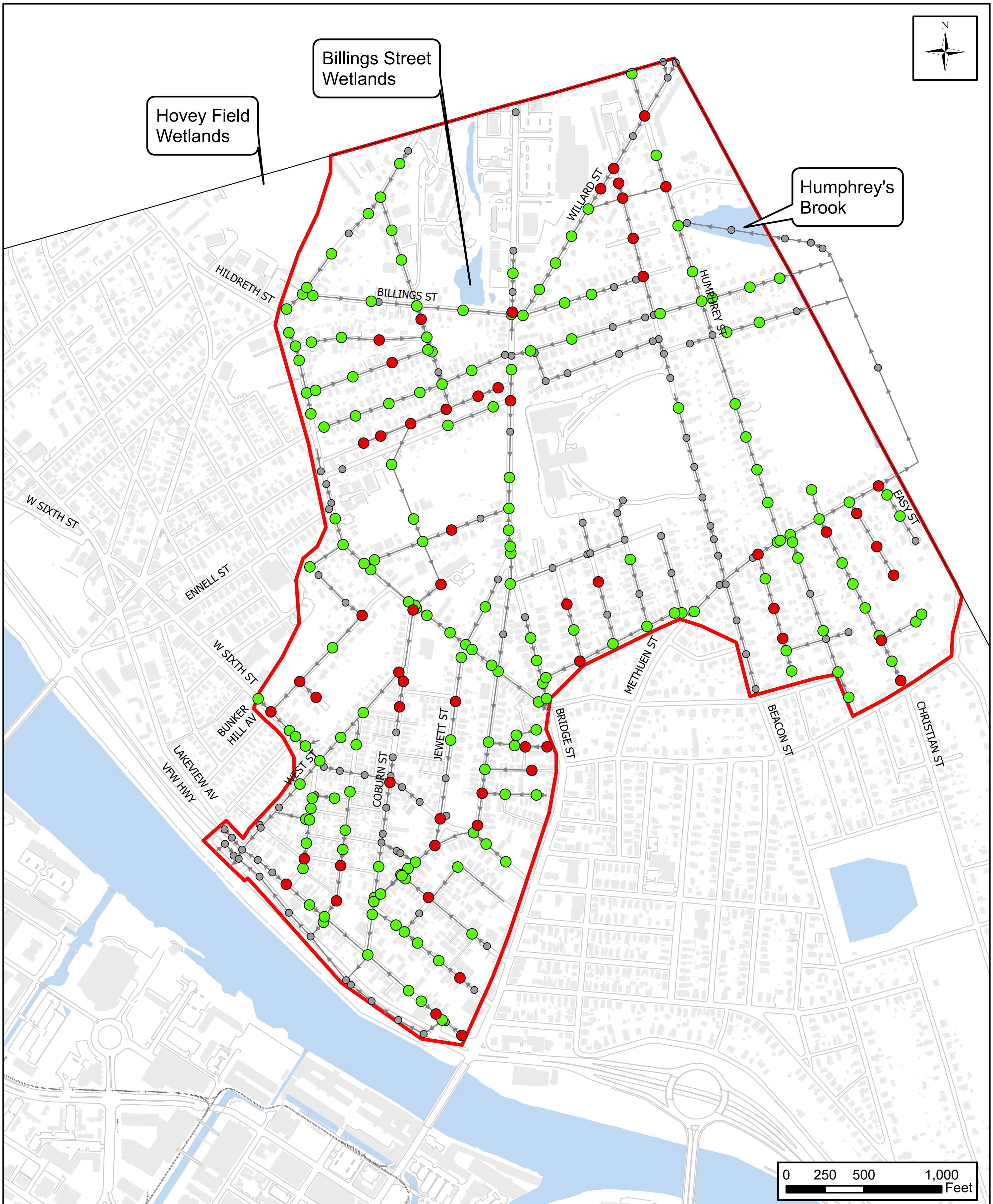
The manhole inspection program (discussed in Section 3.2.3) presented recommendations for the 242 manholes that were inspected during this program. These preliminary recommendations represent the future action that should be taken based on the severity of the manhole condition. **Table 3.4** summarizes those recommendations and the approximate construction cost.

Table 3.4 Summary of Manhole Rehabilitation Recommendations

Preliminary Rehabilitation Recommendation	Number of Manholes	Estimated Cost[a]
No Action	179	$0
Rehabilitation of the manhole	63	$315,000
Replace the manhole	0	$0
Total	**242**	**$315,000**

Note: Estimated cost based on $5,000 per manhole.

Many manholes are labeled for “no action” meaning that most of the manholes are sound and do not need any 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. These results are shown in **Figure 3.7.**



Legend

Sewer Manhole

Preliminary Recommendation

- Rehabilitation
- No Action
- Sewer Manhole
- Sewer Gravity Main
- 2000 HB PDR Area

CDM Smith

DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 3.7

Preliminary Manhole Recommendations

4.0 Hydraulic Modeling of the Drainage System

4.1 Introduction

Hydraulic modeling of drainage and collection systems helps determine the capacity and pipe sizes necessary to convey wet-weather flow under dynamic conditions. This section describes the development and application of EPA's Stormwater Management Model (SWMM) for design of a stormwater pipe network to support sewer separation of the Centralville study area. For this study, the modeled drain network was extended to include the collector drains that are required to capture flow from all existing catch basins.

4.2 Rainfall Design Criteria

4.2.1 General

Rainfall design storms are used to size the stormwater piping system to collect surface water runoff. A range of design storms, based on average recurrence intervals (ARI), may be considered in a study to evaluate the relative cost and benefits achieved by increasing conveyance capacity. Typically, the range of design storms for municipal systems may include 2-year, 5-year, and 10-year ARI storms as evaluation criteria.

4.2.2 Past Evaluation

The 2000 HB PDR used several historical storms to evaluate existing CSS capacity and the proposed stormwater piping network. That study considered several hydraulic and constructability factors, concluding that it was practical to build a new stormwater system with a 5-year design storm capacity. Modeling performed for this PDR reconfirmed that the stormwater system should be constructed for a 5-year storm capacity to convey Humphrey's Brook to the Merrimack River. Larger drain pipe sizes would be required to convey flow generated by a 10-year storm; however, constructability of such large diameter pipes is not feasible for the proposed separation program in this area.

4.2.3 Current Evaluation

For this study, CDM Smith initially assumed preliminary pipe sizes and potential route configurations based on a 5-year 24-hour rainfall hyetograph determined from National Oceanographic and Atmospheric Administration (NOAA) Atlas 14, Volume 10, published in 2015. To consider the impact of a larger storm event, a 10-year 24-hour storm was also simulated for the stormwater system having a 5-year design storm capacity to assess system performance and identify areas that may be susceptible to short-term flooding.

Design storm magnitudes were adjusted to consider future climate change. This study incorporates a 10 percent increase to Atlas 14 depths to account for potential climate change. This increase was estimated based on a 2022 NOAA report "Analysis of Impact of Nonstationary Climate on NOAA Atlas 14 Estimates" [1] which forecasts 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 (RCP) 4.5 climate model results. **Figure 4.1** shows cumulative depth-duration-frequency curves for 2-, 5-, and 10-year 24-hour design storms adjusted for climate change.

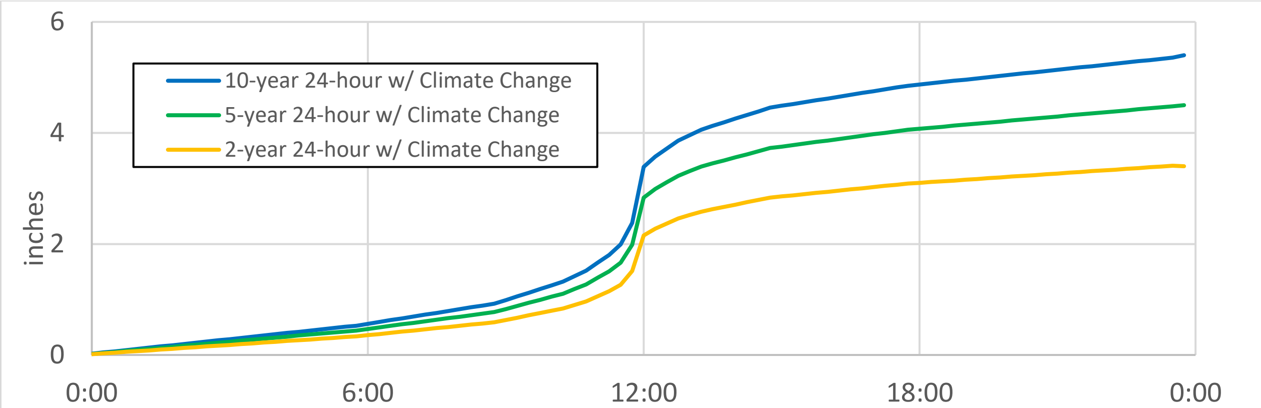


Figure 4.1 Design Storm Cumulative 24-Hour Rainfall

Table 4.1 presents design storm characteristics at selected durations.

Table 4.1 Design Storm Characteristics

Interval	Maximum Design Storm Rainfall (inches) at Selected Durations		
	2-Year	5-Year	10-Year
15 minutes	0.66	0.86	1.02
1 hour	1.14	1.49	1.78
24 hours	3.45	4.51	5.38

4.3 Drainage Area Delineation and Hydrology

The Centralville study area comprises 940 acres in Lowell and Dracut. It includes Humphrey's Brook, wetlands and open channel drainage north of Billings Street, Hovey Field Wetlands, and surface runoff from Lowell. As discussed in Section 2, the primary surface water inflow sources are Humphrey's Brook, which drains into Lowell from the east, and the Billings Street Wetlands and Hovey Field Wetlands, which lie near the northern city boundary. The model uses the NAVD 88 vertical datum (feet) and the Massachusetts Mainland coordinate system (feet, NAD 83).

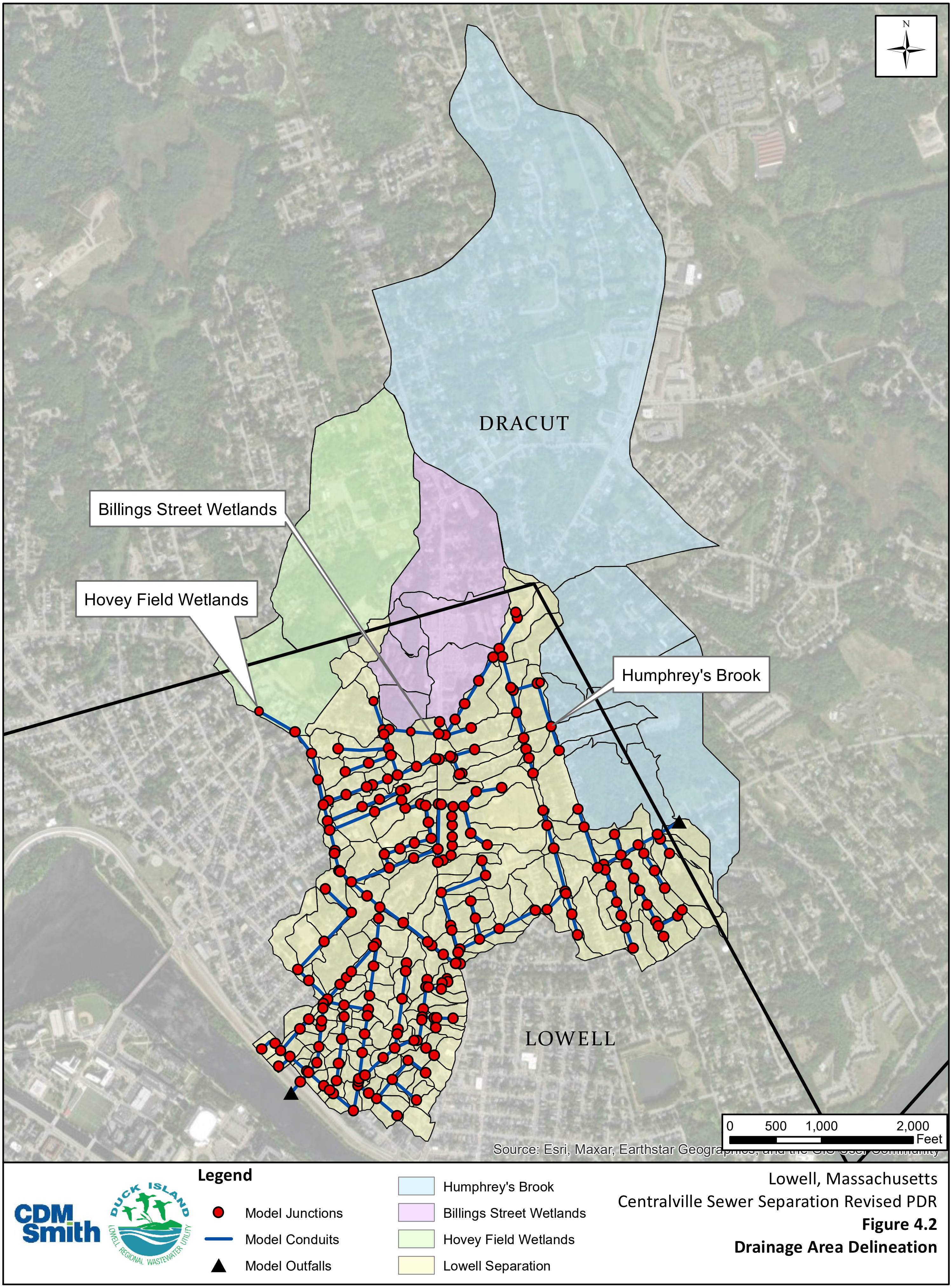
As an initial criterion for SWMM pipe simulations, minimum pipe cover was established at 4 feet below existing ground surface. Pipe slopes and inverts will be adjusted during the design process based on utility conflicts, alternate routing, and topography. The final configuration of the drain system will be re-simulated to ensure conformance with the design standards for conveyance piping such as minimal cover, minimum or maximum slopes, pipe sizing to minimize surcharging, etc. Drain manholes (model junctions) were added near existing catch basins so that these basins can be re-routed from the existing combined sewer system. Changes in pipe diameter were configured to match downstream crowns where feasible. Vertical drops were applied to maintain an acceptable range of slopes and pipe velocities based on pipe size. Pipe slopes and sizes will be revised to resolve utility conflicts as the system design progresses.

Drainage from Dracut via the brook and wetlands was based on subcatchments originally delineated in the 2014 CSO Phase 2 Long-Term Control Plan and refined for this study through additional review. Detailed subcatchment delineation was performed for areas within Lowell to best represent surface runoff within the study area. As part of this process, drainage areas were delineated using 1-foot contours and adjustments were made to the subcatchments to account for roads and streets. Average subcatchment size within Lowell is 1.5 acres. **Figure 4.2** shows the drainage area delineations. The aerial photogrammetry background has been added to the figure to show the relative density of development differences between Lowell and Dracut.

Hydrologic parameters were assigned based on local data and best engineering practices. Initial hydrologic parameters for the SWMM model were developed as described below:

- Imperviousness was calculated from Massachusetts Impervious Surface 2016 data obtained directly from MassGIS [2]. Imperviousness averages 40 percent across the study area.
- Percent routed identifies the fraction of a subcatchment impervious surface that drains onto adjacent pervious ground (e. g., roof leaders that drain to bare ground). Percent routed was specified as 100% 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.
- Average surface slope for each subcatchment was calculated using a digital elevation model developed from the contours.
- Manning's N was specified as 0.02 for impervious surfaces and 0.08 for pervious ground.
- Subcatchment width (the hydrograph shape parameter) was based on the Guo and Urbonas method recommended in the SWMM hydrology manual using a skew factor of 0.5, an upper limit shape factor of 5, and calculated lengths using the "minimum bounding geometry" tool in ArcGIS Pro [3].
- Infiltration from pervious areas is modeled using the modified Horton method. The principal soil type in the study area is sandy loam, according to the US NRCS Web Soil Survey [4]. Soil parameters were uniformly specified as 2 inches per hour maximum infiltration rate and 1 inch per hour minimum infiltration rate.

Development of hydrology and runoff characteristics for the Humphrey's Brook, Billing Street Wetlands, and Hovey Field Wetlands (Dracut surface water inflows) were developed for the SWWM Collection System Model. These characteristics were used in the SWMM Drain Model to represent the potential runoff generated by these surface water streams into the new drainage system. SWMM Collection System Calibration is discussed in Volume 2.



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 4.2
Drainage Area Delineation

4.4 Conceptual Hydraulic Analysis

SWMM was used to identify pipe sizes that would minimize surcharge above pipe crowns during a 5-year design storm. The 10-year storm was then run to identify excessive surcharge and street flooding duration. Flooding was defined as any location that experiences more than 15 minutes of flooding and 10,000 gallons of ponded volume. No locations had any significant flooding under this criterion with the simulation of a 10-year storm except for areas with existing drain pipes (suggesting they are slightly undersized) and a low lying area of concern that will be discussed further in Section 6 Development of Alternatives.

Figure 4-3 shows the modeled pipes, a conceptual pipe route, and initial sizes for a stormwater collection system designed for the 5-year storm. The main conduit follows the route proposed in the 2000 HB PDR, discharging to the Merrimack River across from Stanley Street. This is a comparative analysis to the 2000 HB PDR to see pipe size changes after applying the current design storm criteria.

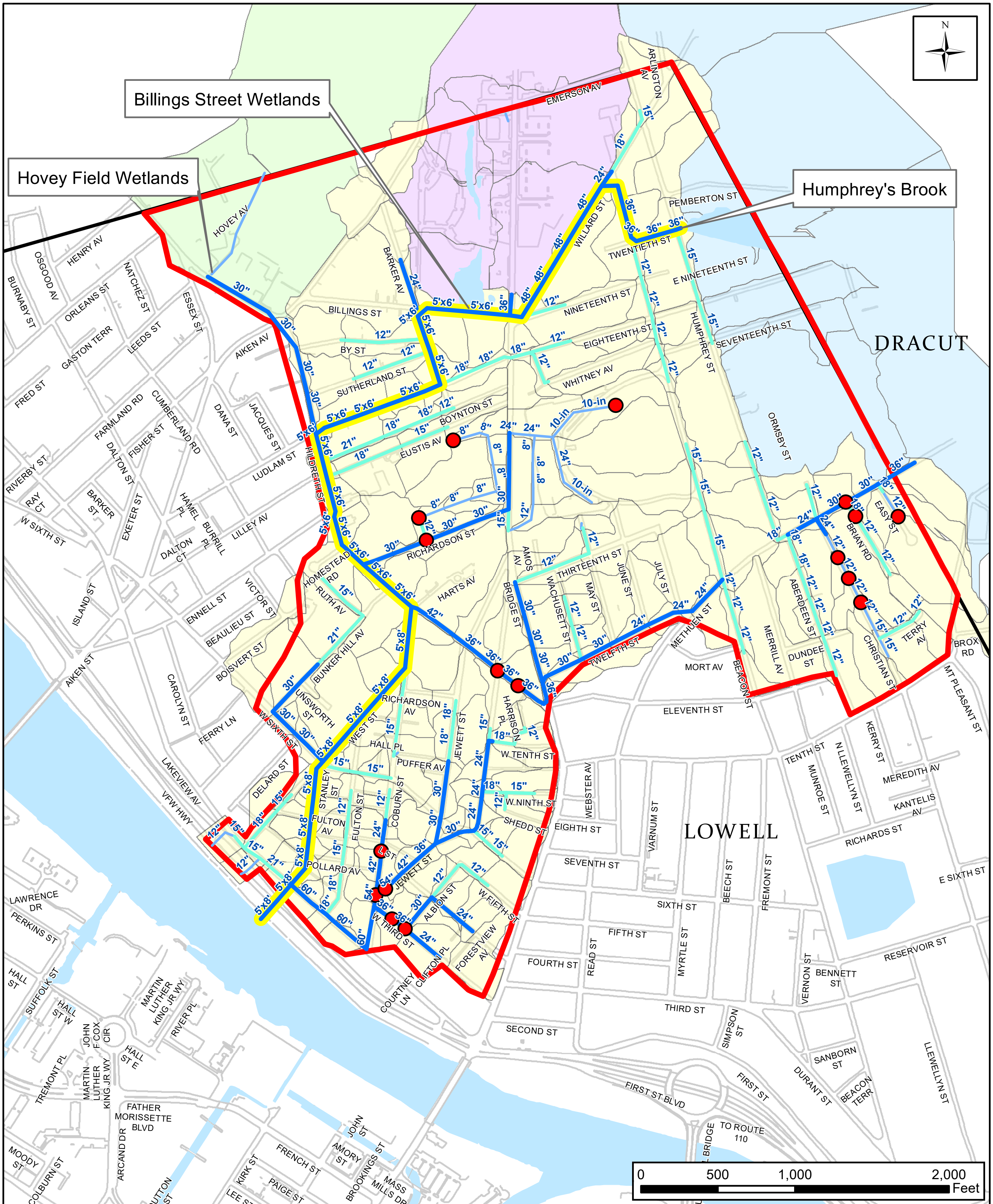
Initial hydraulic simulations indicate that the size of the main conduit for the required brook removal and future combined sewer separation in Lowell varies from 36- to 48-inch diameter at the upstream limit (an existing 36-inch diameter pipe connects the brook to the drain system) to a 5-foot high by 6-foot wide box culvert downstream of Billings Street Wetlands that transitions to a 5-foot high by 8-foot wide box culvert near the downstream end. These results are consistent with the 2000 HB PDR analysis although pipe diameter lengths vary along the route. Additionally, the size of the box culvert south of Hildreth Street continued as a 5-foot by 8-foot dimension to mitigate surcharge along this segment and near the West Station where the conveyance system transitions from steep to flatter pipe slopes to match the existing topography.

Figure 4.4 shows the peak hydraulic grade line (HGL) in the main conduit for the 2-year, 5-year, and 10-year storms from the Humphrey's Brook inlet to the outfall. Figure 4.4 shows surcharge in downstream sections during the 5-year storm (blue line), but no flooding along the main conduit. The 10-year HGL (red line) exhibits minor flooding in low-lying areas. Flooding during the 5-year storm does occur in undersized existing drains near McPherson Playground, Gage Park, and Christian Street. Locations subject to flooding in are indicated in Figure 4.3.

Table 4.2 shows peak flowrates at key locations along the main conduit for each design storm to show the magnitude impacts of inflow sources and separation.

Table 4.2 Peak Flowrates at Key Locations along Main Conduit

	Design Storm Peak Flows (cfs)		
Location	**2-year**	**5-year**	**10-year**
Humphrey's Brook Inlet	28	41	53
Downstream of Billings Street Wetlands	99	156	179
Hildreth Street & Coburn Street Intersection	194	303	353
Outfall	367	545	633



Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 4.3

Conceptual Drainage Network

Legend

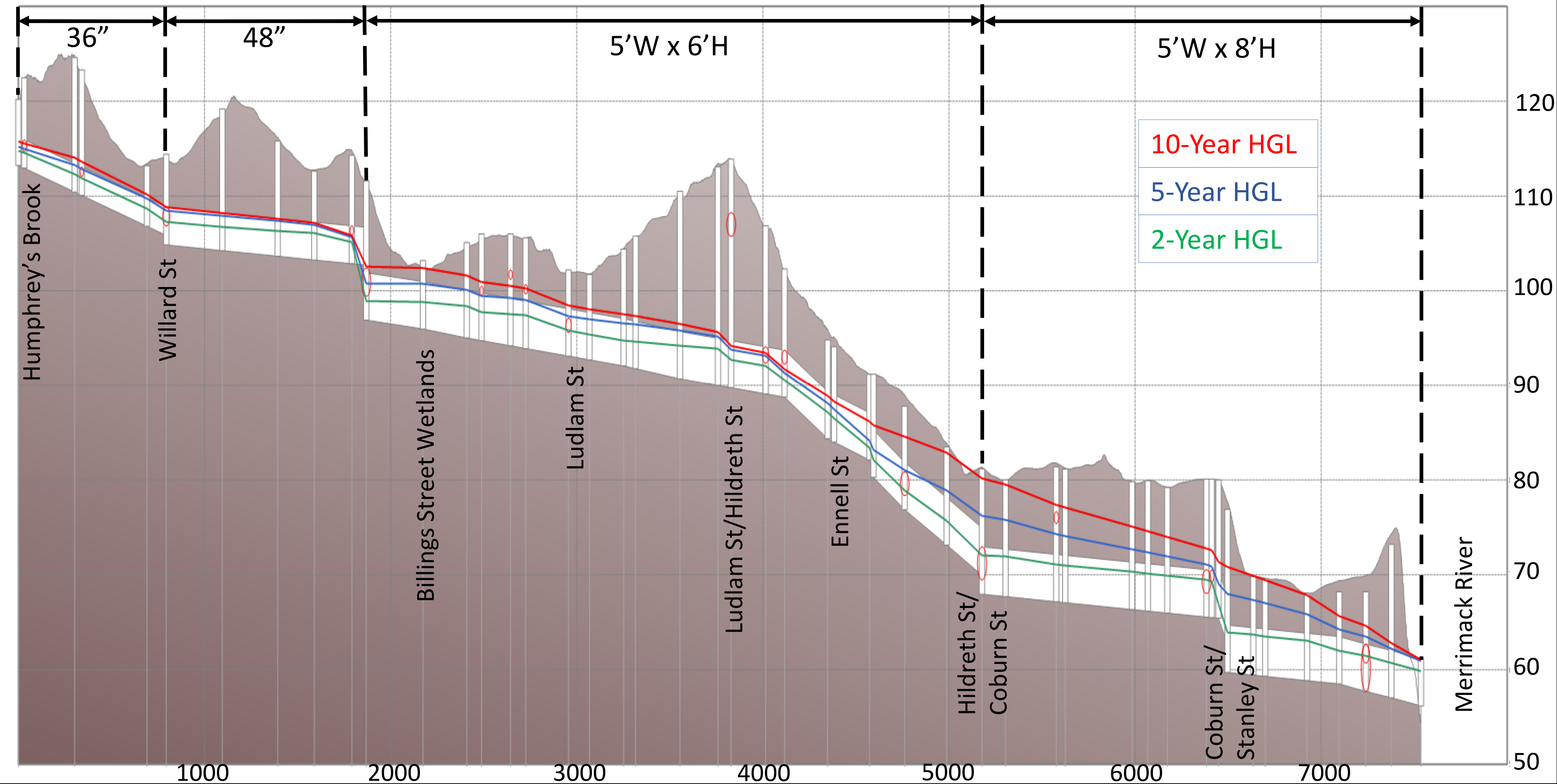
- Main Conduit
- Drain (24" and Greater)
- Drain (18" or Less)
- Existing Drain
- 2000 HB PDR Area
- 10-Year Storm Flooding

Subcatchments

- Humphrey's Brook
- Billings Street Wetlands
- Hovey Field Wetlands
- Lowell Separation

CDM Smith

DUCK ISLAND — LOWELL REGIONAL WASTEWATER UTILITY



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 4.4
Peak Hydraulic Grade Line Profile for 2-,5-,10-year 24-hr Design Storm

4.5 Drainage Modeling Next Steps

The large size of the main conduit required to remove the brook and other Dracut inflow sources creates significant construction challenges. The large conduit could conflict with other underground utilities, requiring relocation, or with existing sewer services, requiring new parallel services. Fitting the drain into narrow streets near West Station would require reconstruction of entire roadways following pipe installation. In addition, downstream river conditions at the outfall(s) need to be evaluated further for discharge potential.

Section 5 discusses the general construction challenges created by this type of pipe installation. Section 6 identifies and discusses alternative approaches to reduce pipe size or identify alternative pipe alignments to reduce construction impacts. These alternatives also used SWMM to evaluate pipe size benefits and flow routing. A comprehensive hydraulic assessment will be performed during final design on the proposed alignment and configuration of the drainage system.

4.6 References

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5.0 Potential Construction Challenges

5.1 Introduction

Potential construction issues and environmental impacts that may be encountered during the installation of new drains or sewers should be considered as part of the design process. This type of work becomes more challenging when pipe diameters exceed 36-inches due to potential conflicts with other underground utilities. In addition, consideration should be given to construction challenges such as 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 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 approaches to avoid or mitigate such impacts. These are discussed further during the alternative development and analysis presented in Section 6.

5.2 General Construction Impacts

5.2.1 Underground 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 that there is no differential settlement. Dewatering for the pipe installation must be carefully planned to avoid excessive dewatering of nearby utilities that could create differential settling within the street.

Depending on the depth of the new sewer or drain, utility conflicts can also increase. If a new sewer is installed, it will likely be lower than the existing sewer to reconnect existing property sewer services. This means that the new sewer will be deeper than any of the adjacent sewers; therefore, construction and associated vibration can impact the surrounding utilities and properties. Vibration monitoring may be required for older utilities.

Drains may be installed shallower. 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. Then either the drain or the sewer profile needs to be modified to resolve the conflict but the ability to change the sewer profile might 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 in the final design process when pipe routing, connectivity, and pipe inverts are established in final plan and profiles.

5.2.2 Traffic Management and Pedestrian Access

Maintenance of traffic and property access along the construction zone is a high priority for this project.

A significant portion of the work in the Humphrey's Brook Basin will take place in dense and highly congested residential, multifamily, and commercial areas. There are several thoroughfares through the Centralville neighborhood that are main transportation corridors. These main transportation corridors include Hildreth Street, Bridge Street, Methuen Street, Aiken Avenue, Willard Street, and Lakeview Avenue, along with work adjacent to and across VFW Highway, a state roadway (for the construction of the outfall pipe(s)). Traffic management issues to be considered include at a minimum access for emergency vehicles, minimizing 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 during the design, then appropriate mitigation must be developed and implemented during final design to minimize the impact.

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, and noise, and will also consider pedestrian access with proper signage. Locations of displaced parking will be identified and coordinated with the City. The public will be engaged to reduce impacts to daily life to the best extent possible.

Many of these traffic and pedestrian measures are generally addressed in the preliminary and final design. More detail will be required 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 incorporate 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, it should be acknowledged that, 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 street will be analyzed to determine the best method to provide access to all entrances. At times, snow fencing will be utilized to direct traffic flow. Advance planning and phasing of construction on each street to address issues related to traffic will minimize disturbances to affected businesses and residents.

5.2.3 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. A majority of the area selected for sewer separation is residential, which is more sensitive to noise impairments than industrial or commercial areas. 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, could be necessary to reduce impacts at some locations. Decibel level restrictions could be added to the design documents in very sensitive areas as long as 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.

5.2.4 Blasting

Based on a review of past construction records, there will be significant areas of the project that require rock excavation to install the pipe (based on visible ledge outcrops seen throughout the project area, and available boring logs from the boring program performed for this study).

Rock may be excavated by numerous techniques including drilling, blasting, wedging, sledging, or barring. Prior to the start of rock excavation or blasting work, a pre-blast survey of all existing structures and conditions in the vicinity of 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. A blasting plan, describing proposed methods and sequence of excavation, including blasting procedures, will be developed to address the specifications. Blasting will 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 CRR 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 in similar excavations in rock and controlled blasting techniques. Prior to blasting, a blasting permit will be obtained from the Chief of the Fire Department.

5.2.5 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-I0) has the potential to be a health hazard as well as a nuisance. Tests conducted for the U.S. EPA 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 [1].

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.

5.2.6 Schools, Parks/Playgrounds, and Sensitive Receptors

There are several schools, playgrounds, and public parks that are adjacent to streets that will be impacted by construction, including the S. Christa McAuliffe Elementary, Henry J. Robinson Middle, and Greenhalge Elementary Schools, along with McPherson Park/Pool and Hovey Field. 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 school, 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 school, especially for students that walk to school.

Construction of new stormwater drains may also occur in the vicinity of McPherson Park and Hovey Field. McPherson Park includes a playground, three softball fields, tennis courts, basketball courts, and a pool. Prior to construction, coordination with the City's Department of Public Works and Parks Department will occur and access constraints during construction to McPherson Park and Hovey Field will be minimized.

Other sensitive receptors in the Centralville neighborhood include daycare and nursery centers, churches, medical, 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.

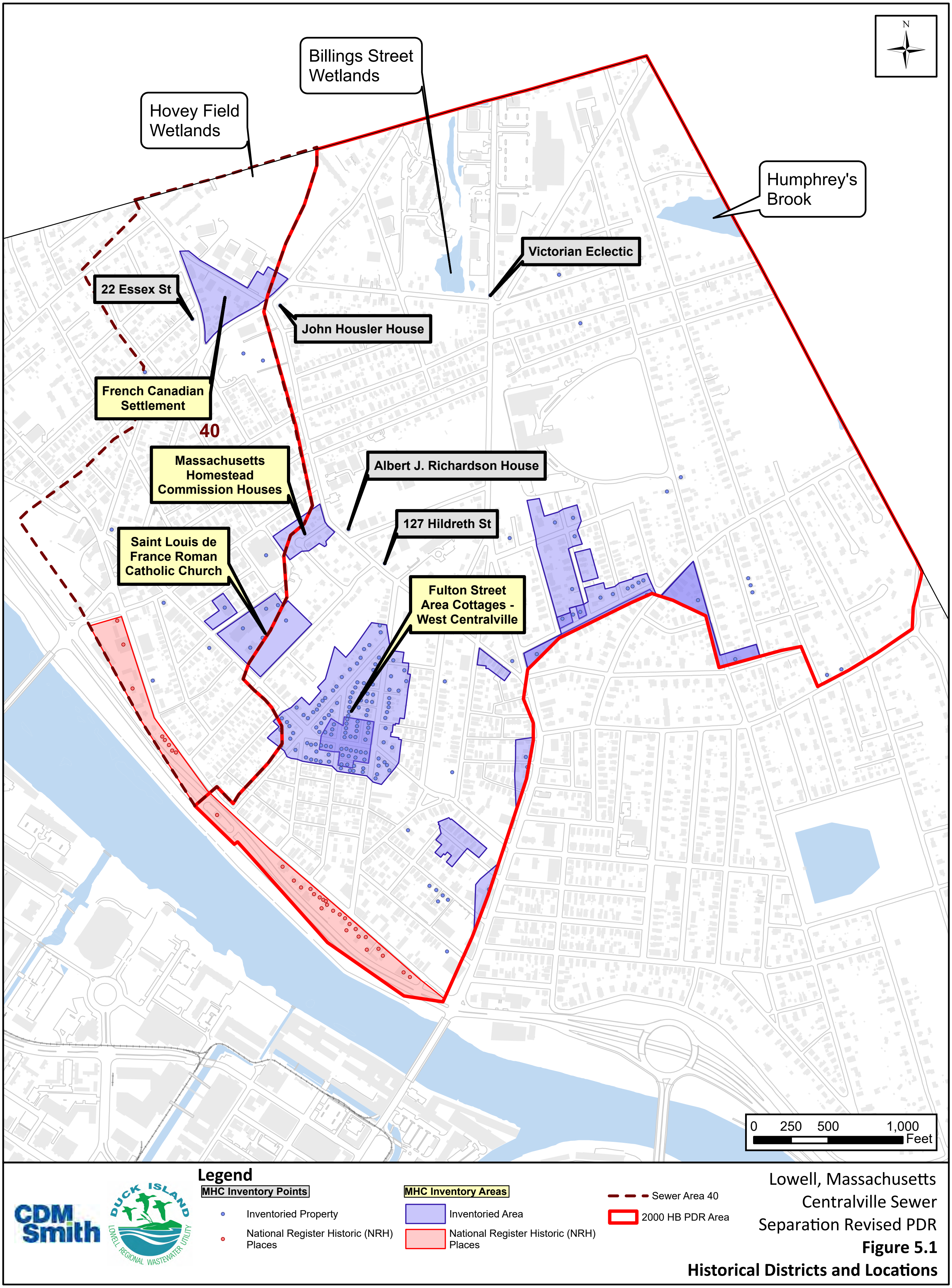
5.3 Environmental and Project Area Permitting

While not a direct construction impact, extensive permitting activities are needed to notify all appropriate federal, state, and local agencies about the project and its impacts, to comply with applicable regulations. Permitting can be extensive for a construction project of this size and complexity. The permitting activities include an accounting of historic and archaeological resources, wetland and water body impacts, and excess soil disposal characterization and disposal.

5.3.1 Historic and Archaeological Resources

Historical and archaeological resources should be identified before the start of construction either through database research and/or coordination with the Massachusetts Historical Commission (MHC). This effort is typically done during the final design process when the immediate construction area is well defined. As a start, CDM Smith consulted with the National Registry (NRDIS designated 1978) and identified some areas of historical or archaeological significance, as shown on **Figure 5.1**, including:

- Local Historical Districts (these include areas or groupings of inventoried points):
  - French Canadian Settlement (MHC ID: LOW AB). Residential District. Significance: Architecture, community planning, and ethnic heritage
  - Massachusetts Homestead Commission Houses (MHC ID: LOW.AE). Significance: Architecture, community planning, landscape, architecture, social history
  - Saint Louis de France Roman Catholic Church (LOW.CR). Significance: Architecture, community planning, and ethnic heritage, and religion
  - Fulton Street Area Cottages – W. Centralville. Residential District. Significance: Architecture, community planning, and Agriculture
- Individual Inventoried Points:
  - 1104 Bridge Street, MHC ID: LOW.742) (Victorian Eclectic)
  - John Housler House at 321 Hildreth Street (MHC ID LOW.771)
  - Albert J. Richardson House at 61 Hildreth Street (MHC IC: LOW.769)



Lowell, Massachusetts
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Figure 5.1
Historical Districts and Locations

- 22 Essex St (LOW.745) (single family dwelling)
- 127 Hildreth Street (LOW.770) (single family dwelling)

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

5.3.2 Wetlands and Water Bodies

Wetlands are classified along every water body in the state and the work required for this project may impact these areas. Stream brook inlets to the drain system will require new inlet structures and piping, which may result in the following impacts:

- Areas of Bordering Vegetated Wetland (BVW) and Land Under Water (LUW) could be impacted by the installation of new piping or structures to connect the Humphrey's Brook inlet at Humphrey's Street to the new drain system. The area impacted by the work may be limited to the extent of the new headwall including wingwalls and riprap.
- Another area of BVW, dominated by Phragmites australis, will be impacted by the removal of the existing inlet structure at Billings Street Wetland and the construction of a new structure. The existing sediment level in this area will be maintained and impact to the wetlands will be limited to the area immediately surrounding the existing inlet structure.

The new stormwater drain facilities will also require outfalls. Work at these outfalls could impact local wetlands as follows:

- Under the proposed Centralville CSS plan, stormwater flows that currently drain to the combined sewer in Methuen Street will be discharged at an existing outlet near Easy Street. This additional flow will have a limited impact on BVW in the vicinity of the outlet. The existing headwall at this location may need to be replaced to accommodate a new drain system and increased flows. Local BVW and the stream bed near the existing outlet may be temporarily impacted during construction of the new headwall and wing walls. Substantial riprap could be provided in this area to help minimize potential impacts of the increased discharge.
- Direct impacts to the Merrimack River may occur at potential new outfalls at Aiken Street, Bunker Hill Avenue, and Stanley Avenue.

Measures to mitigate temporary impacts to wetland resource areas include 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 down gradient wetlands or water bodies, and restoration of disturbed areas to the extent feasible (restoring existing contours and re-seeding with native seed mixtures as needed). Any work that occurs outside the street right-of-way and within 100 feet of wetlands will require a Notice of Intent (NOI) or a Request for Determination of Applicability (RDA). However, it is our understanding that installation of underground utilities within existing streets is exempt from review by the Lowell Conservation Commission per 310 CMR 10.02(b)2.i., to be confirmed during the final design phase.

Some of the new pipe alignment will also occur within the Riverfront Area, a state wetland resource area that typically extends 200 feet from the mean annual high-water line on each side of a perennial river or stream. However, the Riverfront Area is 25 feet in some municipalities in Massachusetts including Lowell. Since most of the work in the Riverfront Area will be in existing streets, the impact is expected to be small. Intermittent streams do not include a Riverfront Area. Similar to installation of underground utilities within existing streets, there is an exemption for minor activities within Riverfront Areas per 310 CMR 10.02(a)(1).

Any temporary or permanent impacts to wetlands will require approval by several regulatory authorities including the Lowell Conservation Commission, Massachusetts Department of Environmental Protection (MassDEP), Division of Wetlands and Waterways (401 Water Quality Certification and Chapter 91 License), the Massachusetts Office of Coastal Zone Management, and the U.S. Army Corps of Engineers.

5.3.3 Wetland and Access Permits

Permits required to construct the Humphrey's Brook sewer separation project may include the following:

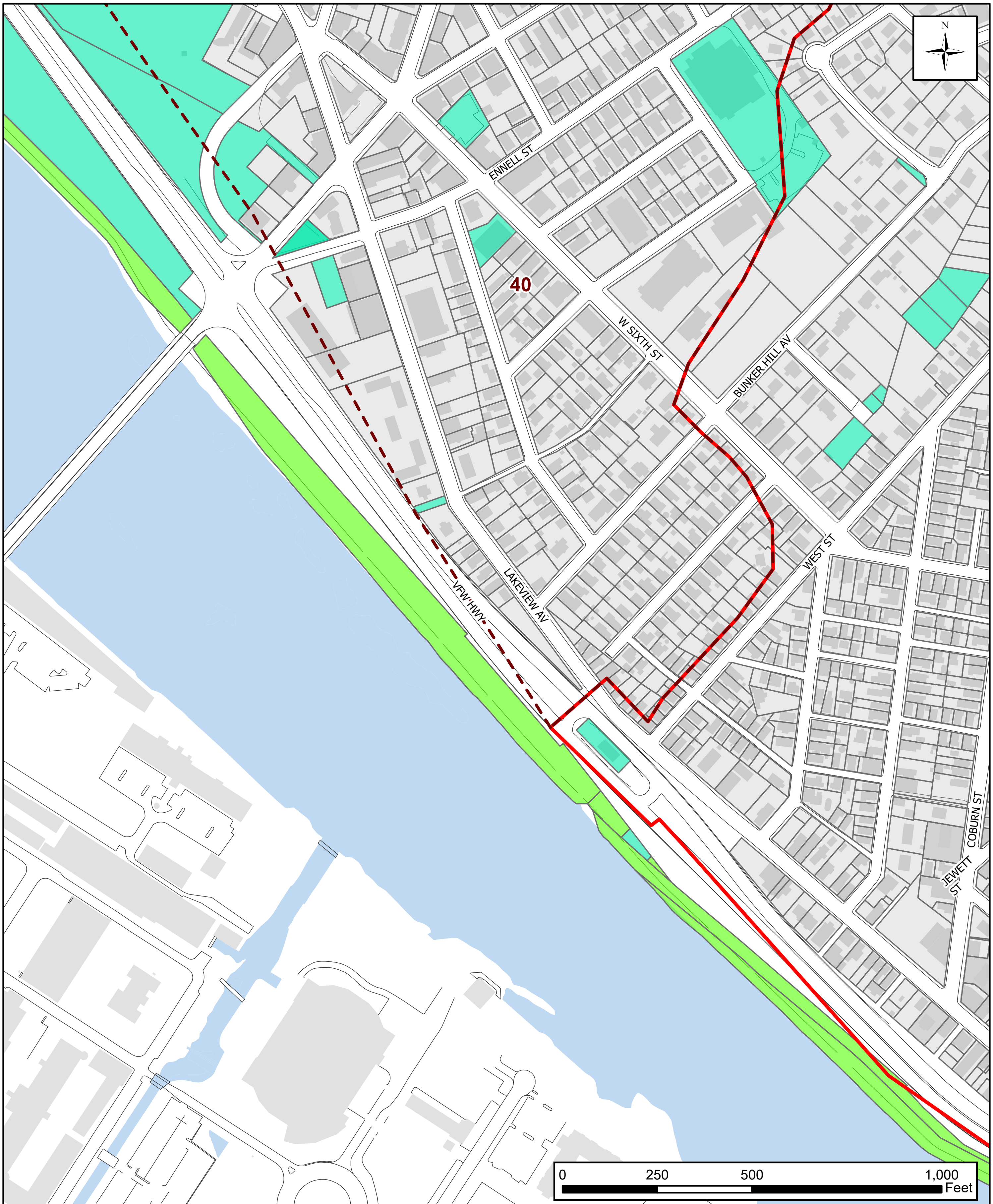
- Written notification to the Lowell Conservation Commission for geotechnical borings within the 100-ft Buffer Zone and Riverfront Area. If geotechnical borings need to be collected from wetland resource areas (i.e., Land Under Water, Inland Bank, or Bordering Vegetated Wetlands) then a Notice of Intent would need to be filed with the Lowell Conservation Commission for approval.
- Order of Conditions (OOC) from the Lowell Conservation Commission for any temporary impacts to Inland Bank, BVW and LUW for the construction of new inlet structures and for a new outlet to the Merrimack River. Less than 5,000 square feet of BVW and LUW is expected to be temporarily impacted by construction activities and therefore the OOC serves as the 401 Water Quality Certification.
- Self-Verification (SV) under the Massachusetts U.S. Army Corps of Engineers General Permit (GP) 6 (effective June 2, 2023) for any temporary <5,000 square feet of alteration to Humphrey Brook and/or vegetated wetlands regulated as Waters of the U.S.
- Massachusetts Environmental Policy Act (MEPA) review. A pre-application meeting with MEPA staff was held for guidance under the MEPA process. Based on these discussions, a dual Expanded Environmental Notification Form (EENF)/Proposed Environmental Impact Report (EIR) will be prepared and filed, along with an Environmental Justice (EJ) Assessment. Earlier phases of the CSO Consent Decree were reviewed by MEPA under EEA file Number 12059.
- Massachusetts Highway Department Access Permit for work in VFW Highway right-of-way.
- Coordination with MHC and Project Notification Form (PNF) Submittal.
- The MHC is the state agency which functions as the State Historical Preservation Office 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 if the Acts of 1988 (950 CMR 71.00) is required for projects with any state action (which includes SRF funding).

Since the proposed project is mainly located within existing streets and in previously disturbed areas, it is not anticipated that any inventoried historical resources or archeological resources would be impacted. A Project Notification Form (PNF) will be submitted to MHC to initiate the consultation process and their review of potential impacts to significant historical and archeological resources.

The PNF would include a detailed narrative description of the proposed project; a description of the existing conditions and the nature of any past development of disturbances on the project site, if any; a list of all the federal and state funds, licenses, and permits required for the project; photographs of existing areas to be disturbed; and a USGS project location map and proposed site plan.

In addition to the wetland and access permits required above, new drain outfalls to the Merrimack River may require the following additional permits/approvals (if the Aiken Street outfall is installed in the non-flood protection portion of the river bank, the Pre-Construction Notification and the Section 408 application/permit may not be required):

- Chapter 91 License from MassDEP Waterways for construction of a new structure below the ordinary high-water mark of the river.
- Article 97 Conversion (Change in Use) petition to the Legislature will likely be required for a new utility easement on Department of Conservation and Recreation (DCR) land (i.e., the Merrimack River bike path) 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 was established by statute and includes a process for submission to the Legislature of petitions to authorize the use of Article 97 land for another purpose. The PLPA is administered by the Executive Office of Energy and Environmental Affairs (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. Land ownership in the study area with respect to state and City property that might be considered in an Article 97 process is included in **Figure 5.2**.
- Pre-Construction Notification under the Massachusetts USACE GP 6 (effective June 2023). Upper federal jurisdictional limit is the ordinary high-water elevation.
- Section 408 approval from the USACE for permission to install new drain pipe through a Civil Works project (i.e., the Lakeview Earthen Levee). The Lakeview Levee is part of the Lowell FDR System and extends from the Bridge Street bridge upstream along the northern riverbank of the Merrimack River up to Aiken bridge. Section 408 allows the USACE the ability to grant permission for another party to alter a Civil Works project upon determination that the alteration proposed will not be injurious to the public interest and will not impair the usefulness or purpose of the Civil Works project. The USACE will review structural design, stormwater design, hydrological and hydraulic design, and compliance with the National Environmental Policy Act (NEPA). Multiple meetings with the USACE Section 408 Program have been conducted. One of the primary concerns of the USACE is maintaining flood protection with any construction opening of the levee. This will have to be detailed in the Section 408 application. Obtaining approval from the USACE for this particular modification to the Lowell FDR System



Legend

Parcel Ownership

- City of Lowell
- Dept. of Conservation and Recreation (DCR), Division of State Parks and Recreation
- Other

- Sewer Area 40
- 2000 HB PDR Area

Lowell, Massachusetts
Centralville Sewer Separation
Revised PDR

Figure 5.2
Parcel Ownership

should help to avoid recertification of the use of the levee for flood protection to properties behind the levee.

- There are low-lying areas behind the existing flood protection levees. If outfalls were constructed with new drainage system in these low areas, adequate protection would have to be provided to avoid backflow of the river into the areas during high river conditions. These modifications will likely be subject to Federal Emergency Management Agency (FEMA) review. FEMA is responsible for the accreditation of levees to provide adequate risk reduction on a Flood Insurance Rate Map (FIRM). Design of these outfalls or drain modifications will likely require documentation that the inland flood elevation/protection will be unchanged during coincidental inland storms and high river elevations.

In addition to the permits listed above, the contractor will be responsible for obtaining any other local approvals needed for pipe installation including but not limited to NPDES Construction GP from the U.S. EPA and Street Opening Permit from City of Lowell.

5.3.4 Soil Disposal and Hazardous Waste

During construction, the project will require excavation of soils, mostly in the street. The soils will be stockpiled, and then backfilled into the excavation and compacted before the final pavement is put into place. During design, typically, an initial investigation to identify known areas of contamination and to anticipate potential hazardous soil conditions along the route will be completed. In addition, surplus soils/spoils are created as the new pipe fills the trench area. These soils must eventually be characterized through environmental sampling to identify final off-site disposal. This soil disposal characterization can either be done before construction begins or when final disposal must be arranged for the surplus materials.

As an initial step, the MassDEP Massachusetts Contingency Plan (MCP) website was 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). There are 11 sites with assigned RTNs listed within 400 ft of the proposed pipe alignments. Of the 11 sites, only one is considered open:

- The Grand Manor Condo Association at the Northern extent of the project area is associated with the open RTN (3-0029226) and two of the closed RTNs (3-0028606 and 3-0028472). This site was assigned an RTN due to the identification of solid waste during excavation related to the installation of new utilities in 2008. Some impacted soil has been removed from the site; however, the use of air purification units within the condominium buildings, due to the concern of vapor intrusion, continues as recently as August 2023.

Of the 11 sites, there are three RTNs that have been closed under an Activity and Use Limitation (AUL). An AUL documents that there is a presence of oil and/or hazardous material that continues to contaminate a site. An AUL is a legal document that establishes how the site may be used and the activities that can be performed on the site. The three RTNs that include AULs are the following:

- Two RTNs associated with 700 Aiken Street (3-0031287 and 3-0031602), both of which are closed under an AUL due to remaining elevated concentrations of petroleum aromatic hydrocarbons and petroleum hydrocarbons. The AUL limits the excavation of soil below 9 feet or if blue soil is observed without the consultation of a Licensed Site Professional (LSP).
- One RTN (3-0001328) for contaminated groundwater from a gas station located at 443 Bridge Street was filed and the site was closed with an AUL to prevent access to contaminated groundwater associated with fuel spills.

The remaining sites were all closed under either Class A1 or Class A2 Response Action Outcome Statement (RAO) meaning contaminants have either been reduced to background concentrations or have been remediated so there is a condition of no significant risk without the use of an AUL. Accordingly, based on this investigation of existing resources, there is a low apparent risk of encountering hazardous materials or soils during construction in the project area.

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, July 2019). A pre-survey will be completed in the design phase, to the extent possible, to identify the potential to encounter these materials and to develop a plan to address them, including handling and disposal. If unanticipated encounters are realized, the Massachusetts guidance document and qualified inspectors will be used to follow the proper procedures for identifying the material, notifications to the state, and the handling and disposal of the pipe and the soil around it. The field inspections and handling/disposal oversight will be completed by a trained and certified person.

5.3.5 Boring Program

CDM Smith conducted a boring program to determine subsurface soil conditions for pipe bedding and support. Concurrent with these geotechnical borings, CDM Smith performed environmental sampling at selected bore hole locations along the proposed main conduit to identify potential hazardous materials. Specific reference to potential areas of contaminated soils will be included in the contract documents and the construction contractor will be required to be prepared to institute proper procedures to minimize the cross contamination of clean soils and to ensure that appropriate health and safety measures are taken to protect both the workers and the public. These procedures will also include reference to pertinent state and federal regulations for the handling and disposal of excess excavated material that may result from the construction.

5.4 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.

As the work on this preliminary design report has progressed, good lines of communication and public notification have been created working in unison with the Department of Planning and Development, and that framework should continue throughout the final design and construction phases of the project. Public notifications, newspaper articles, neighborhood public meetings, City Council meetings, and social media blasts will all be instrumental in keeping the public informed of the project. Public meetings held in the design stages will be important to solicit local knowledge of issues and of 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 has worked with the City to develop the online Lowell Sewer and Street Flooding Issues Survey described in Section 2. This survey, that can be found on the LRWWU website linked here https://www.lowellma.gov/637/Wastewater-Utility, will allow the public to provide real time input on various issues in the project area.

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.

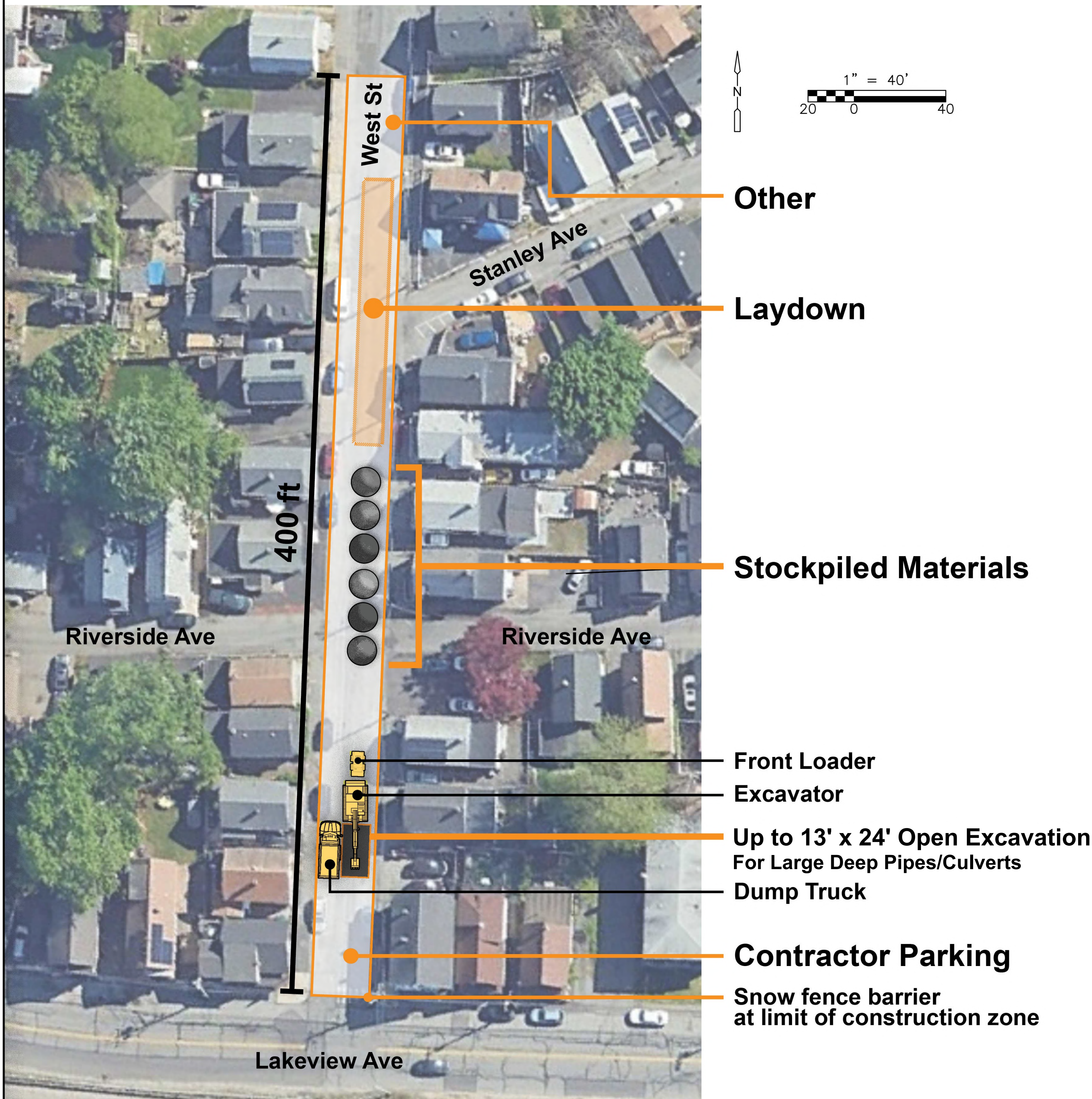
5.5 Constructability Review

During preparation of the preliminary design alignments, CDM Smith completed a site walk along the proposed routes with a resident construction engineer and City staff to identify key construction issues such as the location of wetlands, surface conditions, traffic, general condition of existing roadways, sensitive receptors, and areas of concern, etc. Based on these observations, initial constructability challenges were identified along each of the major pipe routes to consider the potential impacts, mitigation measures, and general feasibility.

To facilitate a further evaluation of these construction impacts, a preliminary work zone was developed to consider the local road and residential impacts. The focus area was West Street, from Hildreth Street to Lakeview Avenue, where the initial alternative pipe route suggested the construction/installation of a 5-foot wide by 8-foot deep box culvert along this very narrow street to complete the drain system outfall to the Merrimack River. This is considered the "worst-case" scenario but does represent the level of construction impact that may occur on adjacent streets like Stanly Street, Coburn Street, and Jewett Street along with some of the small cross streets. In these areas, the single and multi-family dwellings are located very close to the narrow streets, sometimes right along the back sidewalk line, which provides very little buffer to the construction along the street.

For this visualization, the work zone was estimated to be approximately 400 linear feet of roadway, as shown in **Figure 5.3**. This would accommodate areas for construction equipment, laydown area for trench support devices, and stockpiled materials. The work zone would be enclosed by a snow barrier fence. (Concrete barriers might also be used as long as they did not have to be moved every day, which could shorten the daily work period). **Figure 5.4** shows a street view of the potential impacts of construction equipment operating along a street, like West Street, with a very narrow width.

During construction, many roadways will be closed except for sidewalks, and detours will be identified. Housing access and on-street and off-street parking will be impacted and will create disruption to the



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 5.3
Typical Excavation Plan

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 5.4
Lowell Street Disturbance

neighborhood. During the day, an off-street parking area with transportation may be required to allow residents access to their homes, work, and outside activities during the day.

During working hours, access to the properties for emergency services will need to be coordinated with the police officers on detail. In the evenings, after work hours, the streets will ideally be reopened to the public and vehicles. Metal plates will be installed on top of the open excavation at the end of each day.

Disturbances to the street could be substantial for this construction example and full depth pavement restoration from curb to curb could likely be required based on this construction disturbance. Existing curbs may need to be removed and reset and potentially replaced. Existing gas and water utilities would likely need to be replaced to accommodate the large drain pipe and establish a right sized corridor for the excavation and installation of the box culvert with trench support. The existing combined sewer may also need to be temporarily redirected based on the space available to install the new box culvert.

The evaluation identifies the "worst case" situation in this project area, i.e., the largest pipe getting installed along one of the narrowest streets. Other streets in the project area have less challenging construction impacts and are similar to the type of sewer separation work undertaken by the Utility in its past projects. This potential for construction impacts was taken into consideration in the selection of feasible and practical pipe routes in Section 6.

As part of the constructability review, meetings were held with MassDOT to introduce the project relative to needed pipeline crossings beneath VFW Highway. At these meetings, MassDOT identified a planned Pawtucket Boulevard (VFW Highway) Paving Project from Aiken Street to Bridge Street and their plan to install new drainage (to remove the state catch basins from the Lowell sewer system) and new drain outfalls along the Merrimack River. Continued meetings are required with MassDOT to coordinate these projects to minimize conflicts, negate potential for repaving, and ensure positive outcomes for both projects.

5.6 References

[1.] U.S. EPA AP-42, Fifth Edition, Office of Air Quality Planning and Standards Research Triangle Park, NC, 1995. Accessible at https://www.epa.gov/sites/default/files/2020-09/documents/toc_kwrd.pdf

6.0 Development of Alternatives

6.1 Introduction

The goal of this preliminary design is to develop an approach that effectively and economically removes the surface water inflows (Humphrey's Brook, Billings Street Wetlands, and Hovey Field Wetlands) and separates certain areas of the CSS in the Centralville sewershed. Removing stormwater and surface water from Lowell's CSS will help to reduce the frequency and volume of CSOs at the West Diversion Structure (Outfall (#008)) and, to a lesser degree, at other CSO regulators connected by the interceptor system. In addition, sewer separation will help to address system surcharging and street flooding, as discussed in Section 2, and infrastructural renewal needs, and I/I reduction as discussed in Section 3.

Section 6 summarizes the development of alternatives to effectively separate portions of the Centralville CSS. The analysis revisits concepts presented in the 2000 HB PDR, considers other concepts for removal of Humphrey's Brook, and advances the evaluation of alternative pipe routes and drain system outfall discharge locations based on a range of design storms that incorporate climate change.

Given the large size of the Centralville CSS and the requirements of the Final 2023 CD, separation of the CSS in the Centralville area will be accomplished in phases. Phase 1 will focus on the removal of inflow from Humphrey's Brook and the Billings Street Wetlands, and possibly inflow from the Hovey Field Wetlands. The remaining CSS within the Centralville area will be separated into one or more subsequent phases. Determining the routing for the mainline conduit to remove the inflow sources helps define the limits of these individual separation areas and the phasing of this work. Field work described herein has focused on design needs of the Phase 1 mainline conduit alternatives.

Incorporation of I/I removal and green infrastructure will be assessed as part of final design of the separation areas when additional field survey of existing conditions is available and the suitability of subsurface conditions for stormwater detention and infiltration can be further evaluated. Section 6 will focus on drainage infrastructure related to collecting and diverting the stormwater from the CSS.

Section 7 Alternatives Analysis further discusses the most feasible alternatives identified in this Section 6. Section 7 will present estimated project costs and evaluate the ability of specific alternatives to meet the requirements of the CD and address the City's goals for reduced system surcharging and street flooding.

6.2 Base Mapping and Field Investigations (Survey/Borings)

Base mapping is necessary for the development of 20-scale design drawings of pipe routes to identify underground utility conflicts, establish pipeline inverts and depths, and consider the feasibility and construction challenges of each alternative pipe route. This base mapping was prepared using a combination of existing City GIS data and solicited utility information as discussed further below. Select utility sewer record drawings were also reviewed for potential bedrock along the alternative pipe routes (if noted on the drawings).

Volume 2 of this PDR includes a set of preliminary design plan and profile drawings. These drawings were used to develop the most practical routes for new piping and determine the appropriate depth for new pipe, with consideration of general constructability issues and the need to minimize community impacts and avoid utility conflicts to the extent possible. The pipe size/length information presented in this section is based on the hydraulic model developed for this project and may vary slightly from the pipe lengths shown on the preliminary design drawings.

Final survey and borings have been completed along the potential mainline conduit routes (identified further below) to confirm actual positions of underground utilities within the street right-of-way and to identify subsurface soil conditions to determine pipe support and bedding requirements, bedrock depth, and trench support requirements. This comprehensive topographic survey will be used to develop the Phase 1 design drawings for bidding and construction.

Figure 6.1 shows the extent of the final design survey and borings along pipe routes completed to date. This field work was initiated after the primary alternative routes were identified.

6.2.1 Base Mapping

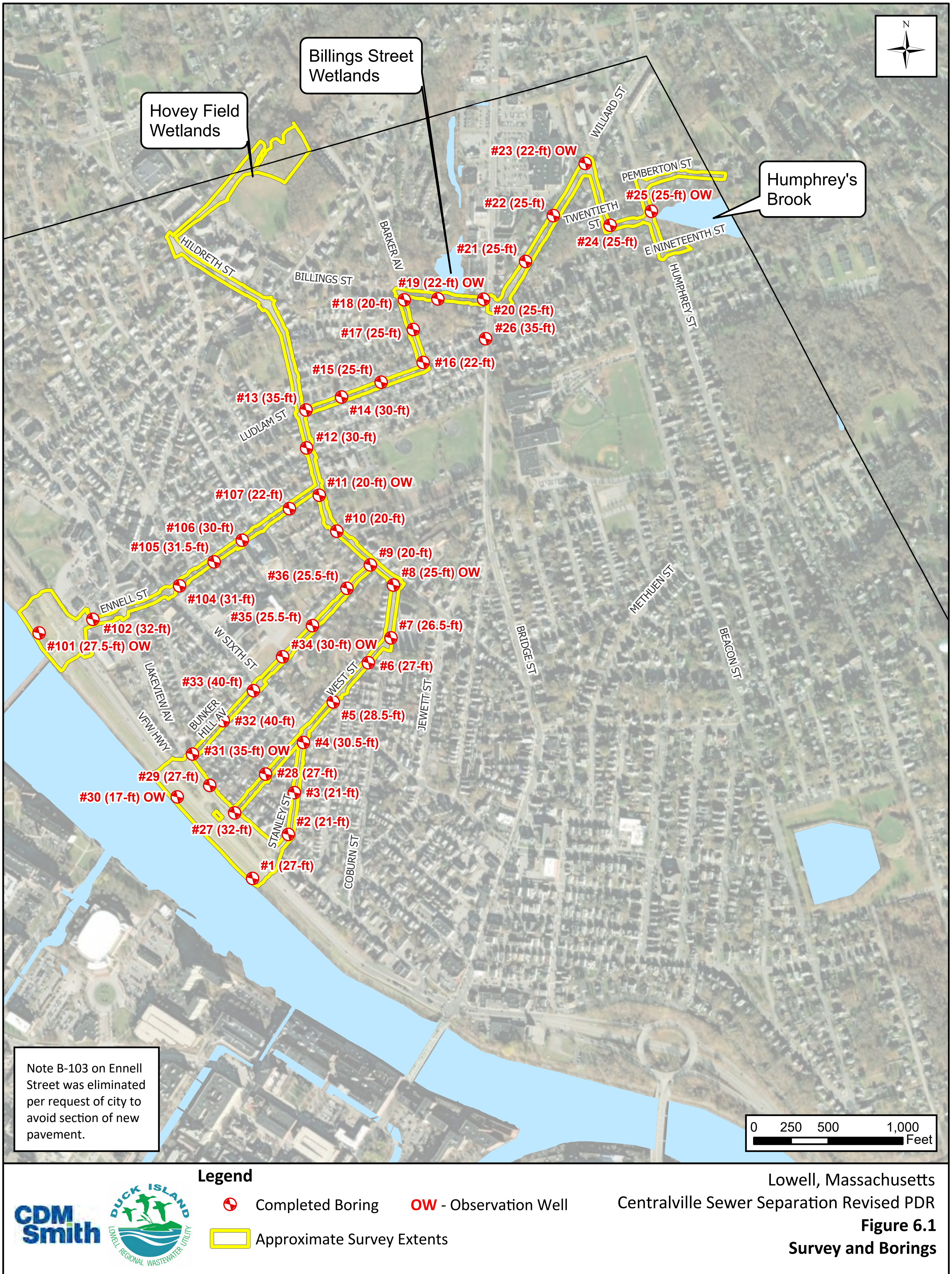
The City's GIS database is a robust source of information that was used to create preliminary base maps. The database includes property parcels, streets, pavement limits, buildings, select hydrologic features, utility poles, and surface contour information. In addition, it also has an inventory of assets including information on sewers, drains, manholes, and catch basins, which was also supplemented with available sewer and facility record drawings. The City's GIS also provided information on water main alignments and sizes. For private utility information, CDM Smith contacted Verizon and National Grid for information regarding the size and location of communications, gas, and electric utilities in the project area. For final design, this base mapping information will be supplemented with information provided by an ongoing field survey.

6.2.2 Geotechnical Investigations

As part of preliminary design, in-situ subsurface investigations were initiated to obtain data to inform the final design. These investigations include borings to characterize the soil conditions below the potential pipe invert, geotechnical samples for laboratory analysis, groundwater depths, and environmental/potential pollutant conditions. As noted above, subsurface conditions will be a factor in the project costs to excavate, dewater, install, and support the pipe and connecting manholes.

Figure 6.1 shows forty-two (42) borings that were completed in the project area. The borings are located approximately every 300-feet along potential pipe routes for the mainline conduit and range from 20 to 40-feet in depth (extending to approximately 10-feet below the proposed pipe invert). Each boring was pre-cleared using a vacuum excavation method to minimize the disturbance of existing underground utilities.

Geotechnical samples for soil laboratory analyses were taken continuously between a boring depth of 0 to 10-feet, and then at 5-foot intervals, to further characterize the soil stability and content. Bedrock depths were noted at refusal but, in some locations, rock cores were also taken to an addition depth of 10 to 15 feet below refusal to confirm bedrock or boulders.



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR

Figure 6.1
Survey and Borings

At ten of the boreholes, an observation well (OW) was installed to monitor the groundwater table. Groundwater information will be used to identify the dewatering measures needed during construction. The OWs in this project were spatially located to characterize groundwater depths in the project area to anticipate potential trench dewatering issues. Groundwater levels will be checked periodically during project design and construction.

The geotechnical investigations began in November 2023 and continued through March 2024. The information obtained during this program will be summarized in a memorandum and used to advance the final design of the mainline conduit. Focused geotechnical analysis reports may be required if unsuitable pipe bedding conditions are discovered and a mitigation solution must be identified. The program also indicated high bedrock in borings B-12, B-13, B-14, and B-15. Rock removal is discussed further in Section 6.6.1: Common Components and Challenges.

6.2.3 Environmental Data Evaluation

Environmental soil samples were collected at select boring locations and depths for excess soil disposal pre-characterization. As discussed in Section 5, the MassDEP Waste Site & Reportable Releases database was consulted to identify any potential waste sites in the project area. One site with an open and active Regional Tracking Number (RTN) was discovered in the project area at the intersection of Willard Street and Humphrey Street; as a result, extra soil sampling was targeted in this area. Two sites at 700 Aiken Street have closed RTNs but have Activity and Use Limitations (AULs) filed for the properties. These sites likely have contamination remaining below the ground surface on the site and there is a chance that contamination could be encountered in the right-of-way adjacent to these sites. In that event, a Licensed Site Professional (LSP) may have to be engaged by the construction contractor during excavation.

Soil samples were collected at select borings within the first five feet of depth with the vacuum excavation pre-clearance. A photoionization detector (PID) was used to continuously monitor the boring headspace for VOCs during the advancement of the borings. If the PID was triggered, additional environmental samples were taken to characterize this potential contamination zone. In addition, a second sample was collected at select locations where deeper pipe installation is anticipated.

All soil samples were analyzed for the parameters required to determine whether the soil would be classified as clean or contaminated with regard to ultimate disposal options for potential excess excavation materials. All testing and results will be compiled during the project final design phase.

6.3 Reuse of the Existing Combined Sewer System

Reuse of an existing CSS as a drain system (and construction of a new sewer) is typically considered as an alternative to the installation of a new drain system as a CSS separation approach. This option works best if there are no known system surcharges or street flooding that would suggest that the existing system has deficient capacity. A similar analysis was completed in the 2000 HB PDR and the report suggested that a new drain system be constructed with the existing CSS rehabilitated for continued use as a sewer.

The advantages and disadvantages of these two approaches were revisited for this study; it is important to note that the downstream areas in Centralville have reported street flooding during severe rain events, suggesting that a new, larger drain system is warranted. **Table 6.1** summarizes the advantages and disadvantages of using the existing CSS as a wastewater collection or stormwater collection system, which are discussed further below.

Table 6.1 Re-Use Analysis Summary

Combined Sewer as a Stormwater Collection System (Build New Sewer System)		Combined Sewer as a Wastewater Collection System (Build New Stormwater System)	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Infiltration Reduction	Creates Elevation Conflicts	Flexibility in Construction	Minimum Pipe Velocities
Maximum Use of Surcharge Conditions	Deep Construction	Reduced Flow Handling	Integrity of Existing System
---	Increased Flow Handling	Less Complicated Construction	Creates Conflicts with Utility Services
---	Requires TV Inspection of Existing System	Option of Slip-Lining Existing System	Requires Smoke Testing of Existing System

6.3.1 Use of Combined Sewer as Stormwater Collection System (Build a New Sewer System)

This approach considers the use of the existing combined system as a stormwater collection system and construction of new sanitary sewers to serve the project area.

6.3.1.1 Advantages

Infiltration Reduction

The Utility conducted a metering program during the Spring of 2023 and an I/I Analysis Report to evaluate the amount of I/I in the existing CSS which was completed by January 31, 2024. New manholes and sewer pipes could significantly reduce the amount of infiltration entering the sewer system.

Maximum Use of Surcharge Conditions

Many upstream areas of the CSS are adequately sized to convey peak stormwater flow generated by a 5-year storm event. If surcharge to road depth is considered, the existing pipelines could convey flow generated by larger storm events. If new, more shallow drain lines are considered, the surcharge potential is less as will be the ability to minimize pipe sizes.

6.3.1.2 Disadvantages

Sewer Service Conflicts

Property sewer service connections are connected to the existing combined sewer in each street typically with a sloped service directly to the sewer. Converting the CSS to a storm drain creates an elevation conflict for every sewer service connection within the project area. This situation requires that either the new sewer be lower than the invert of the “former CSS” drain to connect at least one side of the street and/or have two parallel deep sewers. New sewer services on at least one side of the street would be run under the existing system, which may result in pipe failure with adjacent construction if the existing piping is not first rehabilitated. A deeper sewer also increases the need for more rock excavation in some areas of the project.

Making the new sewer pipe deeper is also a challenge as the new sewer must connect to the North Bank Interceptor system at the end of the run. Accordingly, the deeper invert must be raised at some point to match the existing inverts at the end.

Finally, the existing 96-inch North Bank interceptor is also a direct elevation conflict for the reuse of the existing combined sewer because its invert is currently at the same elevation. Accordingly, to use the combined sewer near its discharge point, a new large diameter pipe would have to be installed to either raise or lower the new “drain” to cross above or below the existing sewer interceptor to discharge into the river.

Depth of New Sewer System – Excavation and Installation Considerations

A new wastewater collection system must be constructed at a depth below the existing system to ensure that all connections currently entering the CSS can be accommodated by the new sewer. Available sewer records indicate that bedrock is present in the project area, and this is confirmed by rock outcroppings observed during field visits and preliminary results from the geotechnical program that is estimating bedrock depths and soil conditions.

Flow Handling

The handling of existing flow while constructing a new wastewater collection system, including the probable replacement of portions of the combined sewer mainline, would significantly increase the complexity and cost of the project.

TV Inspection of Existing System

If the CSS were used as a storm drain system, confirmation that all wastewater connections had been removed from the system would be required, adding complexity to the project. Use of the historical CCTV inspections recently conducted and described in Section 3 could help verify connections; however, additional dye testing may be required in some cases.

Section 3 summarizes manhole and pipeline assessments completed as part of the current project. These assessments found that the existing CSS is generally structurally sound but may require extensive rehabilitation as most of the pipe in the project area is approaching the end of its useful life.

6.3.2 Use of Combined Sewer as Wastewater Collection System (Build a Stormwater System)

This alternative considers using the existing combined system as a wastewater collection system and constructing new stormwater systems to serve the project area.

6.3.2.1 Advantages

Flexibility in Construction

There is more flexibility in constructing a new stormwater collection system than there is in constructing a new wastewater collection system, as drains only need to extend far enough to capture existing catch basins and surface collection patterns can be modified. For example, due to drastic changes in elevation in the 2000 HB PDR area, some streets with steep slopes could use time of concentration along a street curbline and effectively capture stormwater runoff at the end of the street, thus eliminating a new pipe.

Several streets would only require a new drain to extend up a portion of the street to effectively collect the stormwater from the entire street. In contrast, the limits of a new wastewater collection system are more strictly defined by the properties that need to be served and, as a result, often require longer lengths of pipe. The shorter length and shallower depth of a new stormwater system results in a cost savings when compared to the cost of constructing a new wastewater collection system.

Flow Handling

Another advantage of keeping the existing system as a wastewater collection system is that the permanent wastewater collection system would be intact and operational during construction. This makes construction of the project much easier, as the existing system would continue to operate as it normally does while the new stormwater collection system is constructed. This eliminates many of the flow handling concerns associated with construction of a new wastewater collection system.

Overall Constructability

Although a new stormwater collection system would require larger pipes than a wastewater collection system, installation of a stormwater collection system would be easier due to the relatively shallow depth of the drains and the substantially fewer number of connections that would need to be made to a stormwater collection system. The new stormwater system would only require the connection of catch basins and other inflow sources.

Options of Rehabilitation of Existing System

Another advantage of using the CSS as a wastewater collection system is that there would be a substantial amount of excess capacity in the collection system after removing the stormwater component; this excess capacity provides flexibility in applying rehabilitation methods which may reduce the inside pipe diameter. CIPP lining is recommended for most pipeline rehabilitation; however, in certain applications, slip lining could be considered where there are severe structural concerns before using dig and replace methods.

6.3.2.2 Disadvantages

Maintaining Minimum Velocities

Removal of stormwater flow from the CSS would reduce flow velocities within the system and create the potential for accumulation of sediment and debris, which commonly causes maintenance and odor problems. Velocity calculations were performed on many of the larger pipes in the CSS to determine if minimum velocity requirements (usually 2 feet per second) are maintained if the stormwater flow is removed from the system. The 2000 HB PDR analyzed portions of the existing system and concluded that most pipe velocities would be between 1.5 to 3 fps without stormwater flow, indicating that the existing CSS should function properly with only wastewater.

Integrity of Existing System

The overall condition of the existing system is an important factor in recommending its reuse. If the CSS were found to be in generally poor condition, there would be a benefit to constructing a new sewer system and using the existing system as the stormwater system.

Section 3 summarized the existing system conditions assessments completed as part of this project. Overall, the existing CSS was found to be in good condition. Recommendations for rehabilitation and replacement of portions of the existing system can be implemented as part of the sewer separation program.

Conflicts with Utility Services

The construction of new storm drain systems, usually starting with 4-feet of minimum cover, commonly results in numerous conflicts with existing water, gas, and sewer service connections, which often range from 3 to 6 feet of cover. Services impacted by construction are typically replaced all the way from the utility to the property line, which disturbs curbing and sidewalks. Potential impacts to services, and related disruption to curbing and sidewalks, must be accounted for during preliminary design and in the cost estimate for the proposed work.

6.3.2.3 Conclusion

Because of concerns regarding the constructability and cost of constructing a new wastewater collection system, the preliminary design of the Centralville Sewer Separation project will be based on using the existing CSS as the wastewater collection system and the construction of a new stormwater collection system. However, there may be limited exceptions for certain streets as the design of each separation area advances.

6.3.3 Sump Pump and Roof Drain Connections

The elimination of in-home sump pump and roof drain connections will be evaluated under any separation project. Sump pumps and roof drains commonly discharge directly to the local CSS through existing service connections. 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 and roof drain connections in the Centralville CSS area. The City is implementing an online Sewer and Street Flooding Issues Survey which includes questions about whether buildings have sump pumps and where these pumps discharge. This information will be helpful in identifying properties that have sump pumps; however, follow-up inspections will be necessary to confirm survey results.

The City has already successfully implemented sump pump and roof drain disconnection programs as part of the sewer separation completed under multiple construction contracts from the years 2002 to 2012. During that time, more than 2,200 property investigations were completed in those areas. As new drains were installed, the Utility disconnected existing drain connections to the sewer system and provided sump pumps to property owners who may have been draining groundwater around their basement through their sewer cleanouts. The Utility tried several approaches to inflow removal including “Splash” solutions outside the home and connecting to drains to avoid future sewer reconnections. The Utility plans to apply these practices on future separation projects based on past success.

6.4 Humphrey’s Brook Direct Removal Concepts

Given that Humphrey’s Brook and its tributary areas cause the inlet sizing to start at a minimum of 36-inches, the feasibility of diverting the brook towards the Merrimack River using trenchless conduits was considered, as this would substantially reduce the size of the remaining separation study area. **Figure 6.2** shows that the most direct route on City owned land using trenchless conduits is down Bridge Street, which would have a depth range of approximately 20 to 30 feet. This concept was discussed with the Utility in early workshops and it was determined that this option was not viable due to the construction, cost, schedule, and permitting challenges described below.

The idea of using a micro tunnel boring machine (MTBM) was considered given the initial size of the original inlet of the 2000 HB PDR (36 to 48”). Typically, an access pit needs to be dug at each change in direction, which can be costly as the pits are large and can be a major interruption to traffic, particularly along a heavily trafficked areas such as Bridge Street. The Bridge Street route was considered favorable for use of an MTBM because the route is relatively straight, thus reducing the need for pits.

One of the problems with using Bridge Street as a pathway for a mainline conduit is that Bridge Street is in the middle of the basin, making it difficult for separation branches on the western side of the basin to connect, as they would slope against grade and therefore be deeper. Deep branches require more excavation support or costly trenchless installation methods. Connection of the separation branches would require drop shafts which are costly due to the complexity of the connection to the mainline conduit. There are also hydraulic and air venting challenges associated with dropping large amounts of flow in a vertical drop.

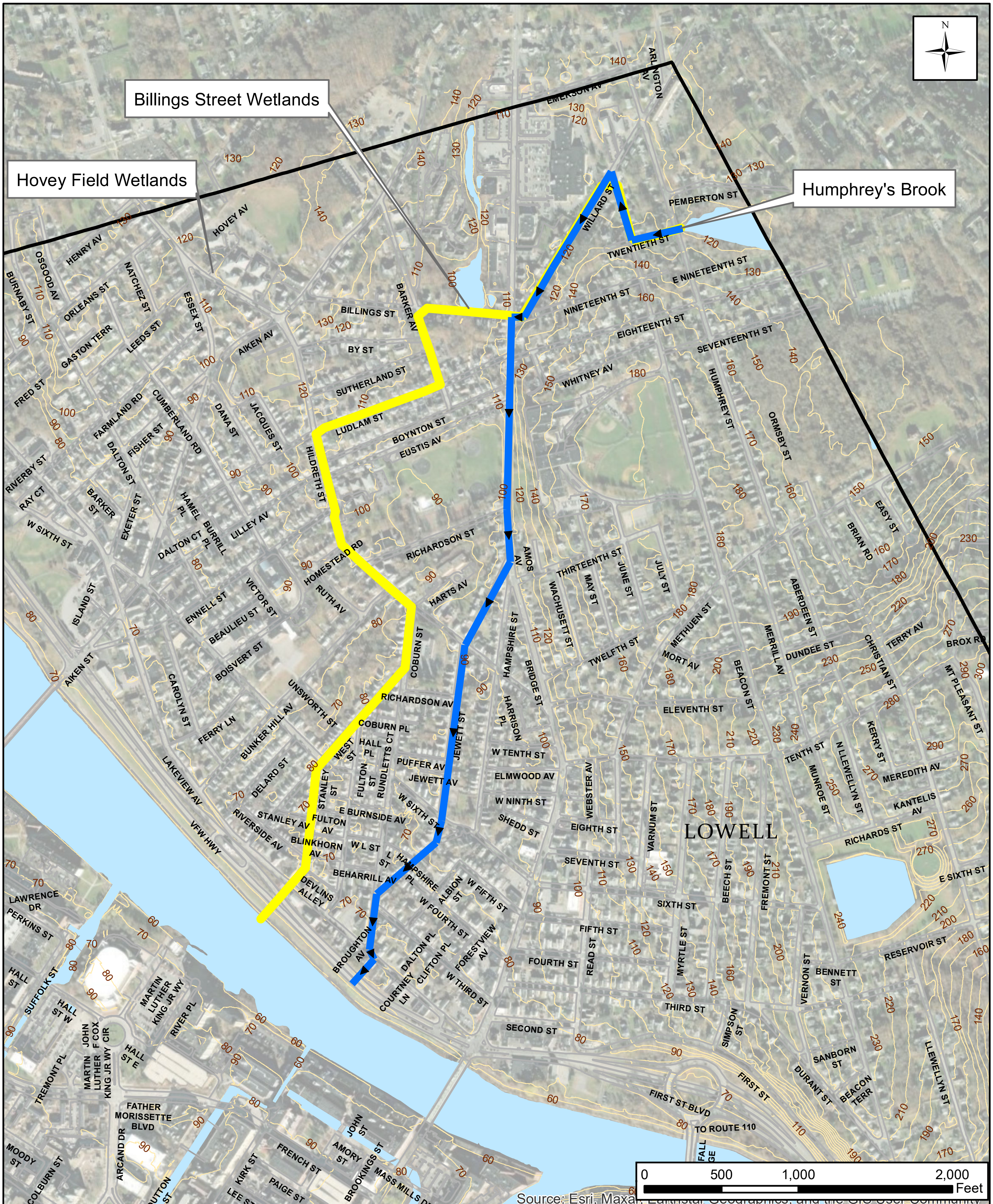
Because of these many alignment, technical, and implementation challenges associated with this concept, the concept of micro tunnel boring as part of this project was quickly determined to not be practical and eliminated from further consideration.

6.5 Methuen Street Separation Area Alternatives

The Methuen Street Area is unique due to its location and topography, which is why the 2000 HB PDR suggested having its own compartmentalized sewer separation solution. Situated directly on the Lowell-Dracut border and at the northern base of Christian Hill, few practical options exist for constructing a new gravity pipe for separation. As described in Section 2, the CSS flows by gravity to the local low point at the base of Easy Street, over the Lowell-Dracut border, and cross-country to the Humphrey’s Street sewer. The cross-country CSS picks up flow from Seventeenth Street and Eighteenth Street.

Two alternatives were analyzed for serving the Methuen Street Area: 1) construction of a drain outfall utilizing the existing culvert at the Methuen Street/Easy Street Intersection; 2) construction of a new sewer for the Methuen Street Area.

Consideration was briefly evaluated if a stormwater system could be directed west against grade to connect to other proposed drainage near Twelfth Street. This alternative would require installation of a pipe up to 40 feet deep, making this option unappealing for both construction and maintenance. Alternatively, the use of a stormwater pump station to provide for a smaller, shallower force main in the same location is not favorable given the infrequent and wide range of flows. For these reasons, this alternative was eliminated from further consideration.



CDM Smith

DUCK ISLAND
LOWELL REGIONAL WASTEWATER UTILITY

Legend

- Concept Trenchless Alignment
- Original 2000 Humphrey's Brook PDR Route
- Topography Contour

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.2
Concept Trenchless Alignment

6.5.1 Alternative 1 – Drain Outfall Utilizing Existing Culvert at Methuen Street/Easy Street Intersection

This alternative would involve constructing a new drainage system in the Methuen Street Area and utilizing the natural topography to flow stormwater east to the Easy Street / Methuen Street intersection and discharge to an existing 30-inch diameter outfall. The outfall culvert accepts the small existing drainage pipe on Easy Street and discharges to an unnamed wetland area in Lowell that is tributary to Humphrey's Brook.

As part of the 2000 HB PDR, field investigations were performed to evaluate this option. Two areas that received attention were the existing headwall off Methuen Street and a culvert crossing on Eighteenth Street, approximately 1500 feet downstream of the proposed discharge point. The existing headwall off Methuen Street would likely need to be replaced to accommodate a larger outfall pipe. A new headwall with wing-walls and riprap was proposed to help stabilize the banks adjacent to the outlet.

The flow discharged from this area would travel more than 0.5 miles through open channels before reentering the proposed stormwater collection system at the Humphrey's Brook inlet. The only hydraulic restriction between Methuen Street and Humphrey Street is a culvert crossing under Eighteenth Street. To minimize any impact from adding additional flow to Humphrey's Brook between Methuen Street and Humphrey Street, it was recommended that the culvert under Eighteenth Street be replaced with a new, higher capacity culvert.

As part of the 2000 HB PDR, performance of the existing brook system between Methuen Street and Humphrey Street was assessed using the 10+ year storm that occurred on September 10, 1999. This investigation determined that the brook has capacity available to handle excess stormwater flow from the Methuen Street area. Confirmation of the culvert upsizing will be done in final design along with the design of modification/replacement of existing headwalls and culverts. A new easement would also need to be obtained.

6.5.2 Alternative 2 – Construct a New Sewer for the Methuen Street Area

This alternative would involve constructing a new sewer for the project area, which would allow the CSS to carry stormwater only. New gravity sewer lines would extend to every property currently linked or tributary to the cross-country sewer line on Methuen Street (194 addresses). This alternative was discussed in the 2000 HB PDR and revisited in the current study as described below.

Sewer flows from 158 of the Methuen Street Area residences would be collected by gravity to a proposed Ormsby Street wastewater pump station. The pump station would pump flow through either a 4- or 6-inch diameter force main along Ormsby Street and Methuen Street and connect to the existing combined system near the Methuen Street/Merrill Avenue intersection. The City has identified undeveloped, open land at the end of Ormsby Street that could serve as a potential spot for a new pump station.

A second wastewater pump station would be needed to serve the remaining 36 residences located on Seventeenth Street and Eighteenth Street, which currently flow into the 30-in cross country sewer in Dracut prior to Humphrey Street. The pump station would be located either along Seventeenth or Eighteenth Street and would pump flow through a 4- or 6-inch diameter force main. The force main would connect to the existing combined system on Humphrey Street. Conceptual sizing and estimated peak flows for the two new pump stations are shown in **Table 6.2**.

Table 6.2 Conceptual Methuen Street Area Pump Stations Sizing

Area	Ormsby Street Pump Station	17th / 18th Street Pump Station
Residences	158	36
Calculated Peak Flow (GPM)	170	38

Advantages

The existing 30-inch diameter cross country combined sewer passes through wetland areas between Lowell and Dracut on its way to Humphrey Street. It is likely that I/I in this area is significant; however, this needs to be investigated further. Using the existing CSS for stormwater conveyance eliminates this I/I component from the existing wastewater collection system and reduces flow to Duck Island.

Disadvantages

This alternative has several disadvantages, including:

- When compared with constructing a new drain for this area, more streets will be impacted by construction activities. The current Methuen Street sewer area would need to be completely replaced, except for Easy Street and Christian Street, which extends further than the required drainage.
- The low point at the Easy St and Methuen St intersection would require that the new sewer on Methuen Street be extremely deep. On the east side of Methuen Street to Ormsby Street, the new sewer would be nearly 27 feet deep at the deepest point. This pipe depth would result in increased construction, maintenance, and coordination costs.
- The additional cost of constructing, maintaining, and operating two new wastewater pumping stations and force mains, and new gravity sewer lines with house laterals. These costs are directly proportional to flow rates and the required pumping head for the station.

For these reasons, this alternative should not be pursued further unless other alternatives prove infeasible.

6.5.3 Methuen Street Sewer Area Conclusion

The most economical and practical solution to separating the Methuen Street area is by construction of a new drainage line that discharges to the existing Easy Street culvert (Alternative 1). **This separation plan is a recommended component of all subsequent alternatives so will not be included in subsequent evaluations presented in this PDR**. **Figure 6.3** shows the peak hydraulic grade line profile along Methuen Street for various design storm events. It should be noted that there are a few existing drains on side streets which may be undersized for the 10-year event as shown in Section 4; however, flood concerns here are minimal as many of the streets have steep slopes towards the trunk drain on Methuen Street, meaning flow will slip to next available catch basin inlet with capacity. Methuen Street also does not have curbs, so green space can also help infiltrate some of the stormwater volume. Given

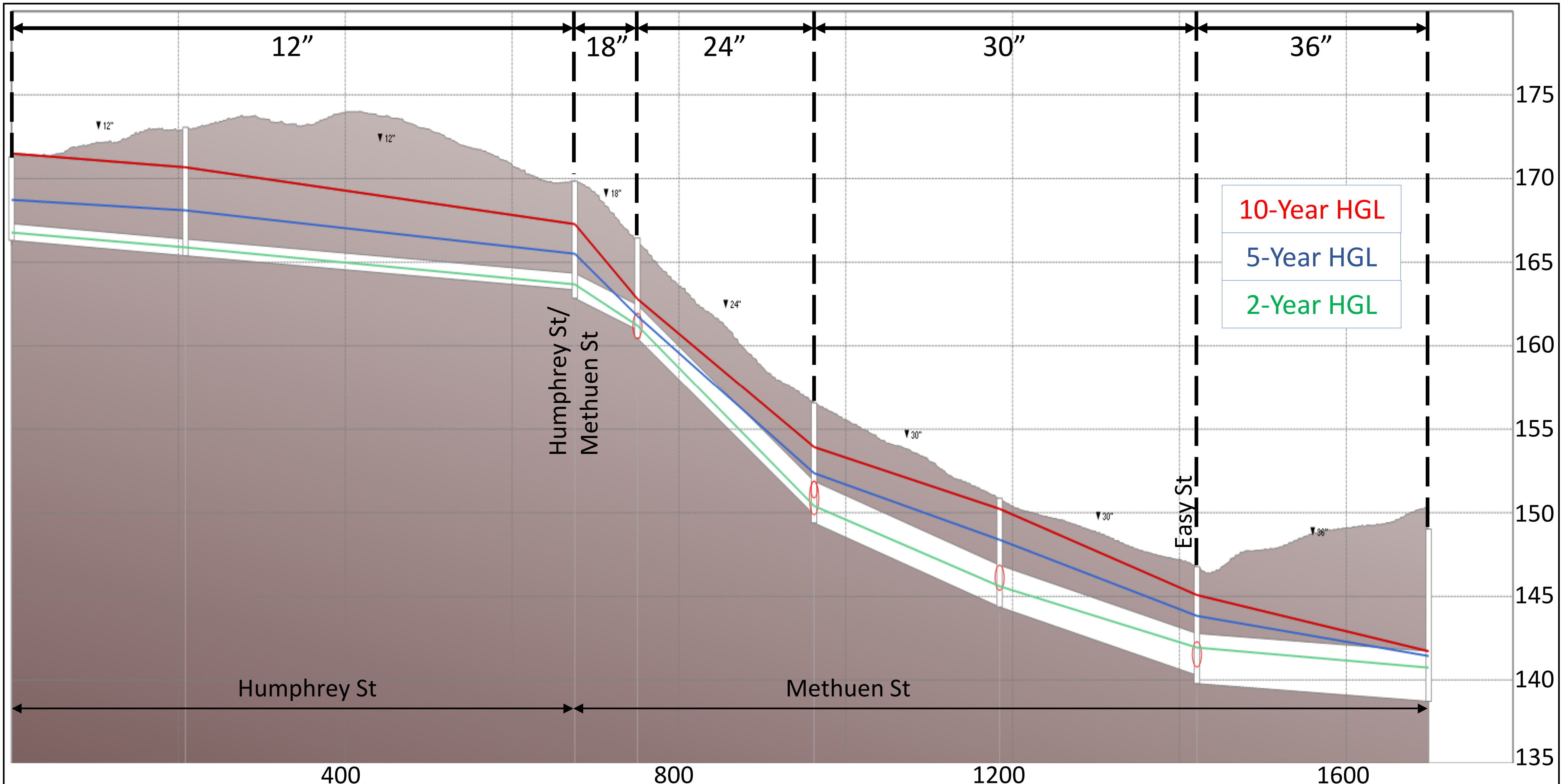


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Figure 6.3
Peak Hydraulic Grade Line Profile for Methuen Street

the infrequency and limited duration of these storm events, it is not considered cost effective to replace the few drains on side streets which may be undersized for the 10-year storm.

6.6 Alternatives for Mainline Conduit for Brook Removal and Other Phased Separation

6.6.1 Common Components and Challenges

The 2000 HB PDR recommended construction of a main trunk line beginning at the Humphrey's Brook inlet and heading west generally with the natural topography to capture Humphrey's Brook and Billing Street Wetlands. The current study also collects a third inflow source of Hovey Field Wetlands via a separation branch from northern area before heading south along Hildreth Street. This is a common component in all alternatives to be discussed below.

In general, the route follows the existing combined trunk sewer in all areas except for a short cross-country segment, where it is located under houses and a recreational park between Ludlam Street and Hildreth Street. From the inlet, the mainline conduit would travel along existing right-of-way to Beacon Street, then northwesterly to Willard Street, and then southwesterly along Willard Steet to the intersection with Billings Street. Flow from the Billings Street Wetlands enters the mainline conduit along Billings Street. From Billings Street, the mainline conduit would travel along Barker Avenue to Ludlam Street and then along Ludlam Street to Hildreth Street, where it would connect a future branch drain that collects Hovey Field Wetlands. The mainline conduit depth would vary from 7-feet to a maximum depth of more than 24-feet at the Ludlam Street/Hildreth intersection. Then the mainline conduit would continue southerly along Hildreth Street towards the southern half of the study area.

After picking up the major inflow sources, the alternative routes vary as summarized separately in this section. Each of the inflow source areas will require modified or new inlet headwall structures, which will require permitting to work within wetlands and maintenance of existing brook flows into the CSS as the inlet is being constructed. Given the distance and elevation difference between the wetlands and abutters to the wetlands, bypass pumping can be minimized or even eliminated, if a slightly increased water surface elevation and wetted area within the wetland does not cause any damage.

The northern half of the mainline conduit route has a common size. In the 5-year design storm, the pipe ranges from 36-inches and 48-inches between Humphrey's Brook inlet and Billings Street Wetlands, where it increases to a 5-foot high by 6-foot wide box culvert (5'x6'). Although the Humphrey's Brook tributary area is larger, its influence on pipe sizes is less because it has longer time of concentration, longer brook channels, and associated wetlands to attenuate or dampen the flow currently captured compared to the other inflow areas. Due to the terrain, there are a few areas with deeper installations (as much as 25-feet) when leaving this low-laying area towards the south and Merrimack River. Any deep excavation will use the slope of the terrain to quickly reduce the cover downstream to meet utility obstacles.

The geotechnical borings suggest that rock removal will be required for the mainline conduit alignment along Hildreth Steet from Boynton Street to Ludlam Street and along Ludlam Street from Hildreth Street to Barker Street. This is common to all alternatives and costs for this rock removal have been included in the Opinion of Probably Construction Cost (OPCC) estimates presented in Section 7.

In the southern half of the study areas, there are additional common challenges, including:

- The need for construction of a large box culvert (minimum size of 5-feet by 6-feet) while maintaining minimal cover.
- The potential for conflicts with multiple large diameter (24-inch and larger) watermains located within West Sixth Street. Two of these watermains are abandoned but still hold water. Any adjacent work should be done with caution.
- Crossing through the levee system and the VFW highway, which was built by MassDOT on top of the levee system.
- Crossing the 96-inch interceptor system.
- Hydraulic capacity limitations which may create street flooding during events higher than 5-Year design storm. As first identified in Section 4, there is particular risk in the low-laying area near Lakeview Ave, Coburn Street, and Jewett Street.
- Separating catch basins from low-laying areas on the inland side of the levee system may not be practical given the potential for surcharge of the system to grade.
- High river elevations under many conditions and the potential need for backflow protection. High river elevations also create additional restrictions for the stormwater discharge and surcharging of the hydraulic grade line, which may present a challenge in low-laying areas with shallow cover. It would be overly conservative to use the 100-year river flood elevation to size the drainage system as there is a small probability of an interior storm occurring at the same time as the 100-year river flood elevation. For the purposes of this report, free discharge conditions were assumed to assess initial pipe sizing and routing challenges. Further joint analysis (i.e. different low probability combinations of high river elevations with interior storm intensities) can be performed once a particular pipe route is selected.

Several mainline conduit routes and branch separation network configurations were explored. In addition to coordination with MassDEP, several regulatory agencies were contacted and invited to provide input on the design challenges listed above.

Representatives of the United States Army Corp of Engineers (USACE) were engaged and asked to provide input on several of the design concepts described in this section. Input provided by USACE representatives is summarized as follows:

- The conduit crossing should be as perpendicular as possible to the levee and proceed straight through the levee to minimize the work area within the levee.
- The crossing should be performed in two phases so that only one half of the crossing is excavated at a given time, thereby always maintaining flood protection during construction.

- USACE provided several of their technical guidance documents regarding construction and backfill requirements to prevent seepage around pipe crossings, including the use of filter diaphragms and controlled low-strength concrete encasement.
- Given the slope of the hydraulic grade line, the operation of the stormwater system will create a positive conveyance into the river even when the outfall is submerged (this will be further explained later in this section). A flap gate will provide backflow prevention to prevent the river from coming inland when the river level is elevated before or after storm events. The need for additional isolation gates was discussed with USACE representatives and will be evaluated further in final design.
- Details of the levee crossing will be advanced in final design and submitted for review through USACE Section 408 application process. O&M plans and Emergency Action Plans will be developed to maintain flood protection.

Representatives of the Federal Emergency Management Agency (FEMA) were engaged and asked to provide input on several of the design concepts described in this section, with USACE representatives in attendance. Input provided by FEMA representatives is summarized as follows:

- FEMA representatives confirmed that, for the brook removal conduit, there is no requirement for an additional isolation gate provided that (1) the O&M plan for the flap gates is signed and stamped by an engineer and approved by USACE; and (2) there are no changes to interior drainage and no changes to the levee crest.
- It was confirmed that the levee will be restored to existing crest heights and that low elevation catch basins will be excluded from the design of the new drainage system.
- More stringent requirements and approvals will be required for separation of low areas such as Lakeview Ave, Coburn Street, and Jewett Street. A Letter of Map revision is required for any modification to the drainage system serving a low-lying area where an average of one foot or greater depth could accumulate during high river flood stages. Additionally, an interior drainage analysis study will be required to document capacity conditions, including coincidental analysis, use of diversion structures, or use of stormwater pumping; this study will need to be submitted to FEMA for review and approval. The areas where this will be required (Lakeview Ave, Coburn Street, and Jewett Street) will be further discussed later in this Section 6. In general, this review and approval process will have a long lead time and does not align well with the schedule for separation of the Centralville area.

Representatives of the MassDOT were engaged and asked to provide input on several of the design concepts described in this section. Input provided by MassDOT representatives is summarized as follows:

- MassDOT is coincidentally separating their catch basins from the combined sewer system as part of their next roadway improvements project along Pawtucket Boulevard and VFW Highway. This has initiated collaborative efforts in outfall planning as MassDOT had originally intended to use areas along the riverbank for a detention area and a separate, smaller outfall.

- Initial discussions indicate that the MassDOT system elevations are higher than the low-laying area risk elevations given that the catch basins are located on top of the levee. The intent would be for the MassDOT drainage system to direct flow to one drain manhole before connecting to the City's drainage system; this will provide a clear delineation of drainage system ownership for the purposes of MS4 sampling programs.
- The MassDOT construction schedule may be sooner than the construction schedule for the City's separation program, so continued discharge to the CSS may be necessary until new outfalls are constructed under the City's phased approach. Additional details of this schedule coordination will be discussed in more detail later in this Section 6.

The Department of Conservation (DCR) owns land along the Merrimack River at each of the proposed outfall locations. Representatives of the DCR were engaged and asked to provide input on several of the design concepts described in this section. Input provided by DCR representatives is summarized as follows:

- In early discussions, it was confirmed that a Public Land Preservation Act (PLPA), Article 97 Legislative Approval is needed because of the change-in-use for a new utility easement taking, especially for maintenance access.
- DCR noted that there is a 1 to 1 compensatory replacement requirement under the recently promulgated PLPA. It may be possible for the City to exchange several City-owned parcels along the Merrimack Riverwalk or other areas with DCR to meet the compensatory replacement requirement.
- DCR Construction Access Permits will also be required for the future utility installation.
- The City has engaged their legal department to help advance the Article 97 process. In DCR's experience, the Article 97 Conversion Legislative Approval process takes more than one year to complete.

The above items are common to each individual alternative to be discussed in greater detail within this section.

6.6.2 Mainline Conduit with Outfall Near Stanley Street

6.6.2.1 Overview

Under this alternative, continuation of the mainline conduit becomes more complex when it changes direction south along West Street and increases to a 5-foot by 8-foot box culvert as described and shown in Section 4 (Figure 4.4). This increase in size is required because the conduit would collect storm flow from the area east of Hildreth Street and add more branches along West Street, Coburn Street, Stanley Street and Lakeview Ave. The large box culvert size exacerbates the challenges of utility congestion within the narrow corridors along West Street and Stanley Street.

The most severe utility challenge is the need for the proposed box culvert to be in the same corridor as the existing 60-inch combined trunk sewer. The box culvert height is limited to 5-feet in order to stay above the existing sewer services while providing some cover, so the width must increase to meet the required conveyance capacity. This was the initial reason for seeking other routes and reconfiguring separation connections to the mainline conduit.

6.6.2.2 Constructability Challenges

The 2000 HB PDR briefly discussed the challenges associated with the downstream crossing from Lakeview Avenue to the Merrimack River. This initial, high-level review has been further developed and detailed as part of the current project.

The first obstacles encountered in this crossing are the two existing combined sewers: a 12-inch ACP located approximately 10-feet deep along Lakeview Ave, and a 48-inch concrete pipe located approximately 12 to 16 feet deep along VFW Highway. The ground elevation is slightly higher on the VFW Highway; this means that there is minimal cover (4-feet or less) when first crossing, allowing for at least 1-foot of clearance and a 7-foot outside dimension for a 5-foot inside diameter pipe.

The VFW Highway (State Route 110) runs along the north bank of the Merrimack River, which was built by MassDOT on the earthen levee system. This is a highly traveled road consisting of two lanes in each direction, separated by a green space occupied by West Station.

The southern slope of the levee system is much steeper towards the river, which means that the last segment of pipe could daylight above the existing riverwalk. Consequently, the last segment or outfall structure is further restricted by the 96-inch North Bank Interceptor. Any portion of the flood plain occupied by the pipeline or outfall structure would require approval by flood control regulators who usually require compensatory storage to offset flood volume lost due to construction in the flood zone. Other options considered include going under the North Bank Interceptor or constructing a conflict structure, but both options have considerable challenges. Going under the interceptor is further explained in the Bunker Hill Ave alternative. A conflict structure is a structure that surrounds a portion of the interceptor at the point that the culvert is crossing, thereby allowing water to flow above and below the interceptor. The advantage of this option is that the connection could be lower, allowing the crown of the culvert to be further below the critical elevation. The concept of a conflict structure was considered but decided to be impractical because having a major interceptor in the flow of water would result in too much head loss and potentially surcharge the system.

River flood stage elevations have a critical impact on the operation of a stormwater system. If the outfall is not high enough to remain free flowing, the outfall could become submerged, thereby creating a hydraulic restriction, and causing surcharge impacts or even flooding low-laying areas. The typical river elevation is approximately 54-feet, and the 100-year flood elevation is approximately 67.5-feet at the Stanley Outfall. Preliminary layout of the outfall indicates that an invert elevation of approximately 58.75-feet is needed to cross above the north bank interceptor, which means that the outfall should incorporate backflow prevention with either a flap gate or Tideflex Duckbill . This elevation also puts areas closest to the river at risk of flooding if the rim elevations of structures are not above an elevation of 70-feet.

6.6.2.3 Conclusions

Combining the inflow source removal and the future separation into one mainline conduit requires a large corridor for a box culvert, which will require extensive utility relocations and protection. The new drain system profile must not conflict with typical sewer collection pipes to maintain services; however, in some instances, the creation of two local sewers to serve each side of the street may be required due to the profile conflicts. A primary concern is that, due to topography, the new drain route would share much of the same route as the existing brick (and concrete) large diameter combined sewer trunk that serves the CSS; this sewer trunk would likely require rehabilitation to protect against damage during construction. Surface impacts under this alternative are also significant given that some roads are narrow with residential homes right on the backside of sidewalks and a lack of driveways, meaning that most residents park on the street. Due to these challenges, it was decided to explore options to reduce required pipe sizes by using multiple routes to accomplish separation.

6.6.3 Mainline Conduit Connecting to West CSO Diversion Station

6.6.3.1 Overview

This alternative reconfigures the network so that the southern half of the Centralville area is divided into three drainage networks that culminate at Lakeview Avenue. This alternative also uses the existing West CSO Diversion Station outfall. **Figure 6.4** shows the proposed mainline conduit for brook removal (phase 1) along Bunker Hill Avenue, two other larger trunk drains along West Street and Lakeview Avenue, and the separation branches from associated separation areas (phase 2). Additional names and letter designation (example Methuen Area) have been added to further differentiate between the Phase 2 areas of work, but these designations do not necessarily reflect individual construction contracts or a required sequence of work.

The mainline conduit route removing the inflow sources would follow the 2000 HB PDR route, collecting flow from the Humphrey's Brook and Billings Street Wetlands and, traveling upstream to downstream, from the Humphrey's Brook inlet along Willard Street, Billings Street, Barker Avenue, Ludlam Street, Hildreth Street; however, the current route would use Bunker Hill Avenue and culminate with other trunks drains before discharging at the West CSO Diversion Station's Outfall. This network would also include future separation of the northern branches, upper half of middle branches at Richardson Street, and Bunker Hill Avenue area.

The second trunk drain, traveling downstream to upstream, would be along West Street, Hildreth Street (East), and Twelfth Street. This network would also include future separation of the remaining middle branches, and areas along West Street.

The third trunk drain, traveling downstream to upstream, would be along Lakeview Avenue, Coburn Street, and Jewett Street. This trunk drain would allow for future separation of the remaining lower areas shown in Pink and Cross gray hatched shown in Figure 6.4. The reasoning for the subdivision of the lower area is explained further with the hydraulic modeling simulations.

6.6.3.2 Hydraulic Modeling Simulations

Hydraulic modeling of the drainage configuration described above was used to size pipes to handle a minimum 5-year design storm; the model was then used to simulate 2-year, 5-year, and 10-year design storms (particularly the 10-year design storm) to assess performance and minimize any temporary flooding. The profile of the three key conduits for inflow removal and separation are shown in **Figure 6.5 through Figure 6.7**. The simulations assume a free discharge to the West CSO Diversion structure to

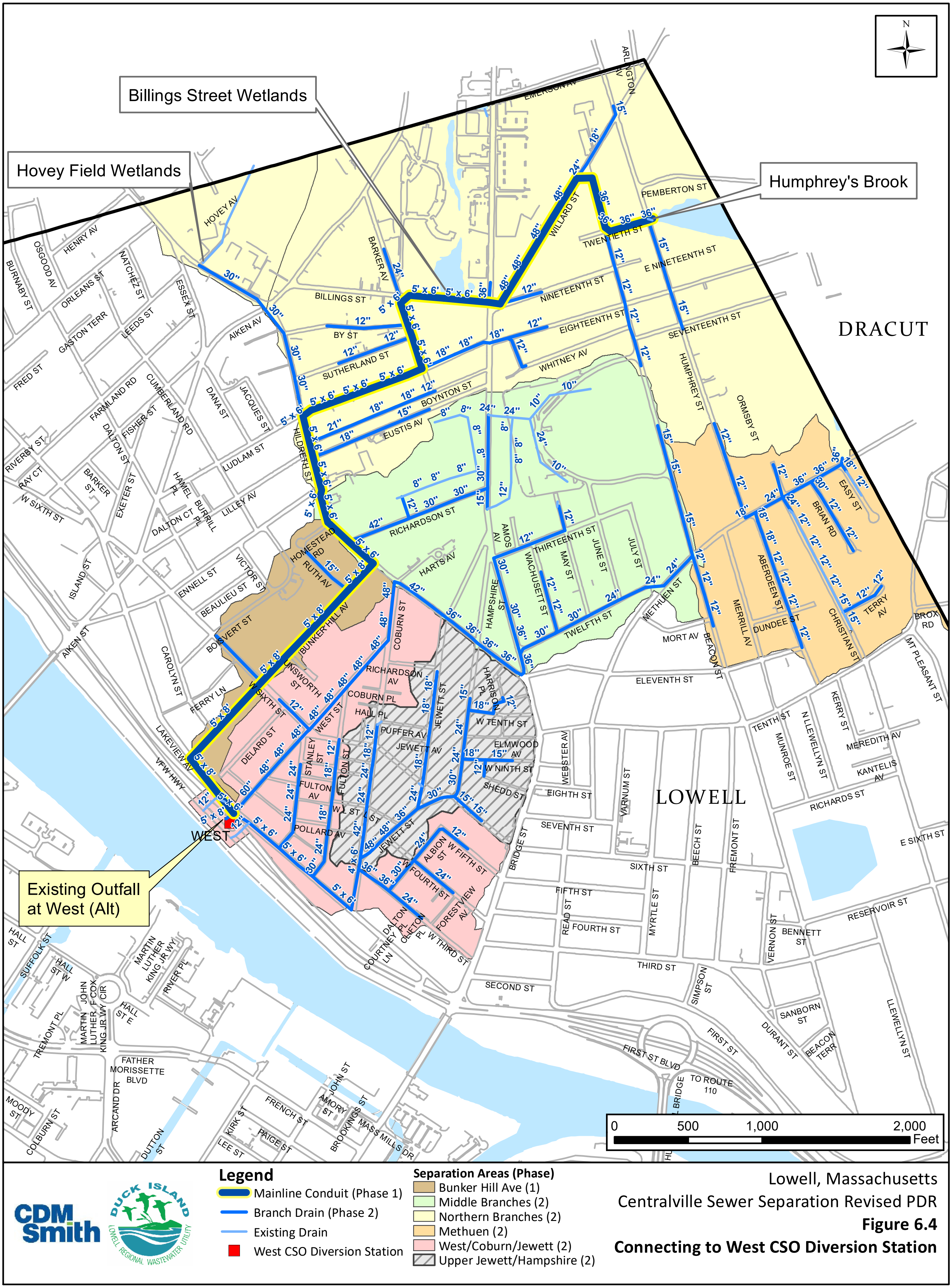

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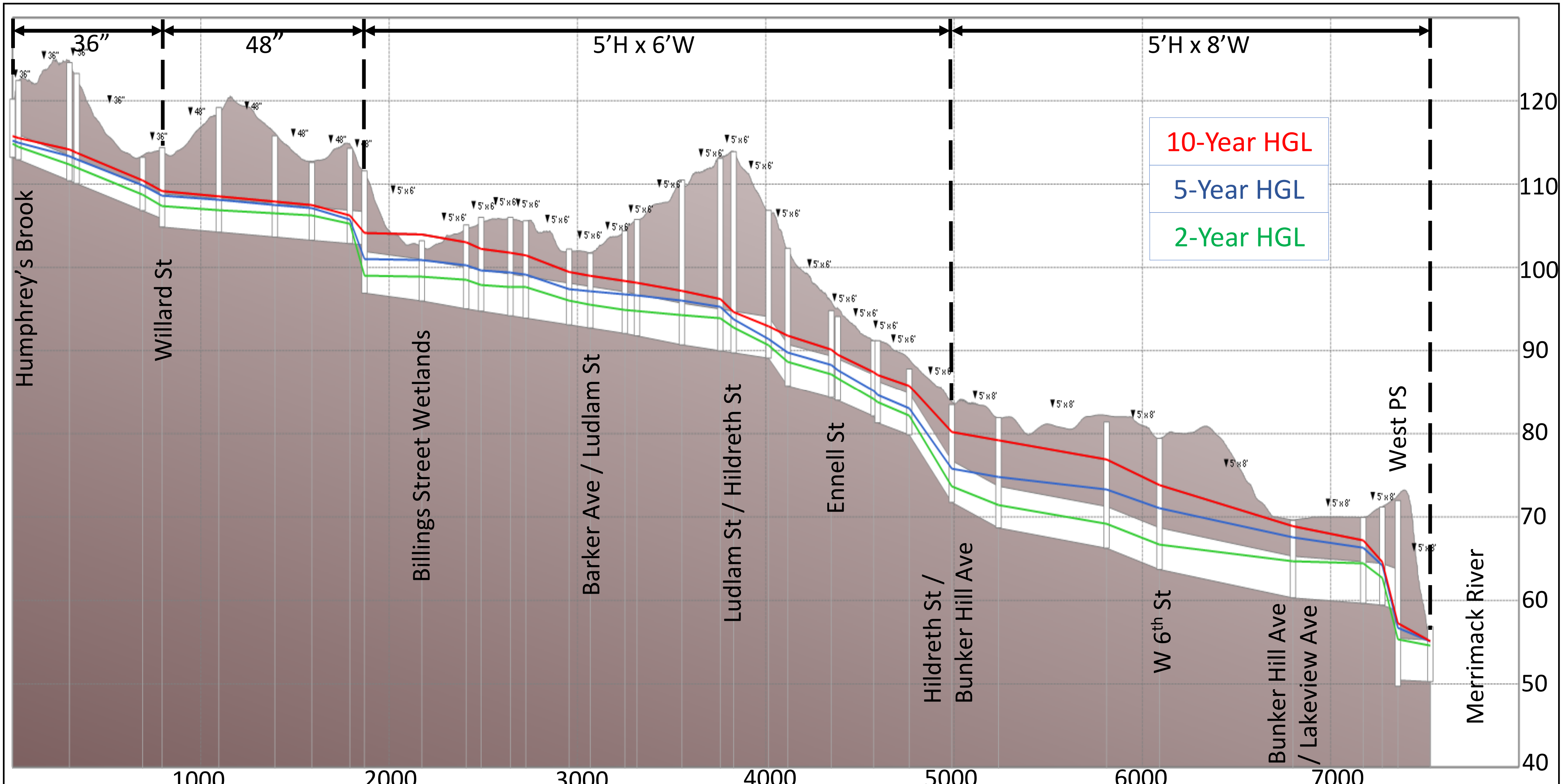
Figure 6.4

Connecting to West CSO Diversion Station



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Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.5
Peak Hydraulic Grade Line Profile for Mainline to West CSO Diversion Station

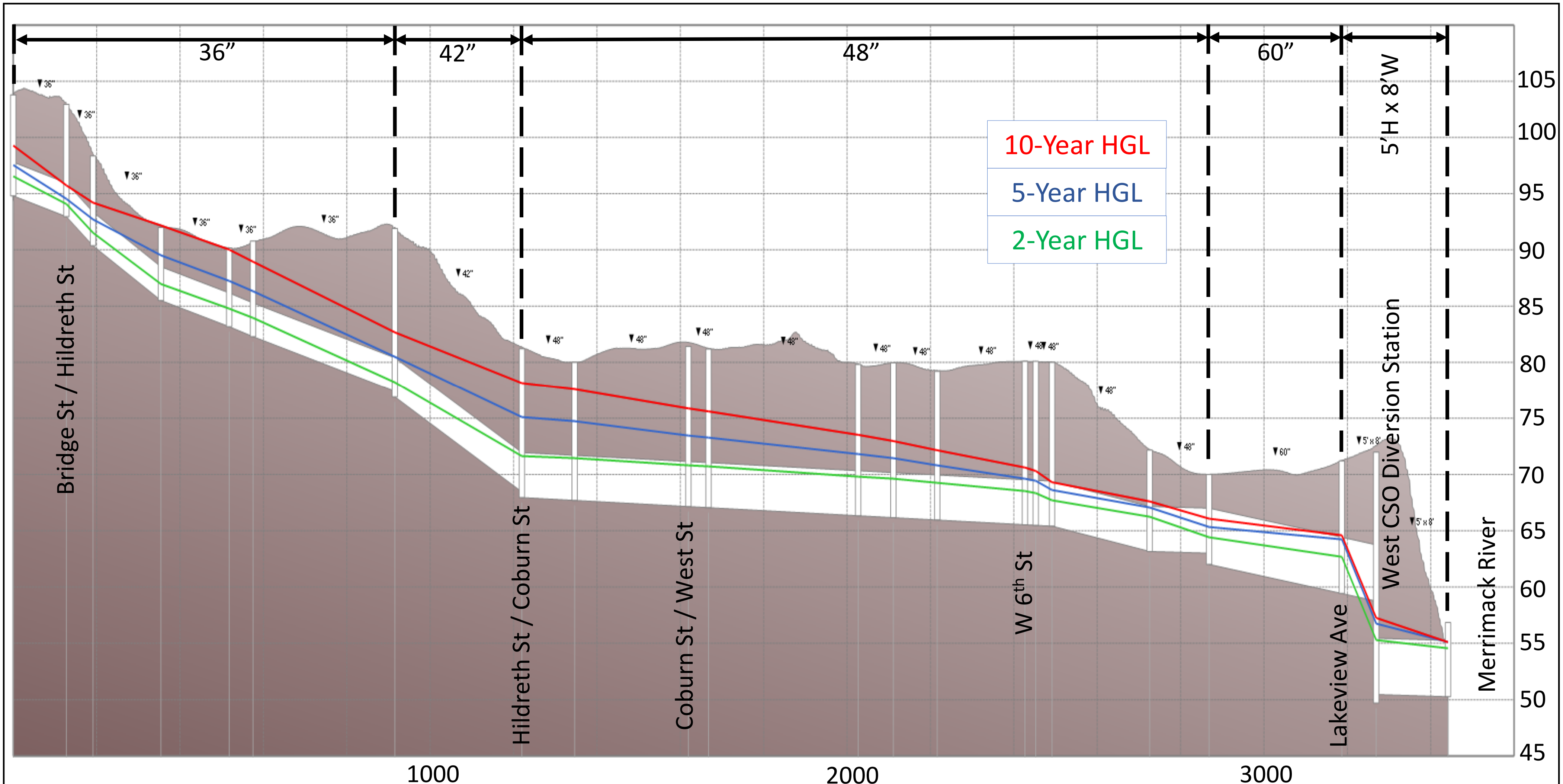

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Figure 6.6
Peak Hydraulic Grade Line Profile for West Street

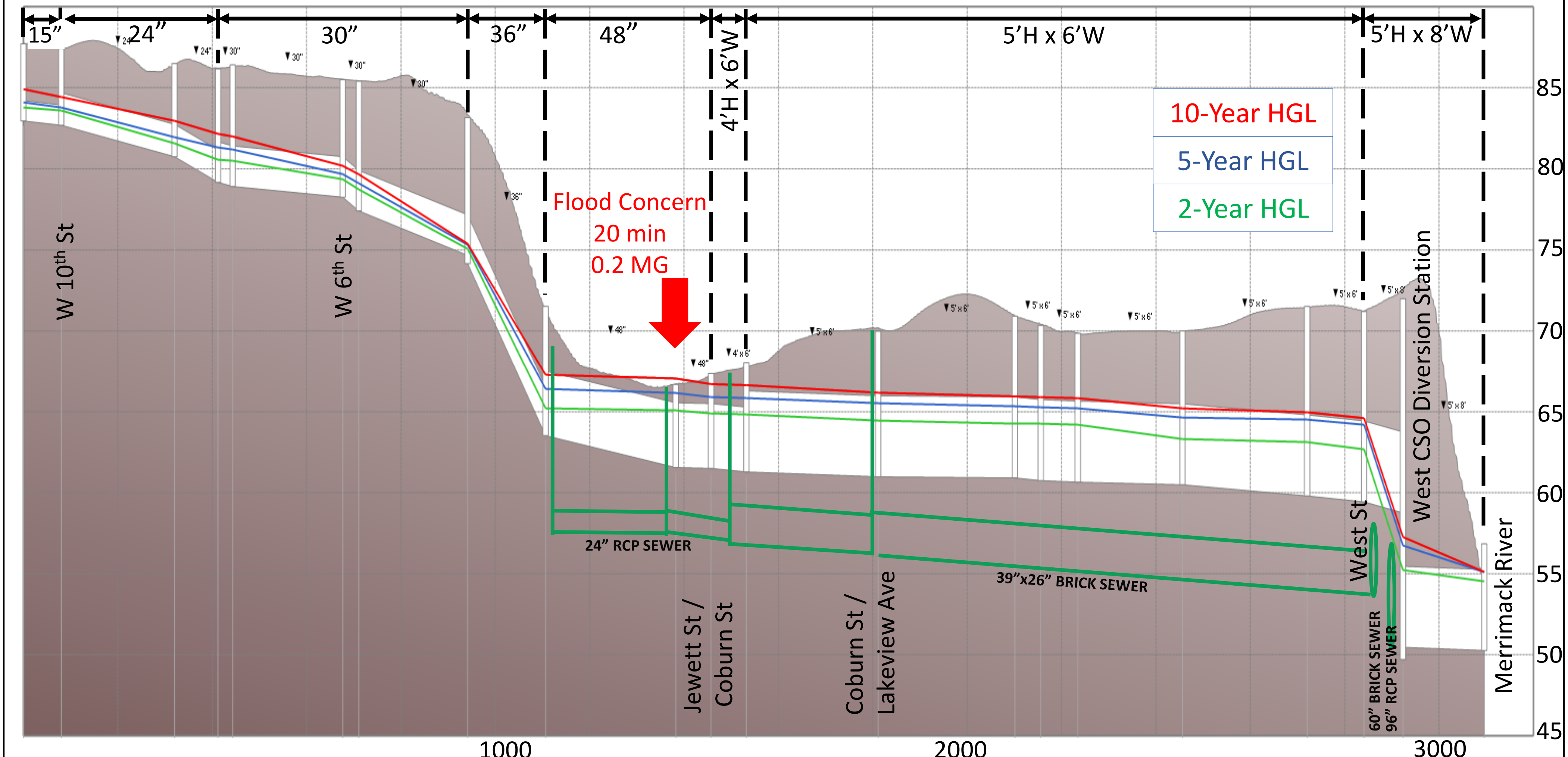

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Figure 6.7
Peak Hydraulic Grade Line Profile for Lakeview Avenue, Coburn Street, Jewett Street

utilize the existing outfall; it does not include additional hydraulic impacts from CSO flow contributions that theoretically could occur in the same junction within the same timeframe. For reference, the 100-year flood elevation is approximately 67.7-feet at the West CSO Diversion Station's Outfall, but this restriction was not applied in these simulations (impacts due to high river levels will be evaluated on the selected route during final design).

Figure 6.5 presents the peak hydraulic grade line profile for the mainline conduit to West CSO Diversion Station. The pipe sizes range from 36-inch to 48-inch moving from Humphrey's Brook to the Billings Street Wetlands, where it increases to a 5-foot by 6-foot box culvert. The large box culvert continues south, collecting additional separation area and increases to a 5-foot by 8-foot box culvert along Bunker Hill Avenue to the West CSO Diversion station. The profile indicates sufficient capacity in the mainline conduit for 2- and 5-Year Storm events; however, during a 10-Year storm, the mainline conduit would flood at the Billings Street Wetlands Area and have significant surcharging in Bunker Hill from Hildreth Street to the West CSO Diversion Station.

The simulation indicates that the stormwater flooding occurring in the street at the Billings Street Wetlands connection occurs for less than an hour during the 10-year event. For comparison, the sewer system model predicts a sewer flooding event for more than 1 hour during the 10-year event; however, the city has never received a complaint of flooding at this location. Separation simulations suggest that separation of the surrounding area will reduce the sewer system surcharge to just above the crown of the sewer pipe; although not ideal, these model simulations indicate that separation will provide a benefit in terms of reduced flooding risk. This flooding risk is isolated to a low section of road where it will surface drain to a wetland. The adjacent homes are higher in elevation and should not be impacted. This stormwater flooding condition is similar to all alternatives presented in this section. In order to improve this situation, the road would need to be raised or the drain profile would need to be lowered; however, the downstream profile of the drain is already more than 25-ft deep due to topography changes near Ludlam Street and Hildreth Street, so further lowering of the drain profile would be difficult.

There are also other hydraulic and operational concerns with increasing conveyance capacity and connecting to West CSO Diversion Station. These concerns are described in the constructability challenges subsection.

Figure 6.6 presents the Peak Hydraulic Grade Line Profile for West Street, which conveys the middle and some of the southern separation areas with required pipe sizes for a 5-year design storm ranging from 36-inches to 60-inches in diameter closest to the West CSO Diversion Station. The impacts of the culmination of the flows from all the networks at Lakeview Avenue, plus the transition from steeper networks to flatter networks, causes significant surcharging to propagate upstream.

The largest impacts to low-laying areas are presented in Figure 6.7 which shows the shallow, large diameter pipe along Lakeview Avenue, Coburn Street, and Jewett Street. Due to the combination of the local separation area transitioning from steep slopes to extremely flat slopes following topography, meeting targeted elevations to cross existing larger diameter sewers, and the significant influence of flows culminating under similar profile conditions, this requires larger pipe sizes to compensate for the capacity issues. The result is over 1500 linear feet of a 5-foot by 6-foot box culvert to meet the 5-year design storm criteria, which is the same size as the mainline conduit with significantly more flow. However, during a 10-year storm event, there is a risk of flooding (0.2 mg for 20-minutes) on a street that does not report any flooding today. Despite being smaller in size, a key characteristic of the existing CSS is that the entire sewer system is a minimum of 5-feet lower in elevation at Jewett Street compared to the new drain so, during larger storm events, it can surcharge higher without flooding. The approximate depths of the sewers are shown on the profile for reference. The new stormwater system cannot be lowered due to conflicts with the existing sewers and river elevation impacts. Subsequent alternative simulations that remove the influence of the inflow sources mainline conduit (Section 6.6.4) found that the removal helps reduce pipe sizes but does not completely resolve the flooding risk. It may be prudent to investigate reducing the flow that is separated upstream of this area since it sends flows from steeper roads to this flat spot or provide additional relief options; both of these options will be discussed later in this section (Section 6.6.5).

6.6.3.3 Constructability Challenges

Hydraulic Considerations

This alternative makes use of the existing West Street Pump Station infrastructure. However, this must be weighed against several hydraulic disadvantages, including:

- conveying larger flows to the station since the new two-pipe system (sewer vs stormwater) increases conveyance capacity downstream compared to the existing one pipe combined system.
- additional conveyance capacity of the separated system overwhelming the West Street Pump Station rated capacity. A separate outfall for the brook removal (rather than a shared outfall) would be preferred.
- constructing new infrastructure over the 96-inch interceptor and connecting to the West Street CSO Diversion Structure.
- larger size of the Lakeview Ave box culverts and the potential for surcharging.
- the challenge of CSO reporting as additional metering would be needed to discount the stormwater portion of the combined outfall discharge.

Increasing the conveyance capacity with a two-pipe system creates a significant concern with overwhelming the capacity of the station should pumping be required to evacuate all the combined flow from the stormwater and combined sewer systems. Early simulations of only the stormwater component suggest that all the drainage connected to the station could contribute flowrates up to 5 times higher than the capacity of the station during a 5-year storm if, coincidently, the river elevation is high enough to require pumped discharges. Consequently, the lower areas adjacent to Lakeview Avenue would flood, which is what the pump station is intended to prevent. Early simulations also indicate that removing the mainline conduit from the station reduces the flooding risk by about 50 percent. This analysis is subjective without adding the combined sewer control components for CSO mitigation and other groundwater, river, and coincidental storm considerations; however, it is apparent that a separate outfall for the mainline conduit is needed, and this requirement is incorporated into subsequent alternatives.

Even with reducing the separation area contributing to the West CSO Diversion station, there will need to be modifications for how the station operates if a connection is made. The Utility is required by the EPA to report the volume of CSOs that exits the station. Currently, a gate dictates when flow is to come into the diversion structure/station and any flow that passes the gate can be measured by an ultra-sonic sensor. Otherwise, all flow goes to Duck Island. With the new connection, flow will be constantly coming out of the culvert and into the diversion structure. This flow will only be drainage flow and therefore does not need to be measured or reported during dry weather. However, this situation would be complicated during wet weather conditions when the CSO gate from the influent channel to the diversion structure is opened and CSO discharged; there would need to be a way to measure only the CSO flow and not the drainage water entering the diversion structure and subsequently the existing outfall. This may be challenging since the CSO flow and non-CSO (drainage) flow would be mixed at the outfall. During final design, further investigation would be needed to develop a flow measure system that would differentiate between the CSO, and drainage flows conveyed to the outfall discharge.

Connection Challenges

<u>West Station Diversion Structure Connection</u>

Connecting the drainage system to West Station will require careful planning and execution. West Station is situated on the VFW Highway along the Merrimack River. The station currently is used to discharge combined sewer overflow to the Merrimack River during high flow situations. In connecting to the West station, the ability for the station to still discharge and pump out CSO needs to be maintained. In reviewing the station operation, it was determined that the east wall of the diversion chamber is a possible connection point. One of the primary considerations for connecting is to make sure that the connection to West Station is below the critical surface elevation for the proposed drains. This critical surface elevation was found to be at the intersection of Jewett and Coburn Street with an elevation of 65.62 feet based on NAVD88. Surrounding the east wall of the station, the main CSO interceptor runs with the crown of the pipe at 56.83 feet. Given these two constraints, a 5-foot wide by 6-foot box culvert would be required with 1-foot-thick walls connecting to the station at an invert elevation of 58.83 feet (see **Figures 6.8 and 6.9);** this arrangement would keep the crown of the culvert below the critical surface elevation and the bottom of the culvert one foot above the top of the interceptor. In addition to considering the elevation of the connection to the station, additional evaluation would be needed to determine how the culvert makes the connection structurally. The culvert should not be able to be placed directly on the interceptor pipe, so a support for the culvert at this crossing would be needed. Additionally, the wall where the culvert connects to the station would require structural evaluation as the structural integrity of the wall may be compromised by puncturing it with the culvert. A new wall between the interceptor and the station may be required to support these loads and avoid interrupting operation of the station. There is no dry-weather operation; however, wet weather (CSO) operations could be limited or temporarily inoperable during installation.

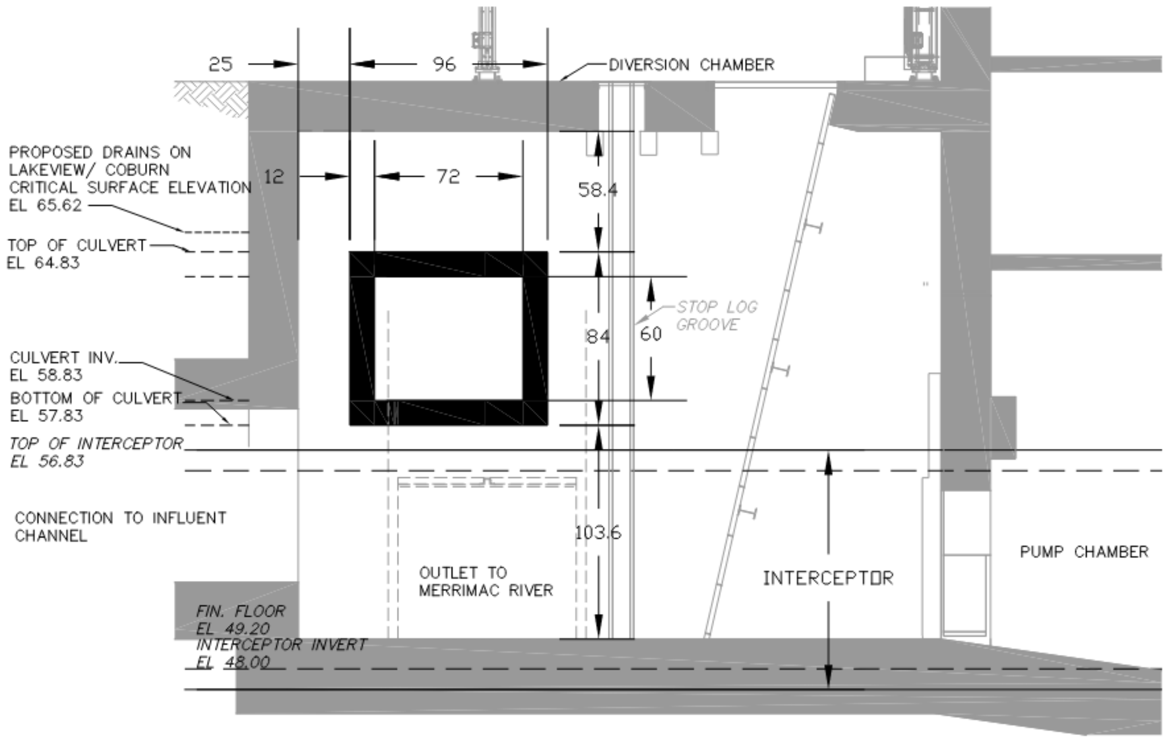


Figure 6.8 West Station Diversion Chamber Connection (East profile)

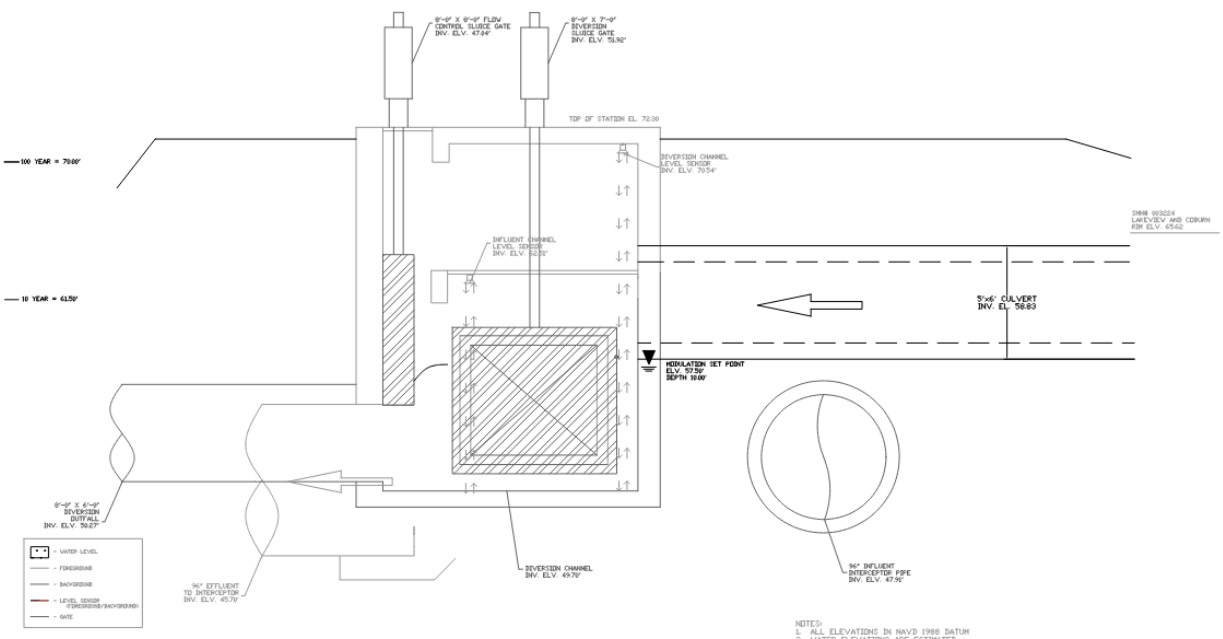


Figure 6.9 West Station Diversion Chamber Connection (South profile)

<u>West Station Outfall Direct Connection</u>

Another option for connecting to the West Station is to connect directly to the outfall conduit. This could be done by bringing the drainage culvert around the north or south side of the station (see **Figures 6.10 and 6.11**). An advantage of connecting directly to the outfall conduit is that, by leaving the diversion chamber untouched, the operation of the station does not need to be modified. The method that is currently used to measure CSO discharge from the station could still be used as the CSO and drainage water would not mix in the diversion chamber. This option would still face the same elevation challenges, as the culvert would need to cross over the top of the interceptor and stay below the critical surface elevation. Structural considerations would also need to be addressed. The culvert would need to be supported as it crosses over the top of the interceptor and the connection between the outfall conduit and the culvert would need to be reinforced. Article 97 approval is required when working within the Department of Conservation & Recreation lands along the Merrimack Riverfront. A benefit to utilizing the existing outfall is that this approach minimizes disturbance of the levee system and minimizes work in areas where an article 97 approval is required. Work in the VFW Highway would require coordination with MassDOT.

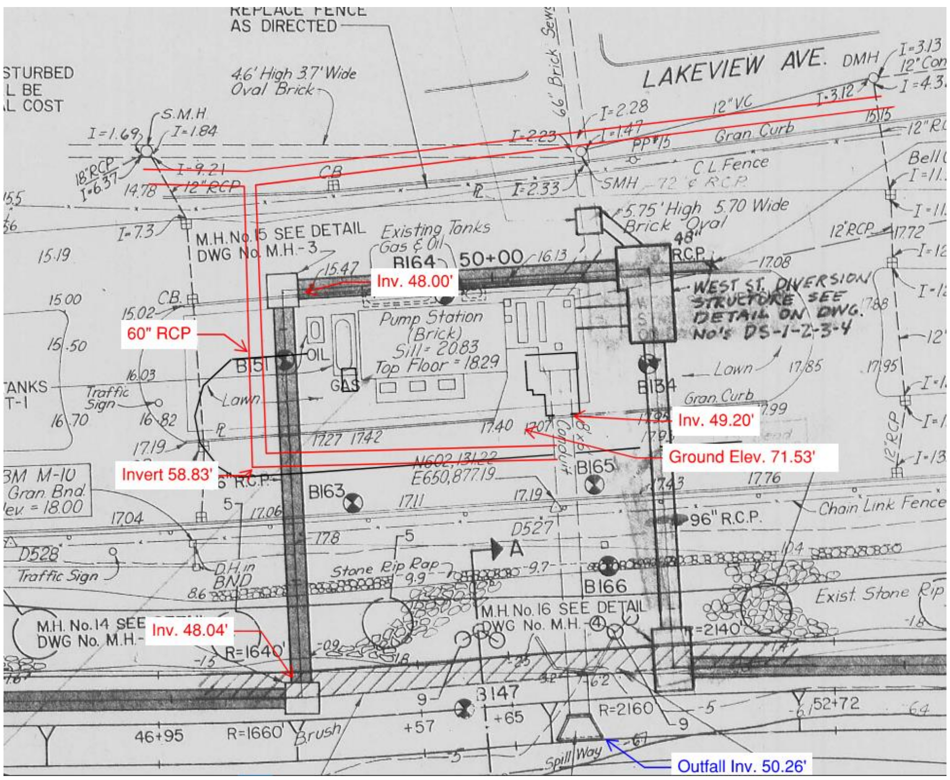


Figure 6.10 West Station Outfall Direct Connection (North Side)

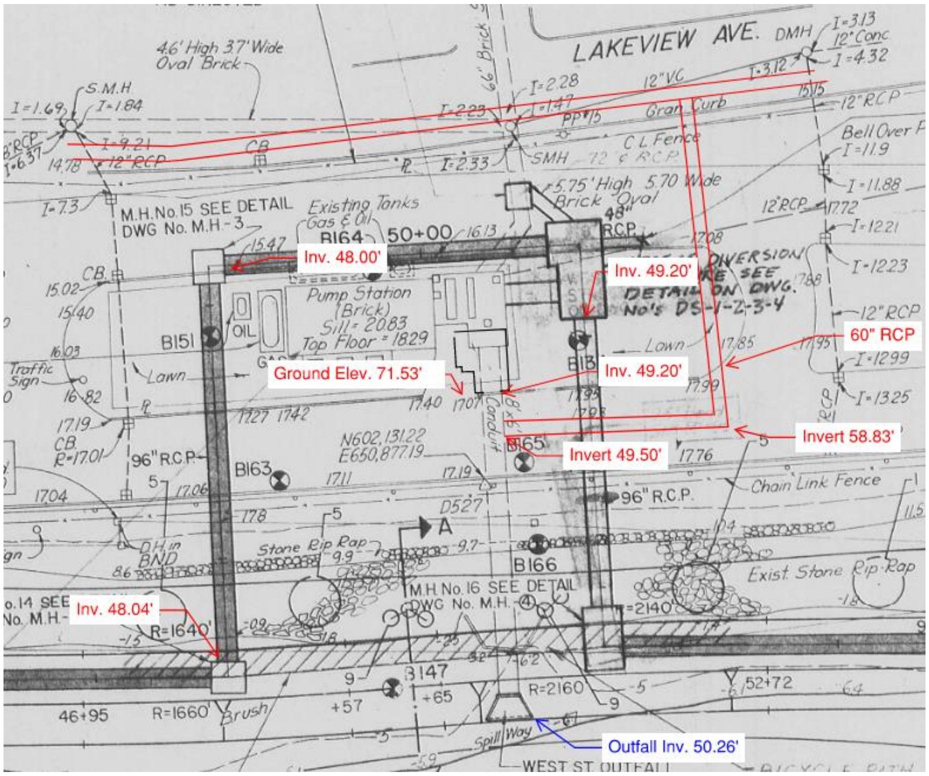


Figure 6.11 West Station Outfall Direct Connection (South side)

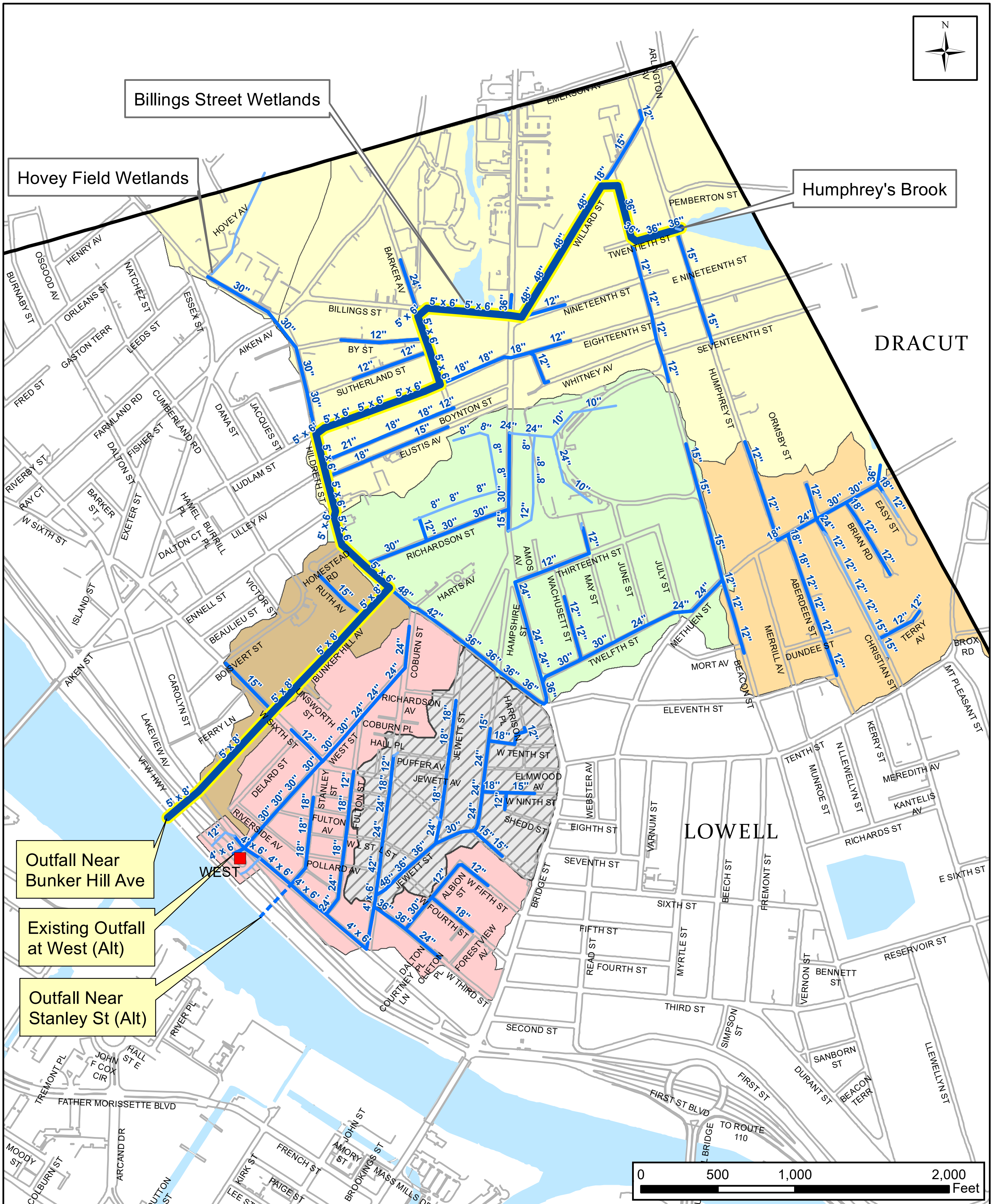
6.6.3.4 Conclusions

Because of the many challenges of routing large diameter pipes to the West CSO Diversion Station, further alternatives were developed with the goal of sending less drainage flow to the station, thereby reducing the size of the piping conveying flow to the station. Based on this evaluation of alternatives, it was clear that inflow sources, being the largest source of flow, should have a dedicated outfall to the Merrimack River, with a much smaller drainage network conveying flow to the West CSO Diversion Station. Use of a separate dedicated outfall also simplifies operations during CSO events because of the complications of accurately measuring CSO flow and stormwater flow in a combined outfall. Therefore, subsequent evaluations aimed to direct drainage flow, to the extent possible, to a separate dedicated outfall.

6.6.4 Mainline Conduit with Outfall Near Bunker Hill Avenue

6.6.4.1 Overview

This alternative dedicates a new outfall near Bunker Hill Avenue to discharge flows from inflow sources and future separation along the mainline conduit. **Figure 6.12** shows the mainline conduit and a second network for the remaining southern half of the Centralville CSS area as described below. Note that the crossing and outfall is shown schematically going straight across in this report. However, the final alignment will need to be further modified to consider ventilation to avoid air binding and avoid erosion of a small island directly across (not shown in GIS).



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Alternative Outfall (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas (Phase)

- Bunker Hill Ave (1)
- Middle Branches (2)
- Northern Branches (2)
- Methuen (2)
- West/Coburn/Jewett (2)
- Upper Jewett/Hampshire (2)

Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 6.12

Outfall Near Bunker Hill Ave

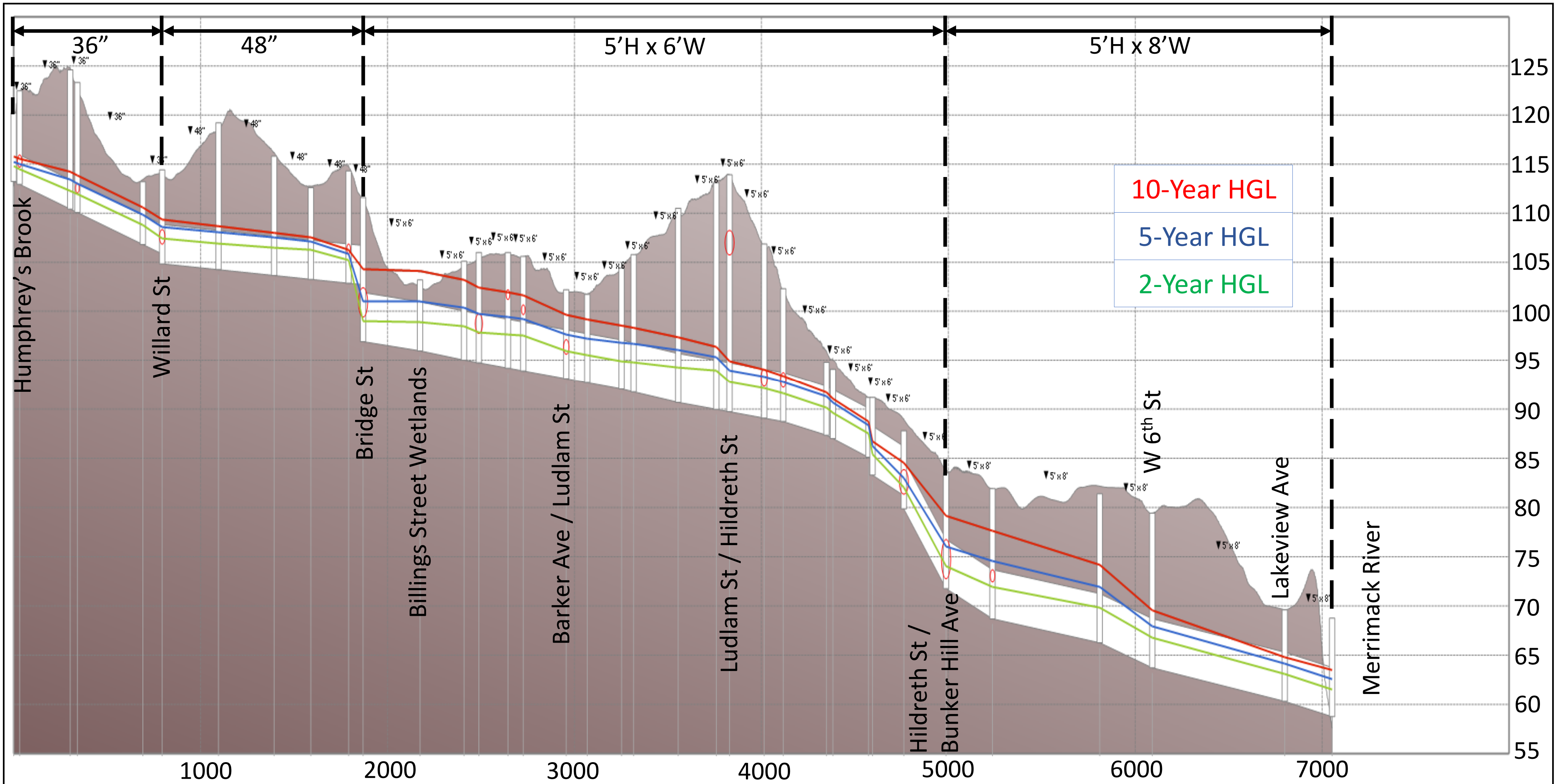
Most of the routing is similar to the 2000 HB PDR routing and the previous alternative (subsection 6.6.3.1); this route collects flow from the Humphrey's Brook and Billings Street Wetlands with the mainline conduit and, traveling upstream to downstream, from the Humphrey's Brook inlet along Willard Street, Billings Street, Barker Avenue, Ludlam Street, and Hildreth Street. This alternative uses Bunker Hill Avenue to continue towards the Merrimack River to a new outfall. This drainage network would also include future separation of the northern branches, all the middle branches, and the Bunker Hill Avenue area. Based on previous hydraulic simulations, it was determined the middle branches from Hildreth Street (East) should be conveyed to the mainline conduit; this avoids larger pipe sizes along West Street and sending too much flow towards Lakeview Avenue.

The remaining separation in the southern half of the Centralville CSS area would be collected with the larger trunk drains located along West Street and Lakeview Avenue. This collects future separation of the remaining lower areas shown in pink and cross gray hatched. Despite flooding risk in the low-laying area, both areas were included in the hydraulic simulations of this alternative to determine the required pipe sizes along Lakeview Avenue. This alternative uses the existing outfall from West CSO Diversion Station to be consistent across all alternatives; however, a second outfall to the Merrimack River (such as the Stanley outfall location) could be further investigated but will require reconfiguration of the flow direction along Lakeview Ave.

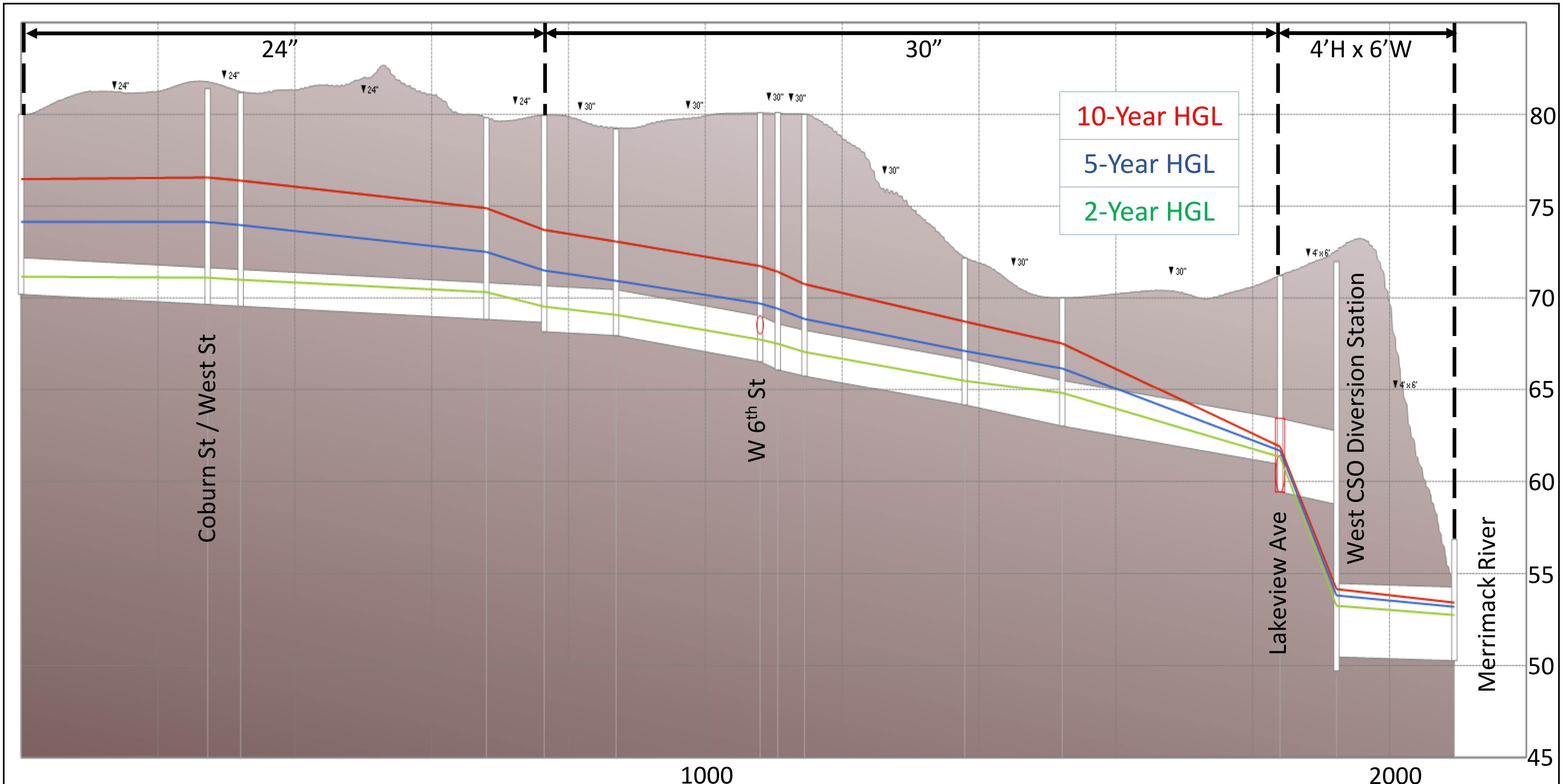
6.6.4.2 Hydraulic Modeling Simulations

Hydraulic modeling of the drainage configuration described above was used to size pipes for a minimum 5-year design storm; the model was then used to simulate 2-year, 5-year, and 10-year design storms to assess performance, particularly the 10-year design storm to minimize any temporary flooding. The profile of the three key conduits for inflow removal and separation are shown in **Figure 6.13 through Figure 6.16.** The simulations assumed free discharge of the mainline conduit to the Merrimack River near Bunker Hill Avenue and free discharge of the remaining separation areas to a second outfall, currently depicted as being connected to the West CSO Diversion station. For reference, the 100-year flood elevation is approximately 67.8-feet at the outfall near Bunker Hill Avenue, but this restriction was not applied in these simulations (impacts due to high river levels will be evaluated on the selected route during final design).

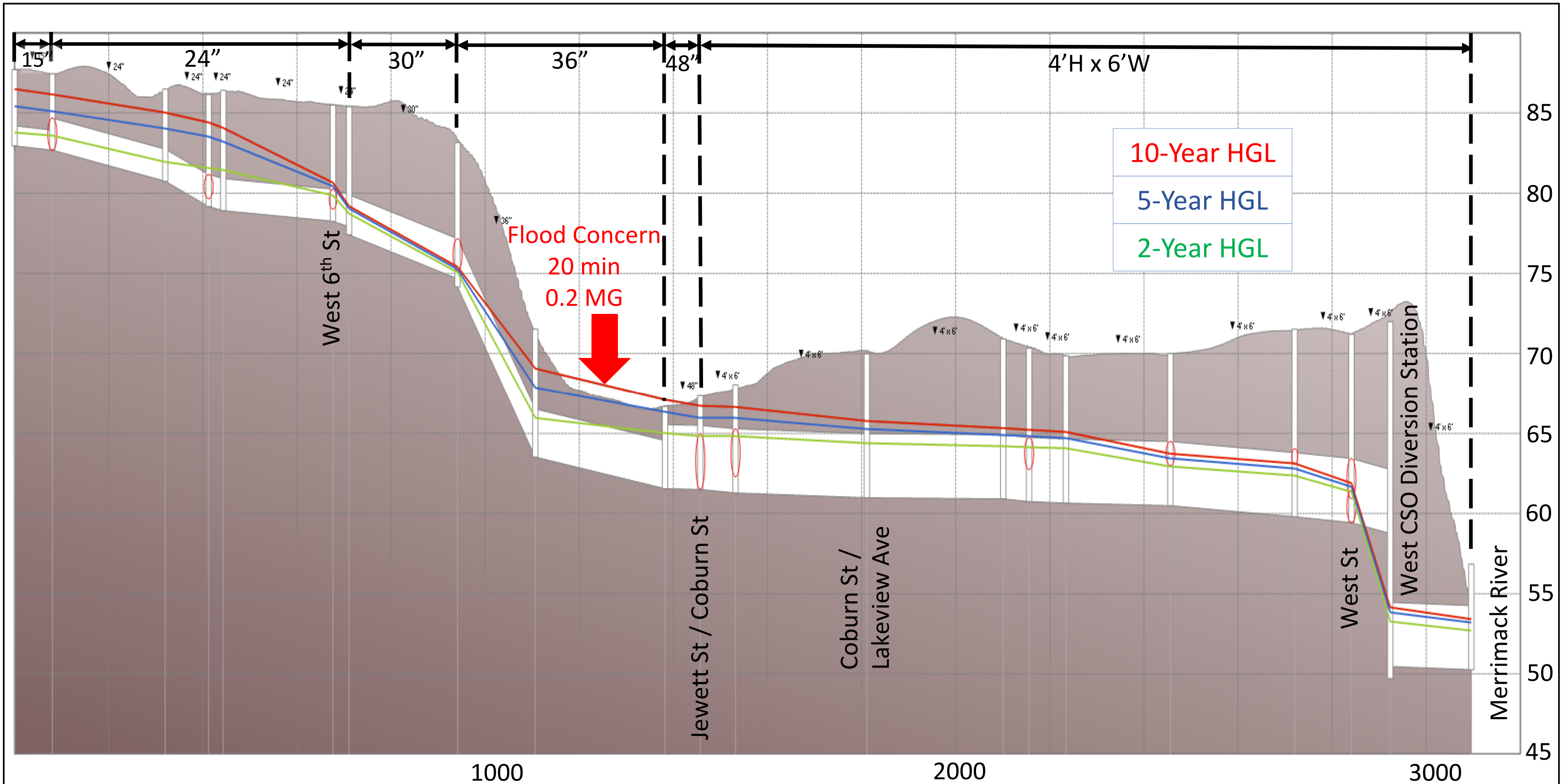
Figure 6.13 presents the peak hydraulic grade line profile for the mainline to outfall near Bunker Hill Avenue, which conveys the inflow sources plus additional separation in the route described in the overview. The pipe sizes are relatively the same as previous alternatives between Humphrey's Brook and the Billing Street Wetlands with pipe sizes ranging from 36-inches to 48-inches; along Hildreth street between Billings Street Wetlands and Bunker Hill Ave, a 5-foot by 6-foot box culvert is required, increasing to a 5-foot by 8-foot box culvert along Bunker Hill Avenue. The only difference is that, under this alternative, the mainline conduit discharges directly to the Merrimack River. This change drops the surcharging in the 10-year design storm a few feet downstream of West 6th Street below the 70-feet elevation. This is discussed further in the constructability challenges subsection.



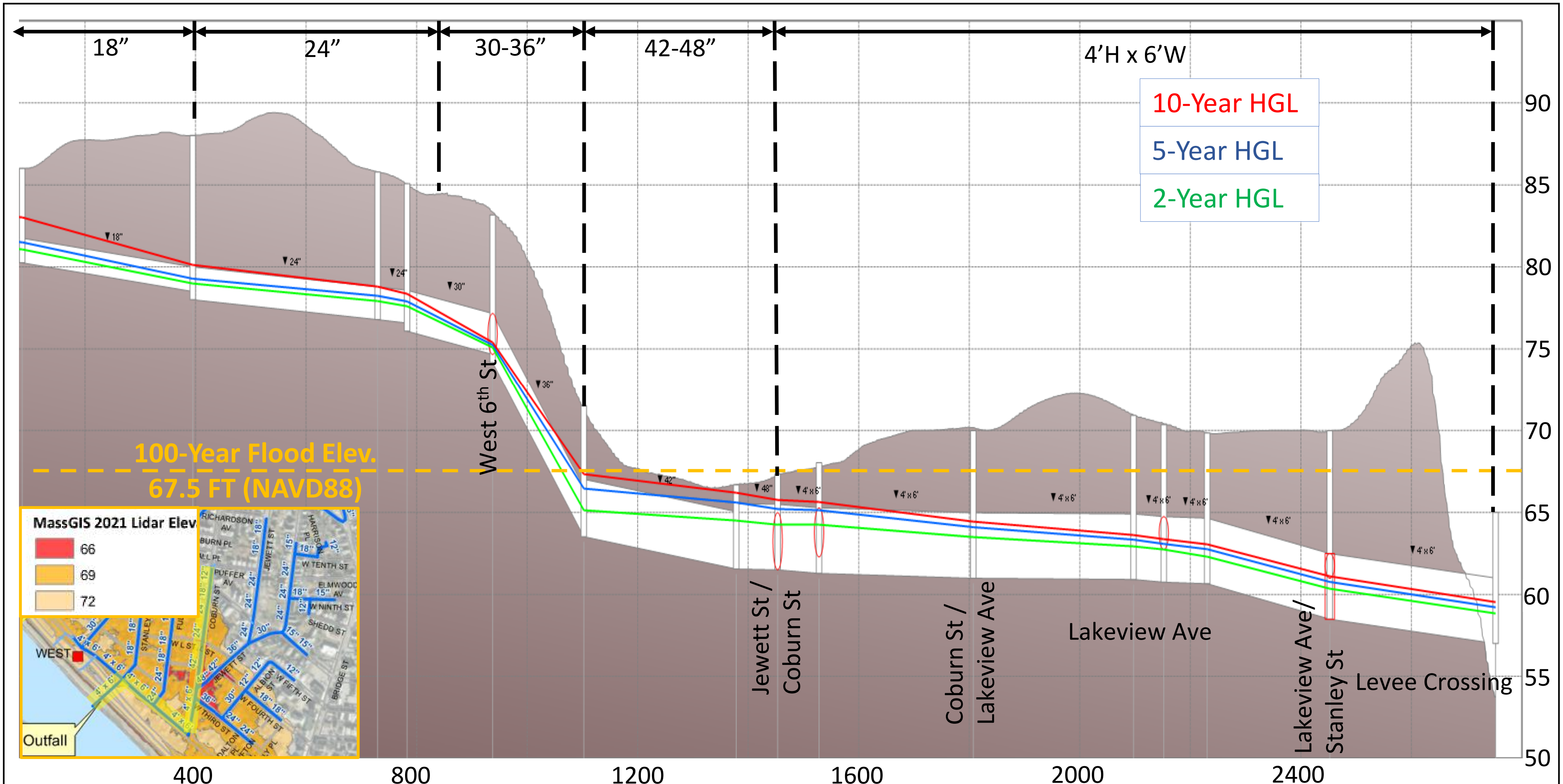
Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.13
Peak Hydraulic Grade Line Profile for Mainline to Outfall Near Bunker Hill Avenue



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.14
Peak Hydraulic Grade Line Profile for West Street



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.15
Peak Hydraulic Grade Line Profile for Lakeview Avenue, Coburn Street, Jewett Street



Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 6.16

Peak Hydraulic Grade Line Profile for Stanley Street Outfall, Lakeview, Coburn Street

Figure 6.14 presents peak hydraulic grade line profile for West Street which conveys a portion of the southern separation areas with the required pipe sized for 5-year design storm criteria; required pipe sizes range from 24-inches to 30-inches in diameter closest to the West CSO Diversion Station. This significant reduction in pipe size along West Street is possible by sending separation flows from the middle branches east to the mainline conduit Bunker Hill Avenue rather than south as under previous alternatives.

Figure 6.15 presents the peak hydraulic grade line profile associated with West/Coburn/Jewett and Upper Jewett/Hampshire without the mainline conduit influence. There is only a minor reduction of box culvert size to 4-foot by 6-foot compared to the previous 5-foot by 6-foot; the height was reduced instead of the width to provide an additional foot of cover and stay below the roadway subbase layer that the previous alternative encroaches into. The flood risk is still 0.2 MG for 20 minutes. This suggests that the two primary factors contributing to flooding risks in these areas are the separation of upstream areas transitioning from steep to flat topography, and the drainage network being too shallow due to downstream conflicts with existing large diameter sewers.

Figure 6.16 presents an alternative outfall location (Stanley Street outfall) to be used instead of the West St CSO Diversion outfall for separation of the West/Coburn/Jewett area. In this simulation, the pipe slopes and bend configurations have been modified to convey flow from the low elevation areas to the Stanley Street outfall (shown in the inset plan). The purpose of this simulation is to investigate whether having the outfall located closer to Coburn Street helps reduce flooding in the area; the simulation found that the closer outfall location does help slightly, along with lowering other head loss parameters. The profile shows the HGL at grade for the 10-year storm; however, the simulation also suggests that other low-elevation manholes in the Coburn/Jewett intersection could flood a marginal amount (less than 0.05 MG for less than 15 minutes with ponding less than one foot).

Simulations for the next alternative assume the removal of additional flow resulting from additional upstream separation, and this additional separation solves the flooding issues. This simulation was conducted with a free discharge; however, for reference, the 100-Year Flood Elevation is shown indicating that, if the river level is too high, this low-elevation area is still at increased flood risk because it cannot discharge. Today, the combined system is connected to the West Street Flood Pumping Station so it is not restricted by the river water level and can always discharge.

When meeting to discuss comments on the December 2023 Centralville PDR, MassDEP suggested the construction of a diversion structure between the new drain and the CSS to facilitate the separation of this low-elevation area. MassDEP suggested that a special permit could be issued to address MS4 regulation concerns. However, this approach would complicate the functionality of the Flood Damage Protection system by requiring special standard operating procedures (positioning of gates) during periods when river levels are high.

A new stormwater pumping system could be considered to allow for stormwater discharge when river levels are high. However, stormwater pumping is not practical for this area as there is no land available for a new stormwater pump station. Temporary pumps could be brought in as needed, but this would essentially be pumping the stormwater twice - once from the drainage system to the sewer system and then again with combined flow at the West Street CSO Diversion station (unless a new direct discharge is established across the VFW highway and levee, which would have several permitting challenges). For these reasons, a new stormwater pumping system to serve this area is not considered viable.

6.6.4.3 Constructability Challenges

As described in the overview of this alternative, most of the mainline conduit route is the same as previous alternatives from the Humphrey's Brook inlet and therefore have the same constructability challenges as discussed earlier. The challenges along Bunker Hill Avenue from Hildreth Street to the Merrimack River are discussed in this subsection.

The 5-foot by 8-foot mainline conduit on Hildreth Street would be combined with a 48-inch future separation of the middle branches and head south. Although it is represented as a T-section with the box culvert making a 90-degree change in direction, hydraulically this corner may be made with two 45-degree bends with the 48" pipe connecting into the side at an angle to minimize head losses when the flows combine. This footprint will be impacted by the amount of available space between utilities and surface feature restrictions.

Along Bunker Hill Avenue, the profile ranges from 10- to 15-foot deep, with a wide excavation due to the conduit size being 5-foot by 6-foot. These box culvert sections would be heavy and difficult to install, even with reduced laying lengths, which impacts installation production rates. Although it may be possible to use trench boxes, some sheeting or solider pile and lagging may be required for excavation support, especially when there are multiple utility crossings.

One area that will be particularly difficult is crossing West 6th Street, where there are multiple large diameter watermains (some abandoned but still filled with water); any exposed crossing would need to be supported and protected with extreme caution as these watermains are critical water infrastructure for the north bank of the City. Coordination with Lowell Water Department would be required to develop the best approach prior to construction. Another conflict downstream of West 6th Street would be with the existing small diameter sewers, where the elevation of the new box culvert would be the same as existing sewer services; resolving this conflict would require building a new, second lateral sewer within the same trench to later cross under the box culvert to meet the combined system along Lakeview Avenue.

Figure 6.17 shows a graphical depiction of the several construction challenges, mostly related to elevation, from the crossing at Lakeview to an outfall at the Merrimack River. These include:

- At Lakeview Avenue, there is a 54-inch by 47-inch brick combined sewer that should be lined prior to installation of the box culvert crossing over it.
- The clearance of large, combined sewers in Lakeview Avenue limits the ability to open cut as there is not enough cover to pipe jack through the levee system without ground improvements to prevent impacts to the VFW Highway. Open cut installation methods would need to be reviewed and approved by the USACE. There currently is no knowledge of any levee sheeting or reinforcement other than earthen embankment materials.

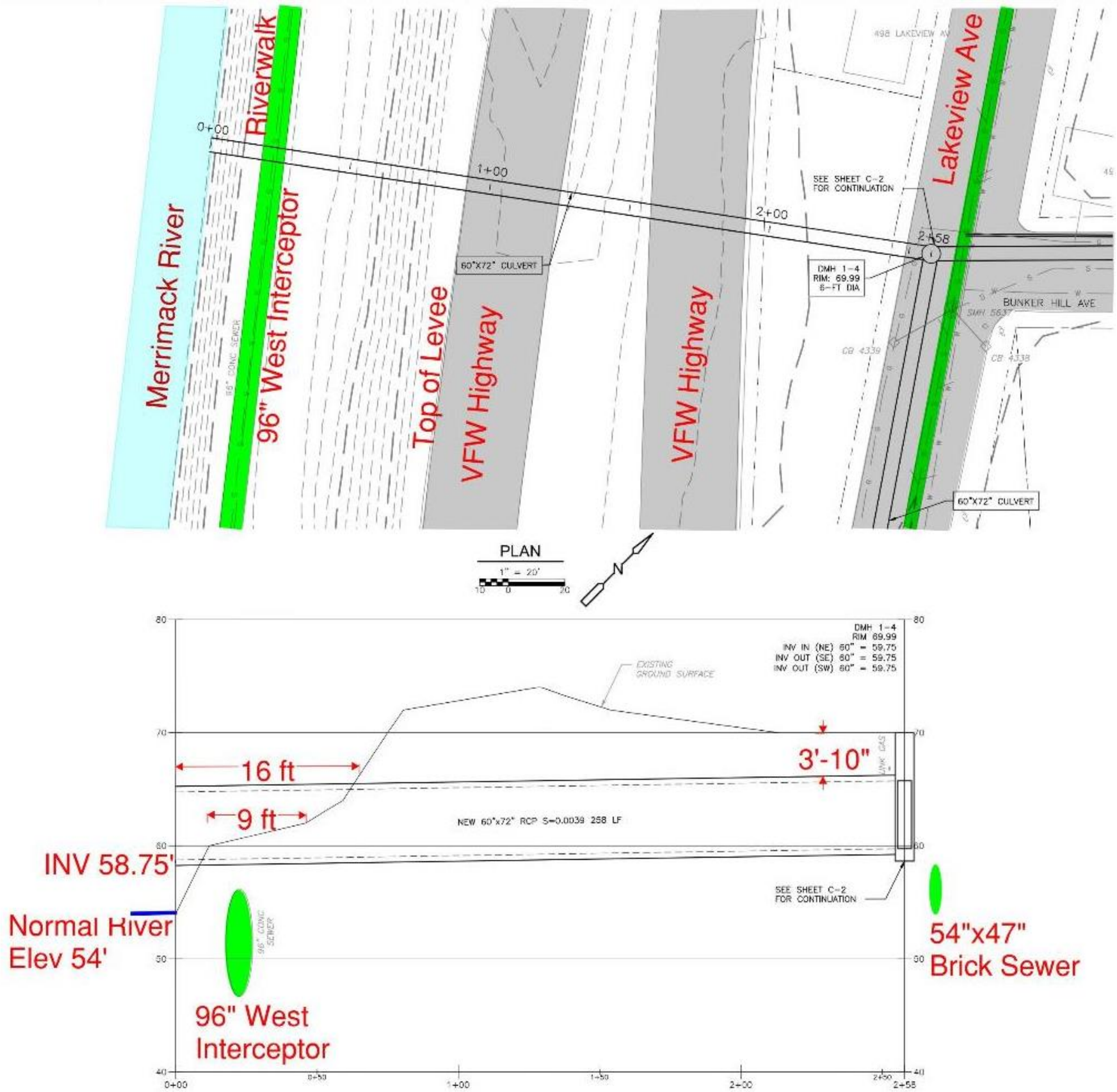


Figure 6.17 Plan and Profile, Bunker Hill Outfall at VFW Highway

- Open cutting across VFW highway would require coordination and planning with MassDOT and the City to maintain traffic. There are two lanes in each direction and an open green mediation strip of land where lanes could be redirected during the open cut installation. MassDOT would also like to discharge their proposed drainage in this area to one of the City's outfalls. Given that the rim elevations of the MassDOT catch basins are above elevation 70, this likely can be facilitated.
- The last segments of box culvert have two elevational challenges – (1) crossing over the existing 96-inch North Bank Interceptor (West Interceptor) with enough clearance and support on each side to prevent applying any additional force/weight directly; and (2) daylighting the top of the culvert due the steep downslope of the levee system's southern face.

- The outfall would conflict with the existing riverwalk, triggering civil site grading requirements. Any grading within the floodplain creates the need for compensatory storage requirements or a waiver from regulatory agencies. The outfall transition/apron may need to be made wider to reduce the overall height.

If the outfall were to be constructed with the invert at elevation 58.75 feet, it would be a few feet above the normal river elevation of 54-feet; however, the outfall could be submerged during the 100-year river flood stage elevation of 67.7-ft. Therefore, some sort of back flow prevention (either by gates or Tideflex duckbill valves) would be required. Considering the hydraulic connectivity of the local separation of the downstream area, there is a temporary flooding risk that could occur based on the additional headlosses from the river stage elevations making the most downstream segments surcharged near grade to keep a positive conveyance direction towards the river. To address this issue, all catch basin connections should have a rim elevation at least 70-feet or greater. Consequently, this means no catch basins south of West Sixth Street could be connected.

Due to the hydraulic connectivity and limited construction width between the river and the toe of the levee system, crossing under some of the elevation obstacles was conceptually considered. **Figure 6.18** shows a profile graphic that drops the box culvert another 10-feet, creating a siphon which would remain full of water. Since the inflow sources will continually convey flow, the water will not become stagnant; however, this creates an opportunity for sediment accrual, which should be minor due to upstream sediment controls at the inlets and catch basin sumps. This concept assumed a trenchless application (pending geotechnical information), but the length of deep conduit can be reduced if done by open cut (if only crossing under the interceptor) or by creating a conflict structure/outfall combination to stay below existing grades and avoid compensatory flood storage. The challenges with the outfall will need to be further advanced during final design.

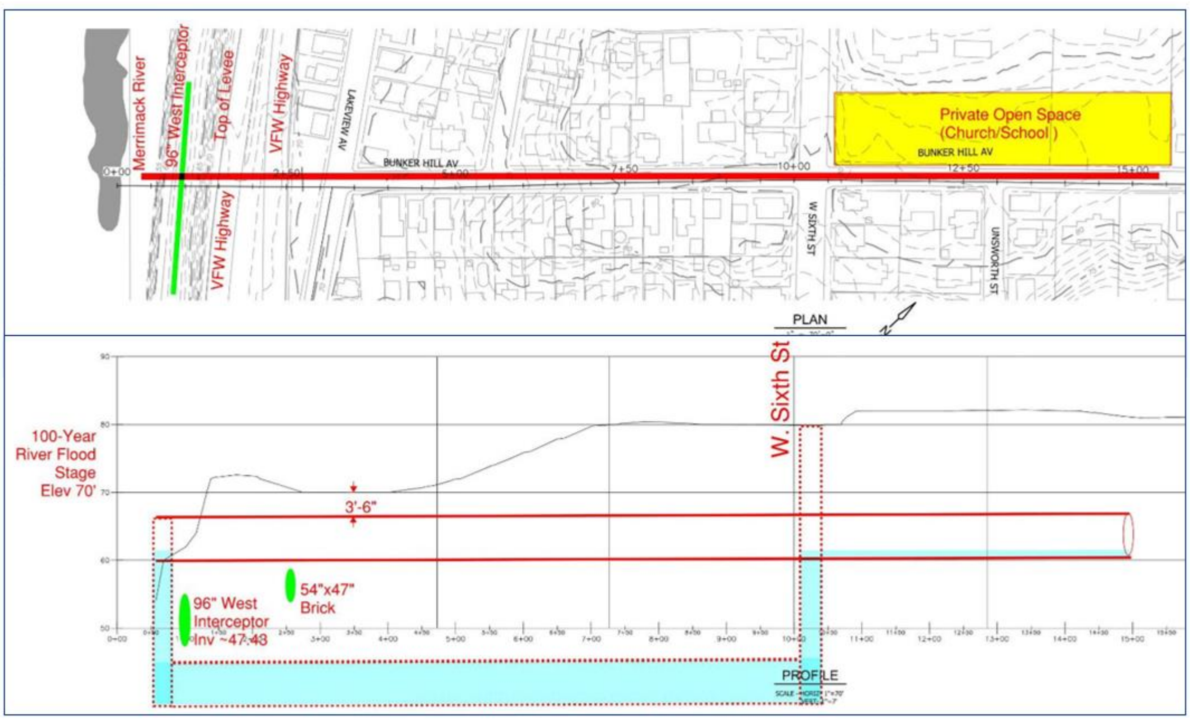


Figure 6.18 Bunker Hill Trenchless Crossing of VFW Highway

6.6.4.4 Conclusions

Given the size of the conduit from Hildreth Street to the Merrimack River, it is more favorable to route the mainline conduit down Bunker Hill Avenue rather than the narrower West Street route described in the 2000 HB PDR. The Bunker Hill Avenue route allows the inflow sources and the majority of the separation areas to be discharged directly to the Merrimack River. This approach also downsizes the remaining pipe sizes south of Hildreth Street. Due to the hydraulic connection and the potential for a high surcharge, the remaining system should be connected to its own outfall. Hydraulic model simulations for this area were based on a connection to the existing West CSO diversion station; however, this would only be considered if the new stormwater pipes could be connected to the existing outfall, downstream of the CSO diversion structure. It is likely that a new outfall, potentially at the Stanley Street location, may still be required, which would trigger permitting requirements with DCR, Army Corp, MassDEP, and other agencies.

Hydraulic simulation of this alternative shows that a flooding concern exists at the intersection of Lakeview Avenue, Coburn Street, and Jewett Street. The next alternative presents an option to resolve this concern by reducing the separation areas upstream of this intersection which contribute to the problem in lieu of implementing other diversion or pumping options.

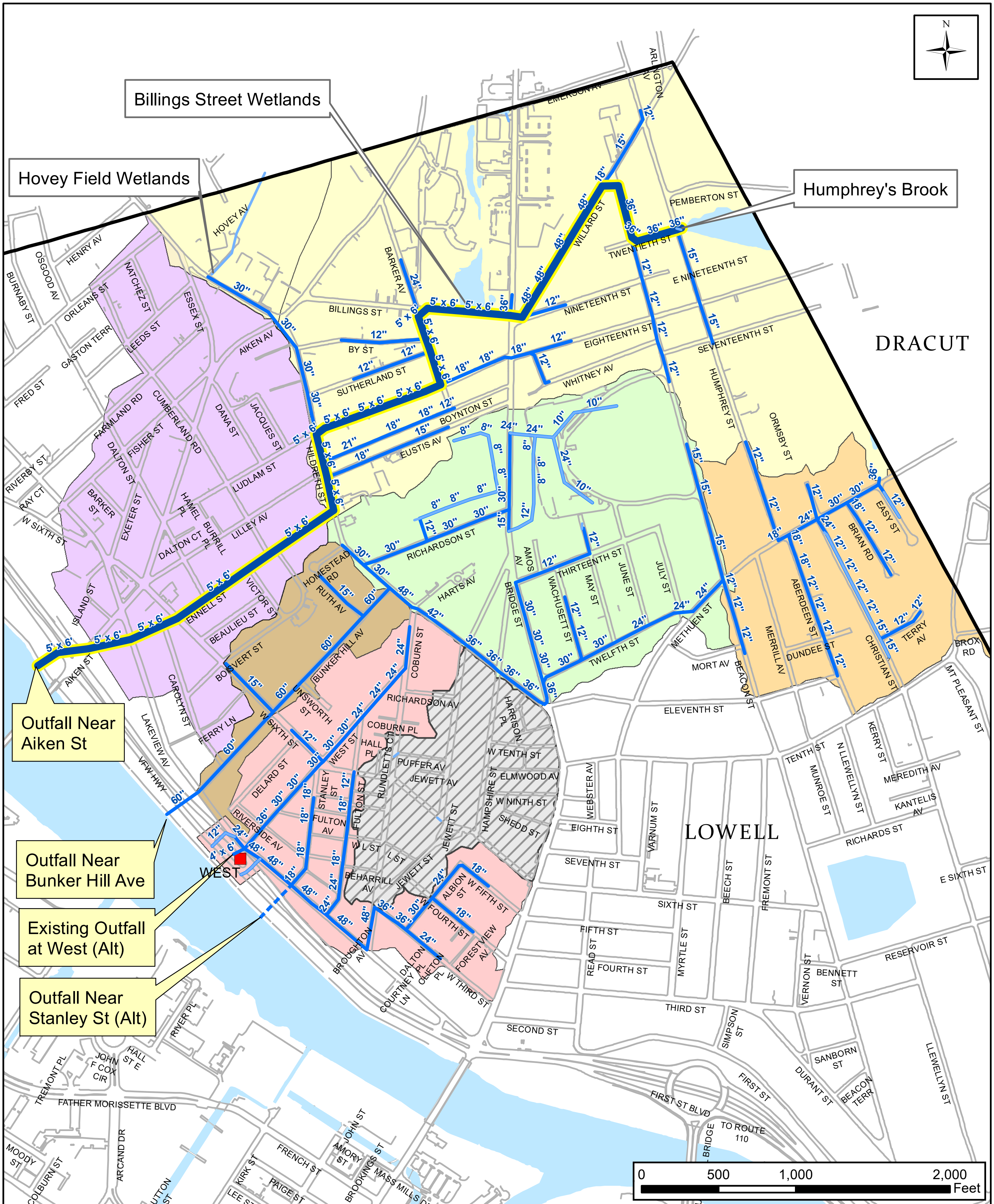
6.6.5 Mainline Conduit with Outfall Near Aiken Street

6.6.5.1 Overview

This alternative considers a new outfall located west of the 2000 HB PDR area to discharge flows from inflow sources directly to the Merrimack River. The advantage of this location is that the outfall would not be located within the levee system, which ends at the Aiken Street Bridge. **Figure 6.19** shows the route of a mainline conduit to an outfall near Aiken Street and reconfiguration of the remaining separation in Centralville CSS area.

The upper portion of the mainline conduit is the same as previous routes except for a shorter length on Hildreth Street before the route turns southwest on Ennell Street towards the Aiken Street intersection. The future separation of the northern branches is still collected; however, the revised route now provides an opportunity to separate parts of Sewer Area 40 instead. Separation of parts of Sewer Area 40 is a cost effective and practical exchange for separation of low-laying areas that are difficult to separate, as this will accomplish the comparable CSO reduction at a reduced cost. The boundaries of an equitable drainage network within Sewer Area 40 are not shown on Figure 6.19 but would include branches off the mainline conduit along Ennell Street and potentially partially extend up Aiken Street.

The remaining separation is shown in Figure 6.19 with a drainage network collecting the middle branches down Bunker Hill Avenue to a new outfall. The West, Coburn, and Jewett Street areas convey flow down to Lakeview Avenue and then east towards the new Bunker Hill Avenue outfall; this avoids connecting any new stormwater systems to West CSO Diversion Station. Further discussion of the decision to exclude some acreage in Centralville is provided under 6.6.5.2 Hydraulic Modeling Simulations.



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Alternative Outfall (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas (Phase)

- Bunker Hill Ave (1)
- Middle Branches (2)
- Northern Branches (2)
- Methuen (2)
- West/Coburn/Jewett (2)
- Upper Jewett/Hampshire (EXCLUDE)
- Sewer Area 40 (2)

CDM Smith

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Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 6.19

Outfall Near Aiken Street

6.6.5.2 Hydraulic Modeling Simulations

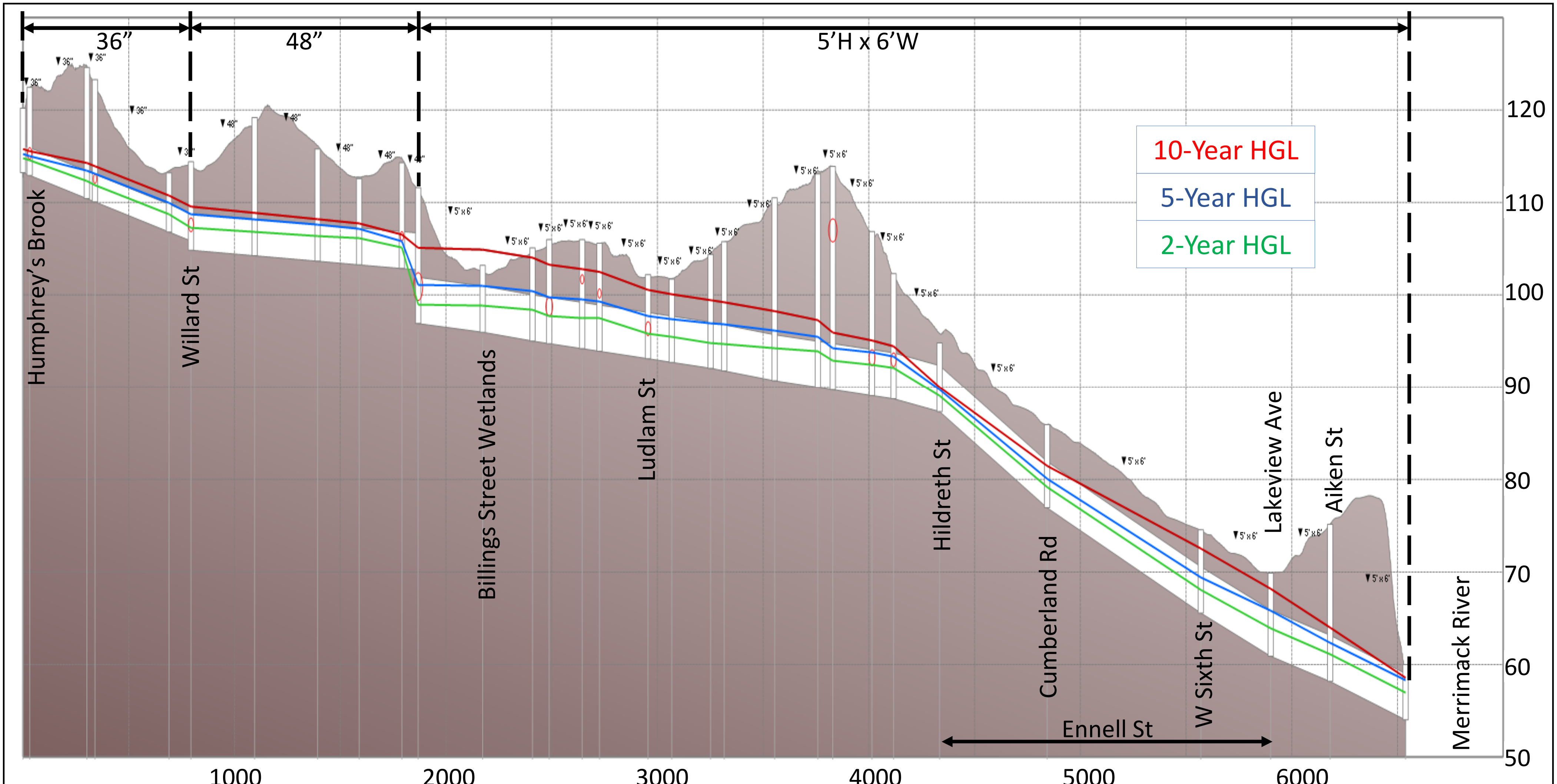
The hydraulic modeling of the drainage configuration described above was used to size the pipes for a minimum 5-year design storm; the model was then used to simulate 2-year, 5-year, and 10-year design storms to assess performance (particularly the 10-year design storm to minimize any temporary flooding). The profile of the three key conduits for inflow removal and separation are shown in **Figure 6.20 through Figure 6.23**. The simulations assumed free discharge of the mainline conduit to the Merrimack River further west near Aiken Street and free discharge of the remaining Centralville separation areas to a second outfall, currently depicted as connected to the West CSO Diversion Station (as previously discussed, another option is an outfall at Stanley Street). For reference, the 100-year flood elevation is approximately 68.5-feet at the outfall near Aiken Street, but this restriction was not applied in these simulations (impacts due to high river levels will be evaluated on the selected route during final design).

The simulations exclude the Upper Jewett Street and Hampshire Street area to confirm hydraulic issues downstream exacerbated by separation of this area. Alternatively, the mainline conduit with an outfall near Aiken Street has been sized for the potential future separation of Sewer Area 40 to accomplish similar CSO reduction (discussed in greater detail in Section 7).

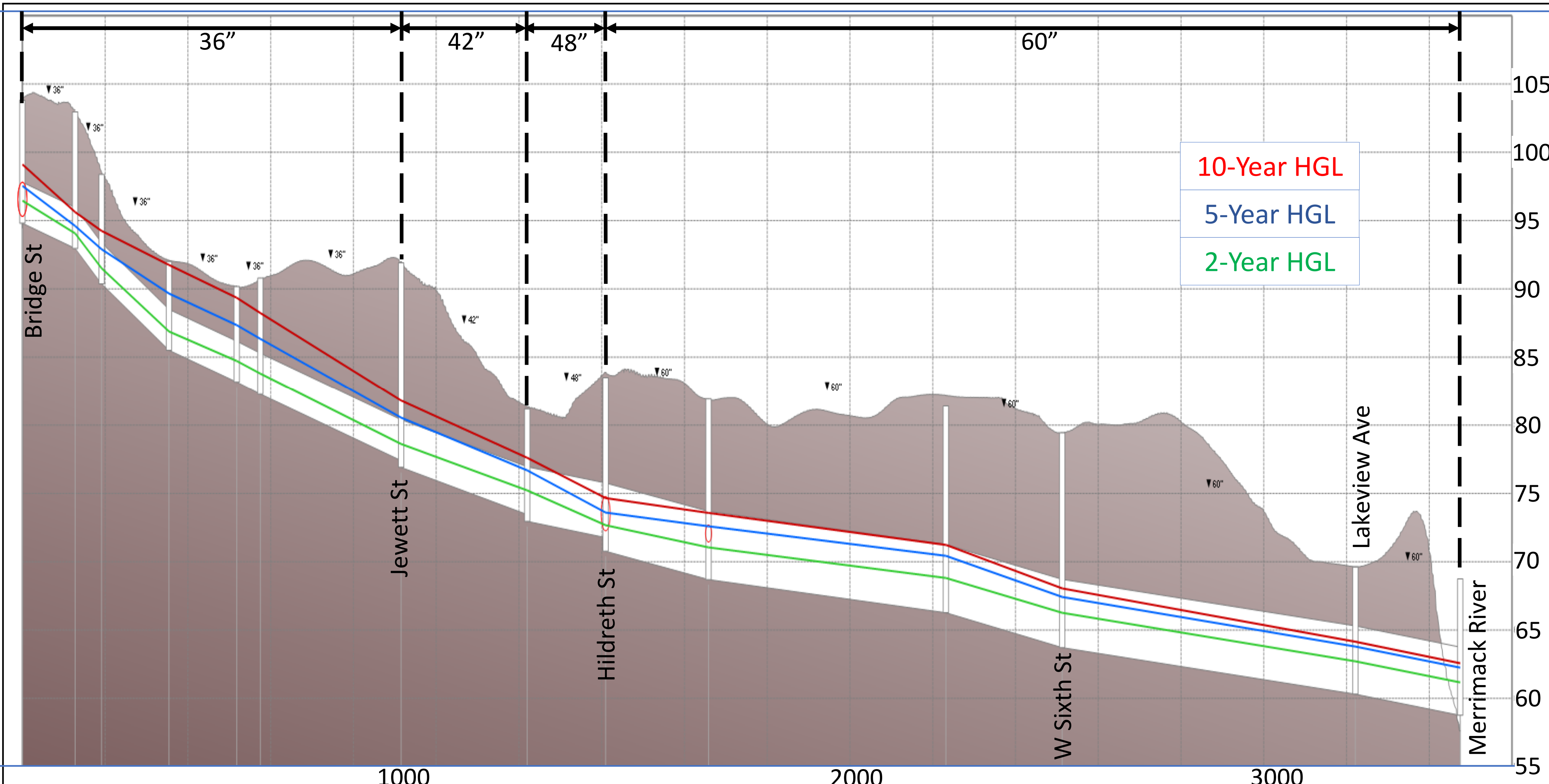
Figure 6.20 presents the peak hydraulic grade line profile for the mainline to an outfall near Aiken Street. The pipe has also been sized to accept future separation within Sewer Area 40. The pipe sizes are approximately the same as shown for previous alternatives between Humphrey's Brook and Billing Street Wetlands, with pipe sizes ranging from 36-inches to 48-inches along Hildreth Street, a 5-foot by 6-foot box culvert between Billings Street Wetlands and Bunker Hill Avenue. Once the drain is conveyed along Ennell Street toward the outfall near Aiken Street, the 5-foot by 6-foot box culvert continues because of the relatively steeper slope of the topography. The pipe capacity is increased with the 10-year HGL staying below the crown of the pipe (Bunker Hill Avenue has significant surcharging); specifically, no surcharging occurs in the low-laying area near the intersection of Ennell Street and Lakeview Avenue. Separation of this intersection would be beneficial as there have been past complaints in the area; however, there are still concerns with river stage influences and the need for backflow prevention. This does not eliminate the risk of flooding at this intersection at a 100-year river elevation of 68.5-feet with a coincidental storm event.

Figure 6.21 presents the peak hydraulic grade line profile for Bunker Hill Avenue with a 60-inch pipe that collects the future separation from the middle branches and Bunker Hill Avenue and conveys it to a separate outfall at the Merrimack River for this network. Note that there are parks and green space in the middle branch separation areas, so further optimization of the pipe sizes may be possible in combination with other green solutions or attenuation to further reduce pipe size.

Figure 6.22 presents the peak hydraulic grade line profile for West Street, which conveys a portion of the southern separation areas. Required pipe sizes for a 5-year design storm range from 24-inches to 30-inches in diameter, with the larger pipe sizes located closest to the West CSO Diversion Station (similar to the alternative with an outfall near Bunker Hill Avenue).

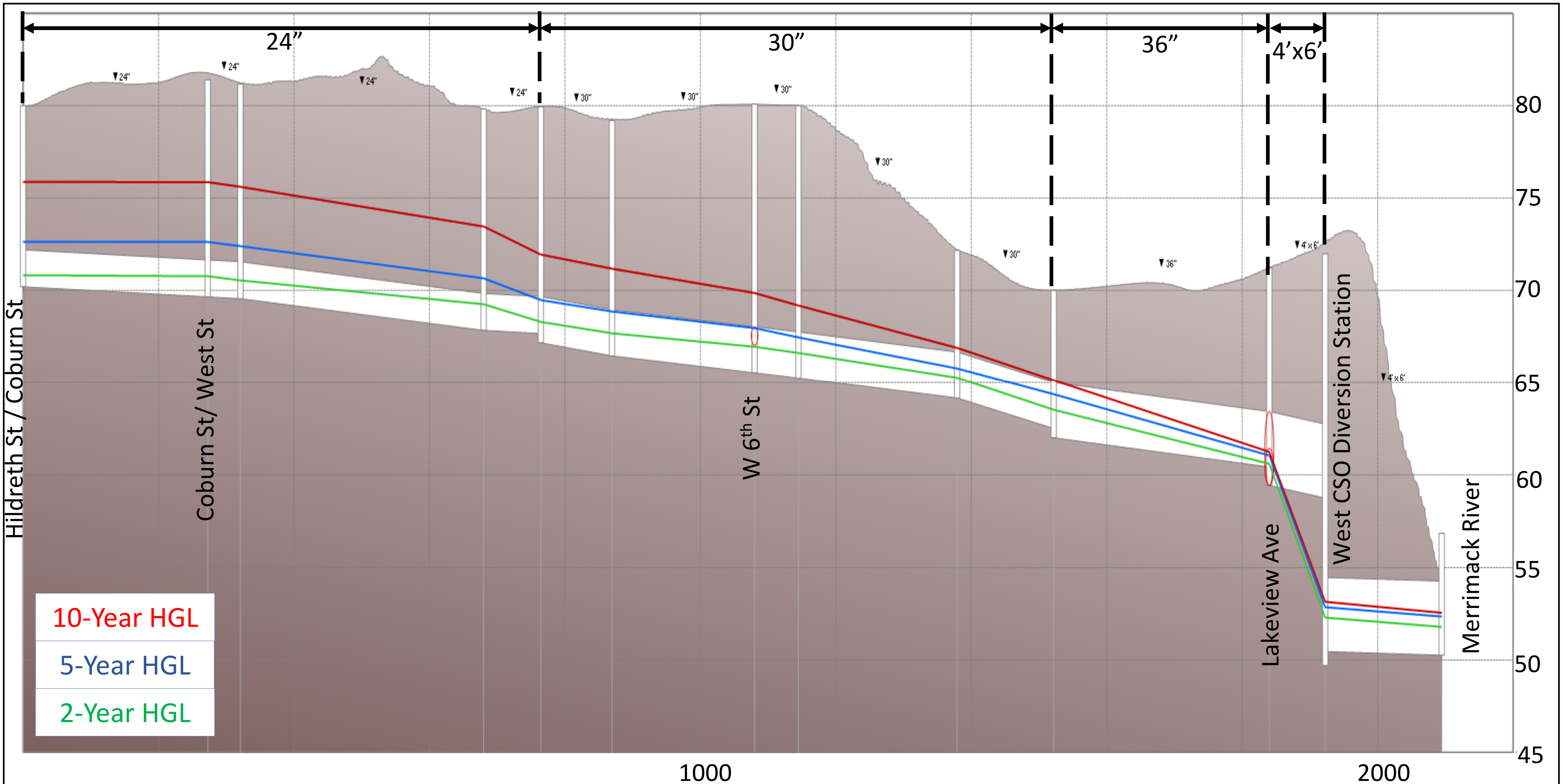


Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.20
Peak Hydraulic Grade Line Profile for Mainline to Outfall Near Aiken Street

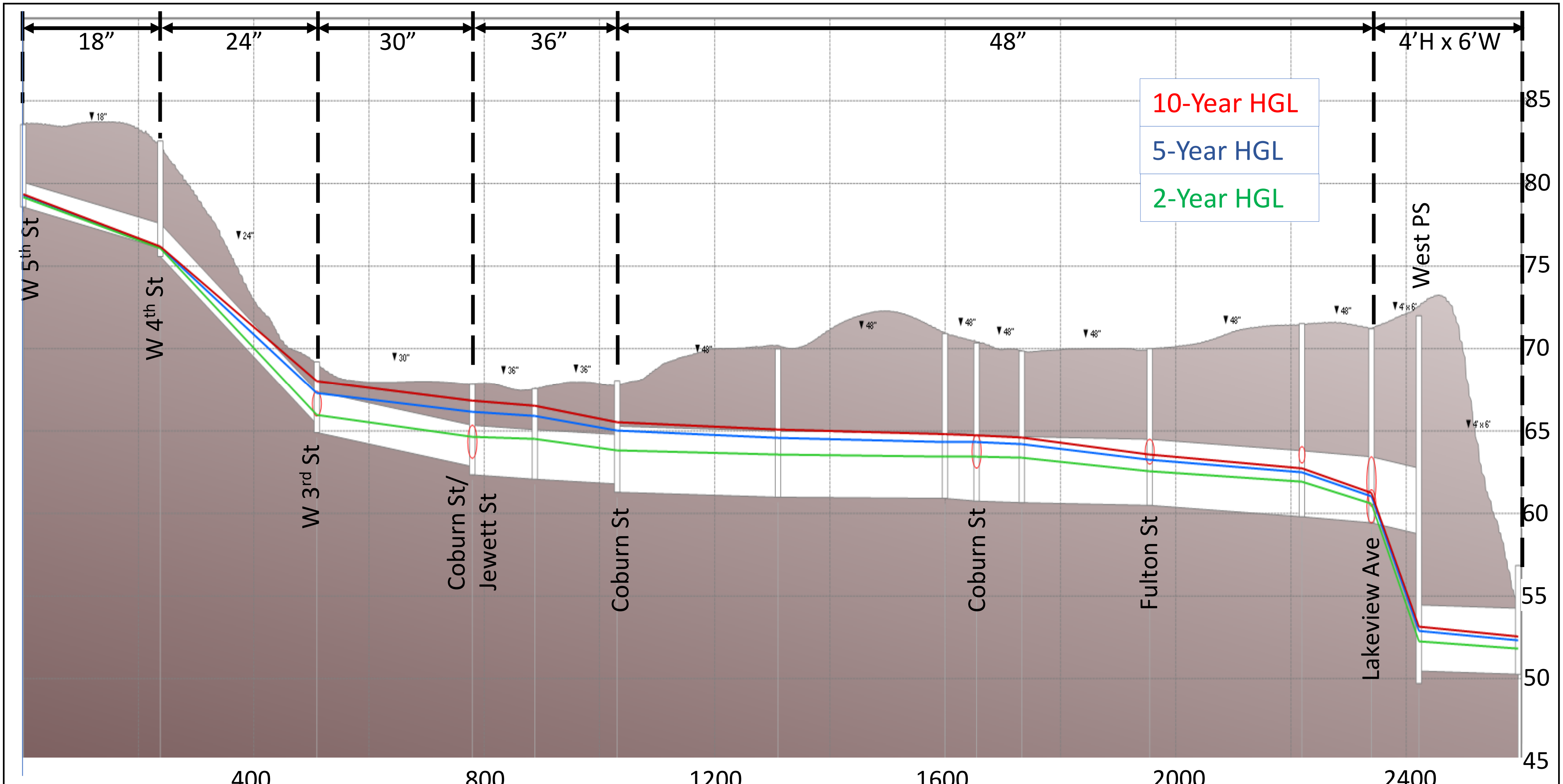


CDM Smith

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.21
Peak Hydraulic Grade Line Profile for Bunker Hill Avenue



Lowell, Massachusetts
Humphrey’s Brook Preliminary Revised Design
Figure 6.22
Peak Hydraulic Grade Line Profile for West Street



Lowell, Massachusetts
Centralville Sewer Separation Revised PDR
Figure 6.23
Peak Hydraulic Grade Line Profile for Lakeview Avenue, Coburn Street, Albion Street

Figure 6.23 presents the partial separation of the low-laying areas (West/Coburn/Jewett only) without the mainline conduit influence. Removing the Upper Jewett/Hampshire contributions brings the hydraulic grade line below the surface, thereby eliminating the flooding concern. The pipe is also further reduced to a 48-inches diameter.

Figure 6.19 presents the reduced separation achieved by excluding 32 acres located in the Upper Jewett Street and Hampshire Street areas upstream of the problem area, with the 5-year HGL closer to the pipe crown and no flooding in the 10-year design storm. Also, for the lower, flatter segments of Lakeview Avenue, the pipe size significantly reduces to a 48-inch pipe, which is more constructable. This reduced area simulation suggests that part of the issues in this area stem from the transition of pipe networks from steep to flat; in the existing CSS, this surcharging is absorbed by the much lower profile of the CSS which provides more freeboard to surcharge during storm events. It is recommended that this area be excluded from the Phase 2 separation program to avoid surcharging and potential flooding of this area.

The historic CSO model parameters of impervious versus pervious area were reviewed to determine which separation areas may provide greater opportunity for CSO reduction. These parameters are presented in **Table 6.3.**

Table 6.3 Imperviousness of Project Area Subcatchments

Area	Acreage	% Impervious Average	% Pervious Average
Dracut	460	31	69
Methuen St	50	35	65
Northern Branches	170	51	49
Middle Branches & Bunker Hill Ave	100	52	48
West/Coburn/ Jewett	50	81	19
Upper Jewett/ Hampshire	32	81	19
Sewer Area 40	86	77	23

The average percent imperviousness of the Upper Jewett/Hampshire subarea is 5 percent higher than Sewer Area 40, which means that 5 percent more of Sewer Area 40 would need to be separated to achieve relatively the same CSO reduction (approximately 35 acres). This exchange of separation areas is explained in Section 7 Alternatives analysis.

6.6.5.3 Constructability Challenges

As discussed, the upstream challenges from Humphrey's Brook and downstream of Billings Street Wetlands is relatively the same along Hildreth Street, which is one of the topographic boundaries behind the sewer areas delineation, until the mainline conduit conveys flow west at Ennell Street, outside of the 2000 HB study area, traversing through Sewer Area 40. The main reason for exploring this option is to locate an outfall outside the flood damage reduction system; however, this option still has similar challenges. At the Hildreth Street and Ennell Street intersection, the mainline conduit is a 5-foot by 6-

foot box culvert which is depicted as a 90-degree turn but may become multiple bends to lessen the headloss in changing flow directions.

This alternative is much deeper, averaging 20-feet, due to avoiding elevational conflicts with sewers and watermains. Despite the depth, this may be preferrable as the local sewer sizes are small (8 to 12-inches) compared to the 48 to 60-inches existing combined sewer trunk in other alternatives. This alternative has the same major elevation obstacle of crossing under multiple large diameter watermains at West Sixth Street. The existing 48-inch brick sewer at Lakeview Avenue may be crossed under if the profile cannot be made shallower. This would likely require a sewer replacement at this crossing or a conflict structure. Bringing the box culvert too low could cause the end of the profile to be U-shaped in order to go below the Lakeview Ave Sewer and then over the 96-inch North Bank Interceptor at the outfall area. This is not ideal for maintenance purposes as it would always be full of water and only refreshed by streamflow.

After Lakeview Avenue, the topography rises making the mainline conduit go against grade and become nearly 30-feet deep, which makes sense as the higher ground is the reason why the levee system stops east of the Aiken Street Bridge. Extensive trench support would be required. One benefit is that there is no sewer in Ennell Street from Lakeview Avenue to Aiken Street. However, the VFW Highway and Aiken Street intersection is wide and heavily trafficked so additional traffic management plans would need to be developed.

Northwest of the intersection is a fair amount of open space that could be utilized for a work zone to construct the outfall before it slopes steeply towards the Merrimack River. Depending on the results of the borings this may also be a potential launch area for a trenchless application heading west.

The outfall area presents similar challenges of being above the interceptor and below the existing riverwalk; however, it appears that less of the 5-foot by 6-foot culvert would be exposed prior to making any height to width adjustments to minimize or avoid compensatory flood storage. Article 97 approval is required when working within the DCR lands along the Merrimack Riverfront as discussed in the previous alternative.

6.6.5.4 Conclusions

Although the mainline conduit route is brought outside the natural topography of the sewer areas and the 2000 HB area, this route provides some benefits and should be considered as a comparable alternative to the discharge of the mainline conduit at Bunker Hill Avenue. An outfall near Bunker Hill Avenue would still be required for future separation of the middle branches and Bunker Hill Area. Due to similar high-surcharge conditions that could occur along Bunker Hill Avenue from West Sixth Street to the Merrimack River, it is likely the Lakeview Ave drain would need to outfall separately as well, creating the need for three outfalls on DCR properties.

Benefits of this alternative include the availability of additional land for the mainline conduit outfall construction, simpler grading required for compensatory storage, and a pipe route that facilitates the exchange of Sewer Area 40 separation for separation of portions of the Upper Jewett and Hampshire area. The next alternative presents the full exchange of Sewer Area 40 for the areas hydraulically connected to the low-laying areas which are currently protected by the West Street Pump Station.

6.6.6 Mainline Conduit with Outfall Near Bunker Hill Avenue and Complete Separation of Sewer Area 40

6.6.6.1 Overview

This alternative is a combination of options previously presented with a new outfall located near Bunker Hill Avenue to discharge flows from inflow sources and future separation along the mainline conduit, as presented earlier in Section 6.6.4. **Figure 6.24** presents the complete separation of Sewer Area 40 in exchange for separation of low-laying areas including the West/Coburn/Jewett and the Upper Jewett/Hampshire areas. These remaining areas will continue to be evaluated as part of the Phase 3 Preliminary Design Report. This exchange of separation areas would provide equivalent levels of CSO reduction at a reduced cost and under an expedited timeline given the additional permitting requirements (flood protection system certification and approvals, etc.) required for work in the West/Coburn/Jewett and the Upper Jewett/Hampshire areas. The pipe sizes and network configuration required for separation of Sewer Area 40 are shown in Figure 6.24. Conceptual plan and profiles are included in Volume 2.

6.6.6.2 Hydraulic Modeling Simulations

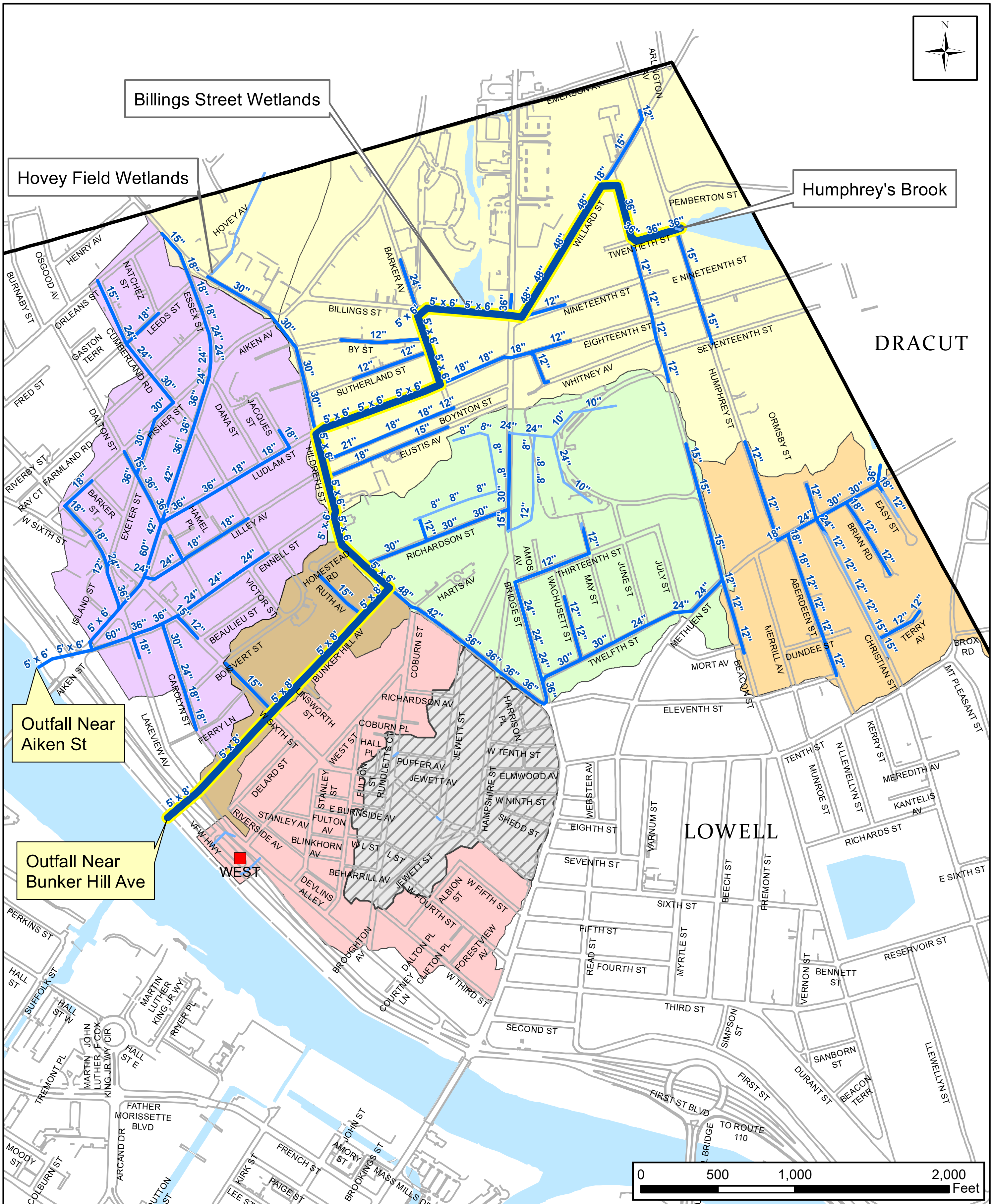
Hydraulic modeling extents of the sewer area 40 drainage network (shown in Figure 6.24) was sized for at least a 5-year design storm (same criteria as used for other portions of the Centralville separation area); the model was then used to simulate 2-year, 5-year, and 10-year design storms to assess performance, with model results from the 10-year design storm used to minimize temporary flooding. The mainline conduit profile with the outfall near Bunker Hill Avenue is the same as presented previously in Figure 6.13. The profile of two other key conduits in Sewer Area 40 are shown in **Figure 6.25** and **Figure 6.26**. The simulations assumed free discharge to the Merrimack River. For reference, the 100-year flood elevation is approximately 68.5-feet at the outfall near Aiken Street, but this restriction was not applied in these simulations. As discussed previously, the intersection of Aiken Avenue and Ennell Street is lower than the VFW highway and has the highest risk to flooding related in surcharging.

Figure 6.25 presents the peak hydraulic grade line profile for the longest run of drainage, which becomes the spine of the system along Aiken Street. Pipe sizes range from 15-inch to 60-inch diameter from the upper reaches of the catchment area to West 6th Street before box culvert sizes ranging from 4-ft high by 5-ft wide and then 5-ft high by 6-ft wide are required.

Figure 6.26 presents the peak hydraulic grade line profile for Ennell Street, which was the proposed route for the mainline conduit alternative that conveys flow to the Aiken Outfall. Without the inflow sources, the pipes range in size from 24-inch to 36-inch in diameter for the upper half of the catchment area until Lakeview Ave, and then increase to 60-inch diameter and then to a 5-ft high by 6-ft wide box culvert. Although there are not many catch basins collected along Ennell Street, the pipe sizes are impacted due to the hydraulic connection of the longer, larger drain alignment of Aiken Street, creating the need for larger pipe sizes to keep the HGL below grade.

6.6.6.3 Constructability Challenges

Crossing the Lakeview trunk sewer poses a challenge, as going under the trunk sewer causes downstream piping to conflict with the 96-inch interceptor. Going over the trunk sewer is also a



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas (Phase)

- Bunker Hill Ave (1)
- Middle Branches (2)
- Northern Branches (2)
- Methuen (2)
- Sewer Area 40 (2)
- West/Coburn/Jewett (3)
- Upper Jewett/Hampshire (3)

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Figure 6.24
Outfall Near Bunker Hill Ave with Sewer Area 40 Alternative

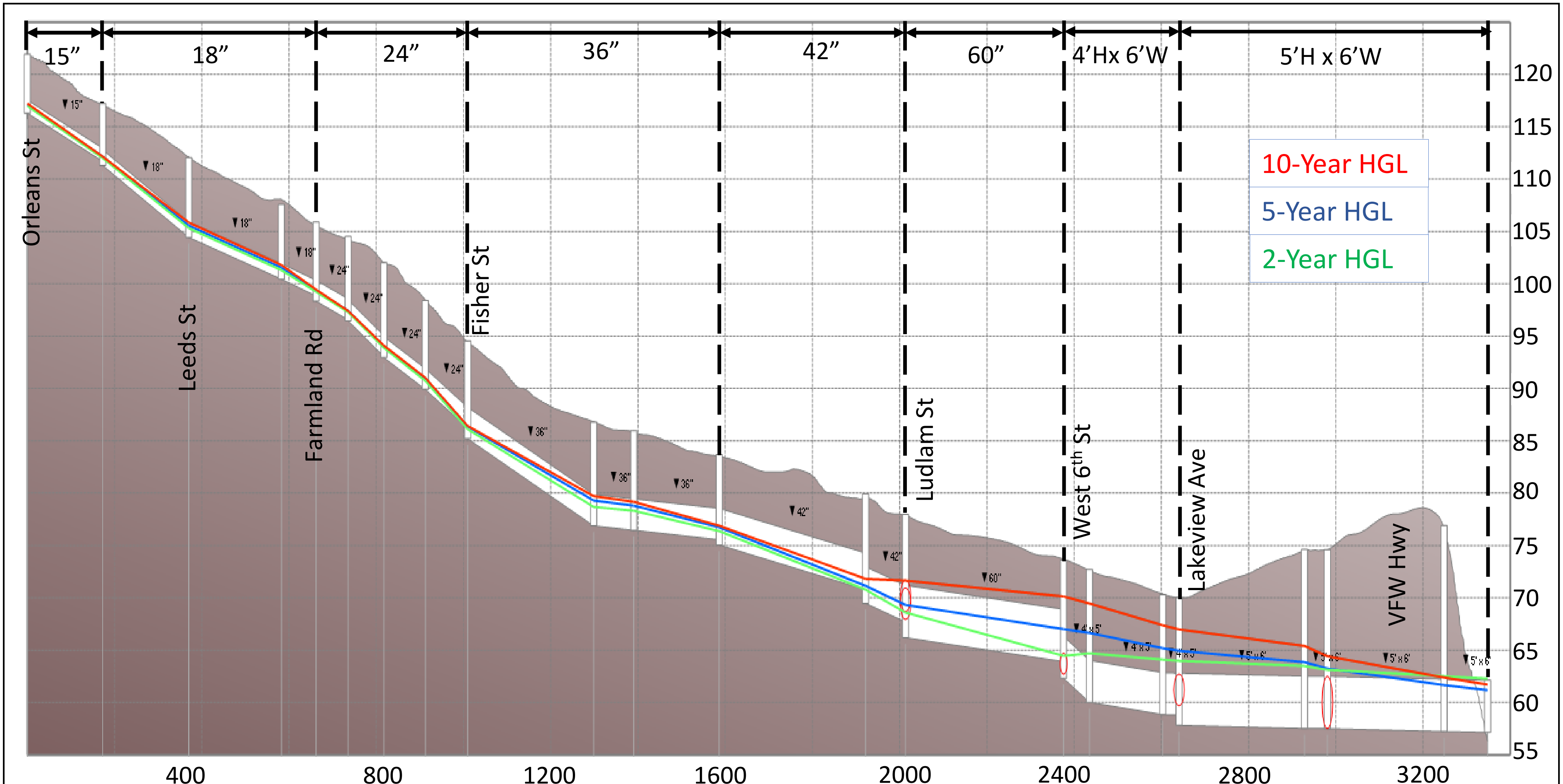

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Figure 6.25
Peak Hydraulic Grade Line Profile for Sewer Area 40 Separation Along Aiken Street

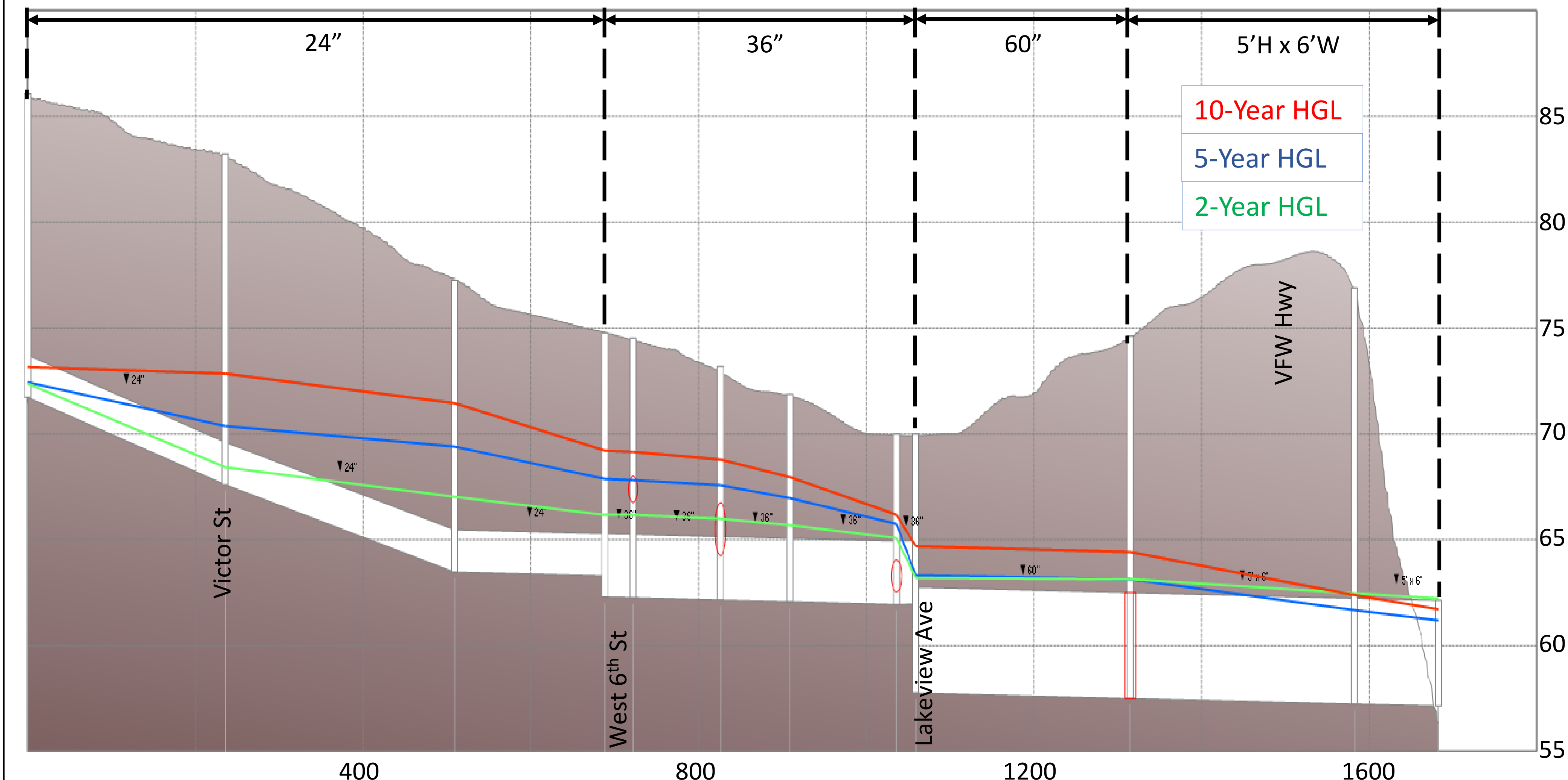

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Figure 6.26
Peak Hydraulic Grade Line Profile for Sewer Area 40 Separation Along Ennell Street

challenge as there is limited vertical space between the bottom of two 30-inch water mains and the top of the trunk sewer. To mitigate this situation, an irregular box culvert size (3-ft high by 4-ft wide) could be utilized, as this would allow the culvert to fit in the limited area available.

In two other areas on West Sixth Street, the 30-inch mains need to be crossed. These crossings may be accomplished by bringing the new drain under the 30-inch mains and crossing as close to perpendicular as possible to minimize the impact on the mains. The mains are at risk of being compromised by an adjacent open trench, so running parallel pipes to the 30-inch water mains should be avoided.

MassDOT is initiating a significant repaving program along the VFW Highway. To accommodate this program, the City could install the Aiken Outfall from the riverbank to just beyond the VFW Highway as part of Phase 1 work, but not connect any pipes to the new outfall until later phases of work. This would negate the need for repaving the VFW Highway again in the near future.

Since the intersection of VFW Highway and Aiken Street is already being excavated, it is likely that the box culvert through this intersection will be installed by open cut methods. However, if open cut construction is not feasible, there is space available on either side of the intersection to accommodate a trenchless option.

6.6.6.4 Conclusion

This alternative avoids bringing increased flow from inflow sources across sewershed boundaries to a high trafficked intersection that is already vulnerable to street flooding and catch basin inlet capacity restrictions. Separating Sewer Area 40 to a dedicated outfall, without the influence of the inflow sources, creates a system with smaller pipe sizes that can more easily navigate the utility challenges and conflicts of the West Sixth Street watermains, the Lakeview Ave Trunk Sewer, and the North Bank Interceptor.

CSO simulations (described in Section 7) indicate that the separation of Sewer Area 40 provides comparable CSO reduction benefit to the separation of low-laying areas within the Phase 2 project area that are more complex to separate.

Creating a new outfall for this area will also benefit planned MassDOT roadway improvements, which include separation of the MassDOT drainage system. Due to schedule considerations, it may be necessary to construct the outfall and the box culvert through the VFW Highway and the Aiken Street intersection as part of Phase 1 work, even though the outfall and box culvert will not be used until Phase 2 implementation.

6.7 Alternatives Development Conclusions

The following conclusions were reached through this alternative development section:

- Reuse of the combined sewer system as a sewer system and construction of a new stormwater system is preferred. However, there may be limited instances on individual streets where the reuse of existing pipes for drainage purposes and construction of a new sewer should be considered.

- The Methuen Steet drainage area will be a new stormwater system that will discharge to the existing Easy Street headwall location; minor modifications to the existing headwall may be required.
- The Stanley Street outfall originally presented in the 2000 HB PDR has several hydraulic and construction challenges, including construction along narrow streets and pipe conflicts around West Station.
- The mainline conduit conveying inflow from Humphrey's Brook and the Billings Wetland requires a separate outfall and should not be connected to the West CSO Diversion Station structure or outfall to avoid interference with the primary purpose of the station, which is to provide flood protection for the low-laying areas behind the levee system.
- A limited separation area, such as the Jewett/Coburn/Hampshire Street area, may utilize the existing West CSO Diversion Station outfall, but with the implementation of emergency procedures (see last bullet below). For this reason, an outfall at Stanley Street may be preferred.
- All alternatives will require coordination with MassDOT to allow for construction in the VFW Highway, the USACE to allow for construction in the levee system, and other permitting agencies such as MassDEP, DCR, and the City Conservation Commission to allow for construction of new outfalls along the Merrimack River.
- The two primary alternatives for discharge of flow from the Phase 1 mainline conduit to the river are the outfall location near Bunker Hill Avenue and the outfall location near Aiken Street.
- Based on discussions with FEMA representatives, additional system capacity analysis, new O&M procedures, and an emergency operations plan would be required to allow for interior drainage modifications within the Jewett/Coburn/Hampshire Street area; FEMA review and approval of these documents would be required. Additionally, FEMA review and approval of a Letter of Map revision would be required. This extensive permitting process will have a long lead time and does not align well with the schedule for separation of the Centralville area.

Section 7 will further evaluate the two primary mainline conduit and outfall alternatives (the Bunker Hill Avenue Outfall alternative and the Aiken Street Outfall alternative) and provide a recommended mainline conduit/outfall alternative.

7.0 Alternatives Analysis

7.1 Overview

Section 6 considered several pipeline routes to separate the Centralville study area. The CD requires the Utility to separate the combined sewer area identified in the 2000 Humphrey's PDR, which included the Humphrey's Brook and Billings Street Wetland surface water inflow sources from Dracut, along with the approximately 400-acre downstream combined sewer in Lowell. Accordingly, Section 6 focused on potential mainline conduit routes to get the Dracut inflow to the Merrimack River or to the West Pump Station for discharge. Development of the downstream separation plans in Lowell followed the mainline pipe route alternatives. In addition, the separation plan was developed to address several of the City's chronic problem areas of street flooding and system surcharge such as at the intersection of Lakeview Avenue and Aiken/Ennell Streets.

Section 6 ultimately identified two practical and constructable mainline conduit and outfall alternatives. During development of the separation plan for the downstream areas, it became apparent that separation of some low elevation areas behind the Lowell FDR System (the area identified as Coburn/Jewett/Hampshire Streets) could not be readily connected to the Merrimack River with a gravity discharge because high-river conditions could convey flow back through the pipe and inundate the area. Accordingly, during development of the separation plans, the Utility identified the potential to separate Sewer Area 40, which is adjacent to the Humphrey's Brook PDR area, as an alternative to separation of the low elevation areas. In addition, one of the mainline route alternatives went through Sewer Area 40, which would facilitate separation of this area. CDM Smith and the Utility met with MassDEP and USEPA in late 2023 to discuss this possible exchange of combined sewer areas to separate.

Section 7 provides further analysis, including a comparison of estimated costs and projected CSO reduction benefits, to determine the better alternative to separate the Centralville study area and to address the MassDEP and USEPA comments.

The two primary mainline conduit and outfall alternatives are:

- **Bunker Hill Avenue Outfall**
  - This alternative comprises the installation of a new mainline conduit along a Bunker Hill Avenue, a wider street (with less construction challenges than the original route down West Street and Stanley Avenue presented in the 2000 HB PDR) and a new outfall to the Merrimack River, west of the West CSO Station. The outfall would be installed in the earthen flood levee portion of the FDR System and under VFW Highway, a MassDOT roadway.
  - Due to topography and potential high river conditions, the new outfall will function under surcharge conditions during some larger storm events depending on river conditions. The surcharge condition along the pipe starts at about West Sixth Street, which precludes the potential connection of some adjacent, but low-lying, streets in an area approximately bounded by Bridge Street, Hildreth Avenue, Lakeview Avenue, and Stanley Street.

  - If this mainline conduit route is adopted (and the agencies accepted the approach not to separate Coburn/Jewett/Hampshire), the Aiken Street Outfall for the separation of Sewer Area 40 is not required.

- **Aiken Street Outfall**

  - This alternative comprises the installation of a new mainline conduit along Ennell Street (to a new outfall at Aiken Street) through Sewer Area 40. One benefit of this route is that it provides the opportunity to separate another problematic street flooding area near the intersection of Lakeview Avenue and Aiken/Ennell Streets. In addition, the new gravity discharge outfall would be located northwest of Aiken Street, which is within the FDR System. Work at this location could also be coordinated with a planned MassDOT VFW Highway paving improvement project that will separate MassDOT catch basins from the Utility's combined system.

  - It is important to note that, under this alternative, the Bunker Hill Avenue outfall would still be constructed (as a second outfall pipe) to separate the Middle Branch subarea with a 60-inch drain along Bunker Hill Avenue. Accordingly, coordination with the USACE to install a pipe through the FDR System is still required.

The two mainline conduit alternatives are presented in **Figure 7.1** (Bunker Hill Avenue outfall) and **Figure 7.2** (Aiken Street outfall) and analyzed further in this section. These mainline conduit alternatives provide for separation of the Centralville area, except for the Coburn/Jewett/Hampshire low elevation area, and both alternatives provide for over 400 acres of separation, in accordance with the intent of the CD.

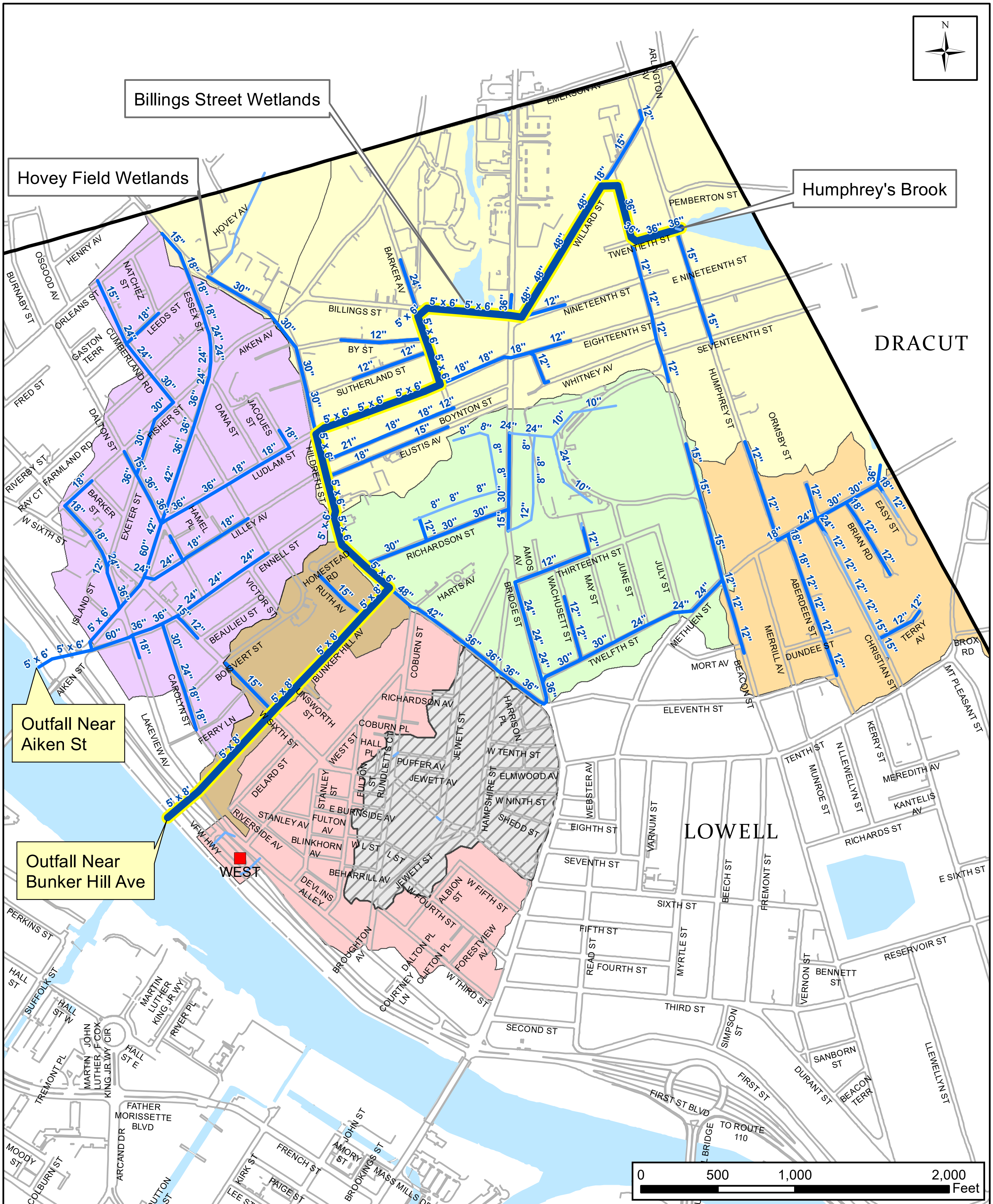
The cost and CSO reduction information presented in this section was presented to the regulatory agencies in May 2023. The Utility showed that a slightly better CSO reduction benefit could be achieved by separation of Sewer Area 40 rather than by separation of the Coburn/Jewett/Hampshire area, with the same separation acreage and comparable costs. Accordingly, by agreement with (and informal approval by) the regulatory agencies, the Utility will include separation of Sewer Area 40 in its Phase 2 Centralville Sewer Separation Program and incorporate further consideration of the challenges and relative priority of separating the Coburn/Jewett/Hampshire area into the Phase 3 Sewer Separation Preliminary Design Report due on December 31, 2024.

Under both alternatives, the area referenced as the Methuen Street area could be separated independently of the outfall options for the separation of the 2000 HB PDR. This is because the Methuen Street area will discharge to an existing drainage channel that ultimately is conveyed via a surface water system north to Humphrey's Brook.

Section 7 presents the quantitative and qualitative comparisons that assisted the Utility and the agencies into mutual agreement of the recommended plan.

7.2 Discussion of the Mainline Options

Table 7.1 lists the individual subareas served under each alternative and the likely phasing of work, with Phase 1 defined as elimination of the Humphrey's Brook/Billing Street Wetland inflow sources and Phase 2 defined as separation of the remaining portions of the Centralville area. The subareas listed in



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas (Phase)

- Bunker Hill Ave (1)
- Middle Branches (2)
- Northern Branches (2)
- Methuen (2)
- Sewer Area 40 (2)
- West/Coburn/Jewett (3)
- Upper Jewett/Hampshire (3)

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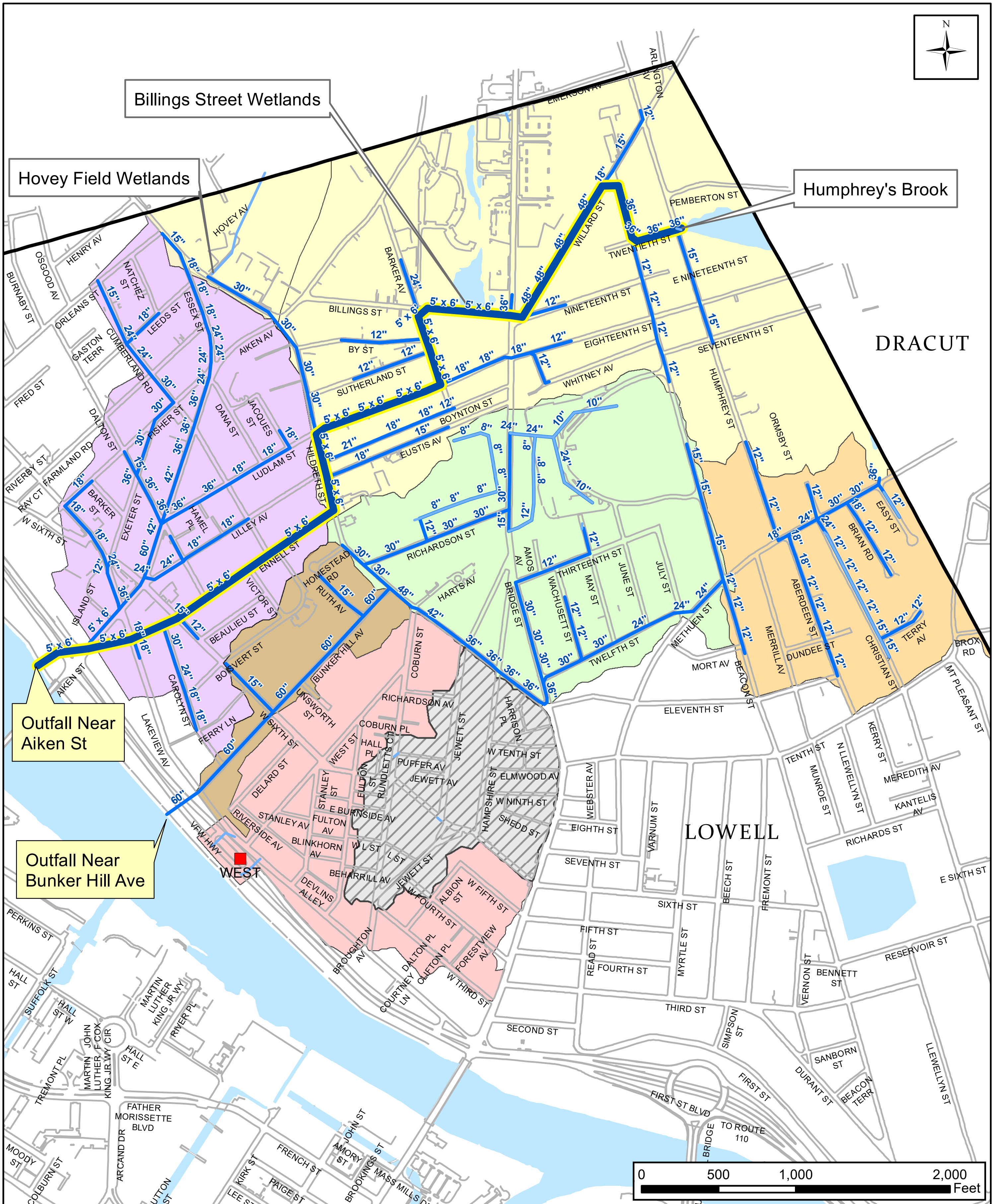
Figure 7.1

Outfall Near Bunker Hill Ave with Sewer Area 40 Alternative



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Alternative Outfall (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas (Phase)

- Bunker Hill Ave (2)
- Middle Branches (2)
- Northern Branches (2)
- Methuen (2)
- Sewer Area 40 (2)
- West/Coburn/Jewett (3)
- Upper Jewett/Hampshire (3)

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Figure 7.2

Outfall Near Aiken Street with Sewer Area 40 Alternative

Table 7.1 represent the “branches” of the separation plans in each subarea that will eventually be connected to the mainline conduit. As noted previously, the Methuen Street area will have a separate outfall and is not included in Table 7.1. Also note that, in order to serve the Sewer Area 40 subarea, the Aiken Street Outfall would have to be constructed under either alternative.

Table 7.1 Subarea Construction Phasing for the Two Most Feasible Drain Outfall Options

Mainline Conduit Outfall Near Bunker Hill Ave (Phase)	Mainline Conduit Outfall Near Aiken St (Phase)
Bunker Hill Avenue Mainline Conduit (1)	Aiken Street Mainline Conduit (Phase 1)
Bunker Hill Ave (1) connected to Bunker Hill Ave Outfall	Bunker Hill Ave (2) connected **to Bunker Hill Ave Second Outfall**
Middle Branches (2) connected to Bunker Hill Ave Outfall	Middle Branches (2) connected **to Bunker Hill Second Outfall**
Northern Branches (2) connected to Bunker Hill Outfall	Northern Branches (2) connected to Aiken Outfall
Sewer Area 40 (2) connected **to Aiken St Second Outfall**	Sewer Area 40 (2) connected to Aiken Outfall
West/Coburn/Jewett connected to Stanley Street Outfall (Excluded and considered in Phase 3)	West/Coburn/Jewett connected to Stanley Street Outfall (Excluded and considered in Phase 3)
Upper Jewett/Hampshire connected to Stanley Street Outfall (Excluded and considered in Phase 3)	Upper Jewett/Hampshire connected to Stanley Street Outfall (Excluded and considered in Phase 3)

Based on these two outfall options, **Volume 2** of this PDR includes a set of preliminary design plan and profile drawings that could serve as the basis for a “construction” contract for each alternative. Section 6 discusses the development of these plans using a comprehensive base map generated from existing GIS and information solicited from the other non-city utility owners in the street. These drawings represent approximately 30 percent design development. Extensive engineering work was conducted to develop the most practical routes for new piping and determine the appropriate depth for new pipe with consideration of constructability issues including the type of trench support, the need to minimize community impacts, and the need to minimize utility conflicts and utility relocations to the extent possible. The proposed pipe size/length information presented in this section is based on the hydraulic model developed for this project; it is important to note that preliminary design work continues to progress and, as a result, pipe length size/length information presented in this section may vary slightly from the pipe lengths shown on the preliminary design drawings included in Volume 2.

The mainline conduit lengths for the two outfall options are within 10 percent of each other, but the Bunker Hill Avenue Outfall will require wider box culvert segments (5’Hx8’W) than the Aiken Street Outfall option at the most downstream end of the conduit. Although the box culverts increase in size for the Bunker Hill Avenue Outfall, the amount of surface disruption and restoration required would be relatively the same for the two alternatives. There are some additional costs associated with the deeper construction of the Aiken Street Outfall pipe along Ennell Street (refer to the design drawings included in Volume 2) because the pipe along this street requires deeper excavation and a lower invert depth to cross under the West Sixth Street water mains and other existing combined sewer conflicts.

The two outfall plans have the same pipe size and length requirements for the Methuen Street and Northern Branches areas. The Middle Branches only differ with respect to the additional lengths of 30-inch pipe required to connect to Bunker Hill Avenue under the Aiken Street Outfall option, as this stretch is part of the mainline conduit under the Bunker Hill Outfall option. A similar situation occurs in the Bunker Hill Avenue area where, if the Aiken Street Outfall is constructed, a new secondary 60-inch outfall pipe would be needed to convey the Middle Branches and local drainage to an outfall at the Merrimack River.

One disadvantage of the Aiken Street Outfall option is that routing of a larger conduit along Ennell Street creates an elevational conflict with the Lakeview Ave trunk sewer. This conflict creates the need for a siphon section which would be full of water, although refreshed by inflow sources contributions. Smaller drainage networks in this area more easily cross over this sewer conflict and meet the outfall elevation requirements downstream.

7.3 CSO Reduction Estimates

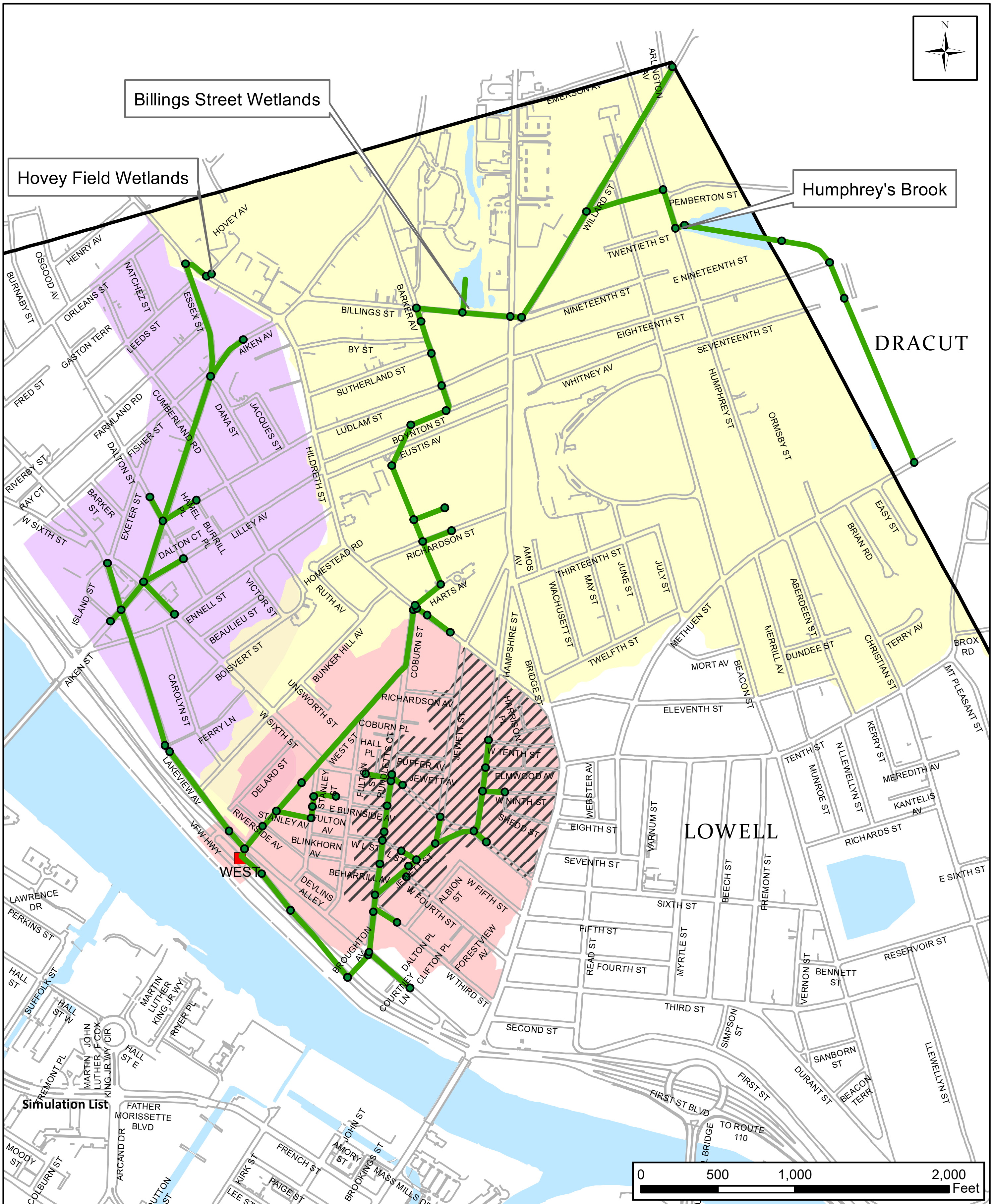
The existing CSO model for Lowell's collection system was updated and recalibrated for the Centralville area. A detailed discussion of these updates and the calibration processes followed is provided in Volume 2. The calibrated model was used to determine baseline CSO estimates and projected CSO reduction for proposed separation projects. While the sewer and drainage subcatchment boundaries may vary slightly, the overall area is equivalent for the CSO reduction simulations. To estimate average annual CSO discharge, existing system and separated system alternative models were used to simulate a representative 5-year period (2005-2009). This representative period was established by CDM Smith for the 2014 LTCP report based on statistical analysis of annual precipitation for Boston Logan Airport hourly precipitation data.

Five simulations representing different separation phases and alternatives are described below. These separation projects are shown in **Figure 7.3** and summarized in **Table 7.2**.

- Simulation 1: Phase 1 inflow removal achieved by separating Humphrey's Brook and Billings Wetland (460 acres)
- Simulation 2: Separation of Upper Hildreth (Northern Branches, Middle Branches, Methuen St., and Bunker Hill Ave.) in addition to Simulation 1 (320 acres)
- Simulation 3: Separation of West, Coburn, and Jewett Street and Upper Jewett/Hampshire in addition to Simulation 2 (82 acres).
- Simulation 4: Separation of Sewer Area 40 in addition to Simulation 2 (86 acres)

The results of Simulations 3 and 4 were used to compare the CSO reduction benefits of separating the 82 acres in the West/Coburn/Jewett/Hampshire area (Simulation 3) versus separating 86 acres in Sewer Area 40 (Simulation 4).

CSO volume and number of events for the 5-year continuous simulation were averaged to get an average annual CSO volume and event count for the baseline model and the 5 separation alternatives. These values for each model simulation are shown in Table 7.2.



Legend

- Model Sewers
- Upper Hildreth
- West/Coburn/Jewett
- Upper Jewett/Hampshire
- Sewer Area 40

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Figure 7.3

Sewer Separation Simulations

Table 7.2 CSO Annual Statistics for the Baseline Conditions of the Five Separation Simulations

<table>
<tr><th>Simulation</th><th>Separation Areas</th><th>Separation Acreage</th><th colspan="2">Cumulative Acres Separated</th><th>CSO Volume (MG/year)</th><th>CSO Events per year</th><th>CSO Reduction (MG/Year)</th><th>Reduction in CSO Events per Year</th></tr>
<tr><td>Baseline</td><td>-</td><td>-</td><td colspan="2">-</td><td>76</td><td>17</td><td>-</td><td>-</td></tr>
<tr><td>Simulation 1</td><td>Humphrey's Brook, Billings Wetland (Phase 1 Inflow Removal)</td><td>460</td><td colspan="2">460</td><td>54</td><td>15</td><td>22</td><td>2</td></tr>
<tr><td>Simulation 2</td><td>Upper Hildreth</td><td>320</td><td colspan="2">780</td><td>28</td><td>9</td><td>48</td><td>8</td></tr>
<tr><td>Simulation 3a</td><td>West/Coburn/Jewett</td><td rowspan="2">82</td><td>52</td><td>832</td><td>23</td><td>8</td><td>53</td><td>9</td></tr>
<tr><td>Simulation 3b</td><td>Upper Jewett/Hampshire</td><td>30</td><td>862</td><td>18</td><td>7</td><td>58</td><td>10</td></tr>
<tr><td>Simulation 4</td><td>OR Area 40 (instead of Simulation 3)</td><td>86</td><td colspan="2">866</td><td>17</td><td>7</td><td>59</td><td>10</td></tr>
</table>

The information presented in Table 7.2 shows that:

- Separation of the West/Coburn/Jewett/Hampshire area (Simulation 3) and separation of 86 acres in Sewer Area 40 (Simulation 4) achieve comparable benefit in terms of CSO volume reduction and reduction in the number of CSO events annually.
- The Centralville area separation project with Sewer Area 40 will reduce average annual CSO volume from approximately 76 MG/year to approximately 17 MG/year, a reduction of approximately 59 MG/year. Additionally, the separation will reduce the average number of CSO events annually from approximately 17 to approximately 7, a reduction of approximately 10 CSO events per year.

7.4 Estimated Project Costs

An Opinion of Probable Construction Cost (OPCC) was developed based on quantities obtained from the preliminary design drawings included in Volume 2 of this PDR. The OPCC includes:

- New drain pipes and 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 based on available sewer record plans along the main conduit.
- Allowances for contractor mobilization/demobilization, light maintenance of traffic, and general utility relocation/offsets.
- Allowance for contractor general conditions and indirect costs.
- CSS rehabilitation and sewer lateral rehabilitation have been estimated separately.

The type of excavation support required for the mainline conduit and outfalls was considered based on the pipe depth, horizontal alignment, and anticipated utility impacts. These assumptions will be refined as the design progresses and information from the geotechnical investigation program is incorporated into the design.

Factors that influence construction costs include, but are not limited to, the following: cost of labor, materials, and equipment; services provided; schedules; contractor methods of determining prices; competitive bidding; and market or negotiating conditions. The planning level OPCCs include direct costs (materials and construction labor), indirect costs (permit fees, insurance, and bonding costs), contractor general conditions, and contractor's overhead and profit. Additionally, construction contingencies and escalation for future implementation are included in the OPCCs. These OPCCs do not include owner costs, finance or funding costs, legal fees, costs for land acquisitions, temporary/permanent easements, Article 97 fees, permitting fees, construction oversight fees, change orders, operations, public participation costs or any other costs associated with the project that are not anticipated to be part of the bidding contractor's proposed scope of work.

Accordingly, the following contingencies and allowances were added to the OPCC to develop a total project cost:

- Engineering and implementation costs: 20 percent
- Project Contingency: 35 percent

Tables 7.3 and 7.4 present the project cost estimates for the two outfall options. The Utility's goal in developing and prioritizing projects is to target sewer separation that is cost effective and provides the greatest benefit in terms of CSO reduction. As noted previously, there are concerns that separation of the West/Coburn/Jewett area and Upper Jewett/Hampshire area may increase the risk of flooding under certain conditions and, therefore, it is recommended that the Utility not proceed with separation of this area at this time. **Table 7.5** shows the cost associated with these areas for reference only.

Given the level of design development, the OPCCs for the two proposed outfall options are considered equivalent.

Table 7.3 Alternative 1 - Mainline Conduit to Bunker Hill Avenue Outfall

Description	Construction Cost ($Millions)	Project Cost Subtotal ($Millions)
Mainline Conduit - Humphrey's Brook to Outfall Near Bunker Hill Ave	**$32.4**	**$50.2**
Mainline Conduit Cost	*$28.7*	*$44.5*
CSS & Sewer Lateral Rehabilitation	*$3.7*	*$5.7*
Bunker Hill Ave (adjacent to Mainline Conduit)	**$0.8**	**$1.2**
Separation Cost	*$0.7*	*$1.1*
CSS & Sewer Lateral Rehabilitation (included in mainline above	*$0.1*	*$0.2*
Middle Branches	**$11.8**	**$18.3**
Separation Cost	*$8.1*	*$12.6*
CSS & Sewer Lateral Rehabilitation	*$3.7*	*$5.7*
Northern Branches	**$20.3**	**$31.5**
Hovey Field Wetlands Connection	*$2.8*	*$4.3*
Remaining Separation Cost	*$13.7*	*$21.2*
CSS & Sewer Lateral Rehabilitation	*$3.8*	*$5.9*
Methuen	**$8.8**	**$13.6**
Separation Cost	*$5.4*	*$8.4*
CSS & Sewer Lateral Rehabilitation	*$3.4*	*$5.3*
Sewer Area 40 (includes second outfall near Aiken St)	**$27.8**	**$43.1**
Aiken St Outfall and VFW Highway Crossing	*$3.9*	*$6.0*
Remaining Separation Cost	*$17.6*	*$27.3*
CSS & Sewer Lateral Rehabilitation	*$6.3*	*$9.8*
TOTAL	**$101.9**	**$157.9**

Table 7.4 Alternative 2 - Mainline Conduit to Aiken Street Outfall

Description	Construction Cost ($Millions)	Project Cost Subtotal ($Millions)
Mainline Conduit - Humphrey's Brook to Outfall Near Aiken Street	**$32.6**	**$50.5**
Main Conduit Cost	*$28.8*	*$44.6*
CSS & Sewer Lateral Rehabilitation	*$3.8*	*$5.9*
Bunker Hill Ave (includes second outfall near Bunker Hill Ave)	**$7.3**	**$11.3**
Separation Cost	*$6.9*	*$10.7*
CSS & Sewer Lateral Rehabilitation	*$0.4*	*$0.6*
Middle Branches	**$12.0**	**$18.6**
Separation Cost	*$8.3*	*$12.9*
CSS & Sewer Lateral Rehabilitation	*$3.7*	*$5.7*
Northern Branches	**$20.3**	**$31.5**
Hovey Field Wetlands Connection	*$2.8*	*$4.3*
Remaining Separation Cost	*$13.7*	*$21.2*
CSS & Sewer Lateral Rehabilitation	*$3.8*	*$5.9*
Methuen	**$8.8**	**$13.6**
Separation Cost	*$5.4*	*$8.4*
CSS & Sewer Lateral Rehabilitation	*$3.4*	*$5.3*
Sewer Area 40 - Branches Only	**$21.4**	**$33.2**
Separation Cost	*$15.6*	*$24.2*
CSS & Sewer Lateral Rehabilitation	*$5.8*	*$9.0*
TOTAL	**$102.4**	**$158.7**

Table 7.5 - Other Separation Cost Background

Description	Construction Cost ($Millions)	Project Cost Subtotal ($Millions)
West/Coburn/Jewett	**$20.1**	**$31.2**
Separation Cost	*$16.1*	*$25.0*
CSS & Sewer Lateral Rehabilitation	*$4.0*	*$6.2*
Upper Jewett/Hampshire	**$10.8**	**$16.8**
Separation Cost	*$9.2*	*$14.3*
CSS & Sewer Lateral Rehabilitation	*$1.6*	*$2.5*

Notes:

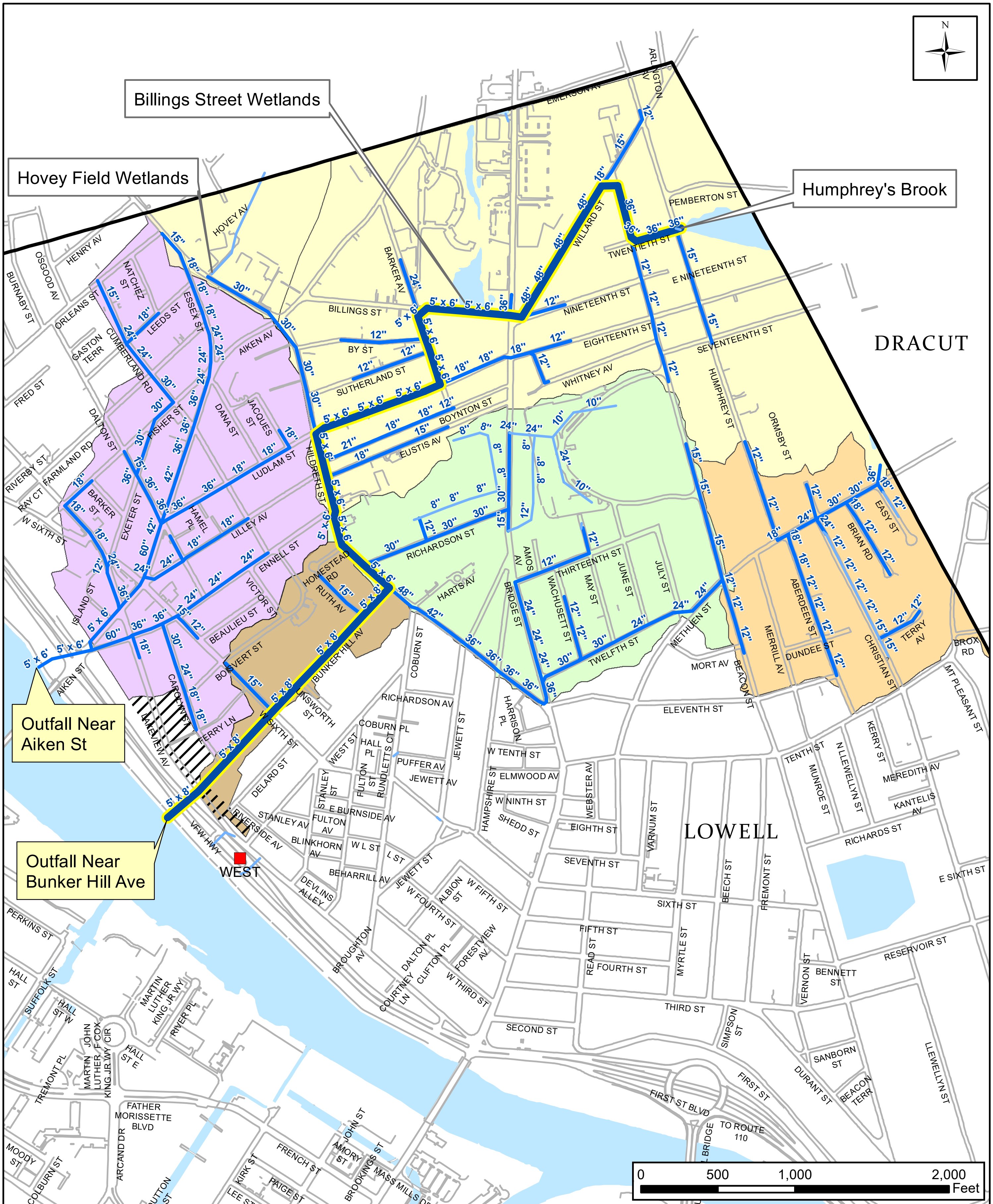
1. Construction Costs include CCI Markups of General Conditions, Indirects, Construction Contingency, Escalation assumed to mid-point of construct
2. Project Costs include 20% Engineering and 35% Project Contingency
3. Limited rock removal has been included based on available sewer records (incomplete), however more complete rock removal costs to be added based on Geotechnical Investigation Program.
4. Costs include some general allowances for small diameter sewer relocations but not include any watermain or private utility relocation.
5. Costs do not include bypass pumping or extensive dewatering costs, extensive traffic management plans, or any easement or land acquisitions
6. CSS Rehabilitation costs vary for Mainline Conduit route, Bunker Hill Ave, and Sewer Area 40 depending on alternative.

7.5 Conclusion and Recommended Plan

Given that the two mainline conduit conveyance and outfall alternatives considered have similar costs and provide equivalent CSO reduction benefit, the selection of Alternative 1 (Main Conduit to Bunker Hill Avenue Outfall) as the recommended alternative is based largely on the following qualitative factors:

- The Bunker Hill Avenue provides a more direct, wider corridor to bring the mainline conduits from Hildreth Street to the Merrimack River.
- The large box culvert is better able to navigate utility challenges by crossing under the large diameter watermains on West 6th Street, over the Lakeview Avenue Trunk Sewer, and over the 96-inch North Bank Interceptor. (The benefits of mid-sized pipes along Ennell Street are discussed below for separation of sewer area 40)
- Based on discussions with USACE and MassDOT, it is feasible for the box culvert to cross the earthen levee by open cut methods. The layout of the VFW Highway in this area (two lanes in each direction and grass median in between) provides better temporary traffic opportunities so that work can be phased while maintaining some level of flood protection during construction.
- There is more open space along Lakeview Avenue to mitigate the hydraulic surcharge and accommodate the venting needed to prevent air binding from the outfall through the most downstream segments of the mainline conduit route. The variability of the water levels in the Merrimack River also creates additional hydraulic constraints.
- There is a slight CSO reduction benefit associated with the separation of Sewer Area 40 instead of the West/Coburn/Jewett and Upper Jewett/Hampshire area. Due to the many design and permitting complexities associated with separation of the West/Coburn/Jewett and Upper Jewett/Hampshire area, this area will be moved from Phase 2 to Phase 3 and evaluated as part of the Phase 3 Preliminary Design Report.
- The pipe configuration and sizing required for separation of Sewer Area 40 as its own basin provides benefit in terms of navigating potential conflicts with existing large diameter sewer and water utilities.
- Both proposed outfall locations provide an opportunity to connect the planned MassDOT drainage improvements and eliminate a number of smaller outfalls that would have been necessary to separate the VFW Highway drainage system.
- There is a small area with catch basins near elevation 70 or below that should be excluded from the separation area due to the risk of flooding from surcharge of downstream segments; these catch basins will remain connected to the combined system. The impact of excluding up to 6 catch basins will be mitigated by the fact that most of the surface water will have already been collected upstream by the new drain networks.

The recommended plan for Phase 1 and Phase 2 separation of the Centralville area is presented in **Figure 7.4**. Given the size of the separation area and the cost and complexity of the required construction, it is recommended that the separation program be implemented under multiple construction contracts. Section 8 presents this phased approach with a recommended implementation schedule and preliminary cost estimates for each construction contract.



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas (Phase)

- Bunker Hill Ave (1)
- Middle Branches (2)
- Northern Branches (2)
- Methuen (2)
- Sewer Area 40 (2)
- Areas Excluded (Topography/Hydraulic Risk)

CDM Smith

DUCK ISLAND — LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts

Centralville Sewer Separation Revised PDR

Figure 7.4

Recommended Plan

8.0 Recommended Implementation Plan

8.1 Introduction

Section 7 identified the selected alternative for sewer separation in the Centralville area. The recommended program will include the following:

- Phase 1 – Mainline Conduit Project
  - Sewer separation along the Mainline Conduit of the Centralville area to remove large inflow sources from Humphrey's Brook and the Billings Street Wetlands, with discharge to the Merrimack River via a new Bunker Hill Avenue Outfall.
  - In addition, Aiken Outfall and crossing VFW Highway is presented in this section to be advanced to Phase 1 to provide synergy with MassDOT separation of VFW Highway.
- Phase 2 – Sewer separation in the remainder of the Centralville study area
  - Sewer separation in the Methuen Street, Middle Branch and Northern Branch Areas (identified in Section 6), all of which will be connected to the Phase 1 Mainline Project.
  - Sewer separation in Area 40 inclusive of the Aiken Street Outfall.
  - The West/Coburn/Jewett and Upper Jewett/Hampshire areas are excluded from Phase 2 work and will be further evaluated as part of the Phase 3 Preliminary Design Report (due December 31, 2024).

Key components of each of these recommended project phases include:

- Pre-design efforts including survey, geotechnical borings, evaluation of system rehabilitation needs, and wetland delineation.
- Design, bidding, and construction phase engineering services.
- Permitting efforts during the design phase including coordination with the USEPA, MassDEP, USACE, FEMA, MassDOT, Executive Office of Energy and Environmental Affairs, and state legislators to secure required permits and approvals, and to obtain an Article 97 conversion for the location of the drain pipe and outfalls along the Merrimack River.
- Incorporation of green infrastructure components where appropriate based on survey and City land availability.
- Incorporation of sewer line rehabilitation work sewer lateral rehabilitation where needed.
- Removal of private inflow sources based on field investigation performed to date in the Centralville area, and additional such investigations to be performed in Area 40.

The remainder of this section presents the proposed implementation plan to meet the Consent Decree (CD) milestone dates of December 31, 2027 for removal of flows from Humphrey's Brook and the Billings Street Wetlands from the City's CSS system (Phase 1 work), and December 31, 2031 for separation of the sewer and drain system in the remainder of the Centralville Area with the exception of the West/Coburn/Jewett and Upper Jewett/Hampshire areas (Phase 2 work).

8.2 Implementation Plan Challenges

The Phase 1 Mainline work includes approximately 7,600 feet of sewer separation work; design of the Phase 1 work is currently underway. The Phase 2 project will consist of approximately 11,700 feet of sewer separation in Area 40, and approximately 21,400 feet of sewer separation for the remainder of the Centralville area. Careful sequencing of the Phase 2 work is critical to meeting the goals of the separation program, including CD milestone date compliance. Factors considered in developing an implementation plan that both provides adequate time for execution of the work and properly sequences the required work include:

- Ability to provide for City coordination and oversight of multiple construction contracts simultaneously.
- Recognition that certain portions of Phase 2 sewer separation cannot be constructed until the Phase 1 program is complete, and that staggered starts of construction projects are preferred to help manage and mitigate construction impacts.
- Providing adequate time for the significant design and permitting efforts required for a pipeline project of this magnitude, including pre-design efforts such as survey, borings, and evaluation of sewer pipe requiring rehabilitation.
- Public outreach, coordination, and recognition of construction impacts to residents resulting from the execution of multiple construction contracts within a small, urban project area.
- Need for traffic detours and alternative routing given the narrow, congested roads; traffic flow patterns; presence of schools and bus routes; parking constraints; and presence of hospitals requiring emergency accessibility. Major traffic corridors include but are not limited to VFW Highway, Aiken Street, Hildreth Street, Methuen Street and Bridge Street.
- Allowance for large pipe production and delivery times and associated impacts on construction schedules.
- Consideration of winter shutdown periods and the potential impact of these shutdowns on the overall project schedule.
- Coordination with the MassDOT relative to the VFW highway paving project, which requires early installation of the Aiken Street outfall in phase 1 to avoid future repaving.
- Coordination with city roadway paving projects and other planned utility improvements/upgrades that are scheduled for the next few years.
- Consideration of paving needs following a freeze/thaw cycle and schedule allowance for reseeding/plantings inclusive of warranty periods.
- Developing construction packages and a bidding schedule that encourages multiple competitive bids, with consideration of the bonding and project execution capacity required for general contractors to perform this work.

- Developing timeline for project costs incurred so that the City can take steps to maintain adequate funding to meet project obligations throughout the construction program.
- Meeting State Revolving Fund (SRF) requirements and deadlines to maximize available SRF funding.

These challenges have been considered in developing the recommended implementation presented in Section 8.3.

8.3 Implementation Plan and Schedule

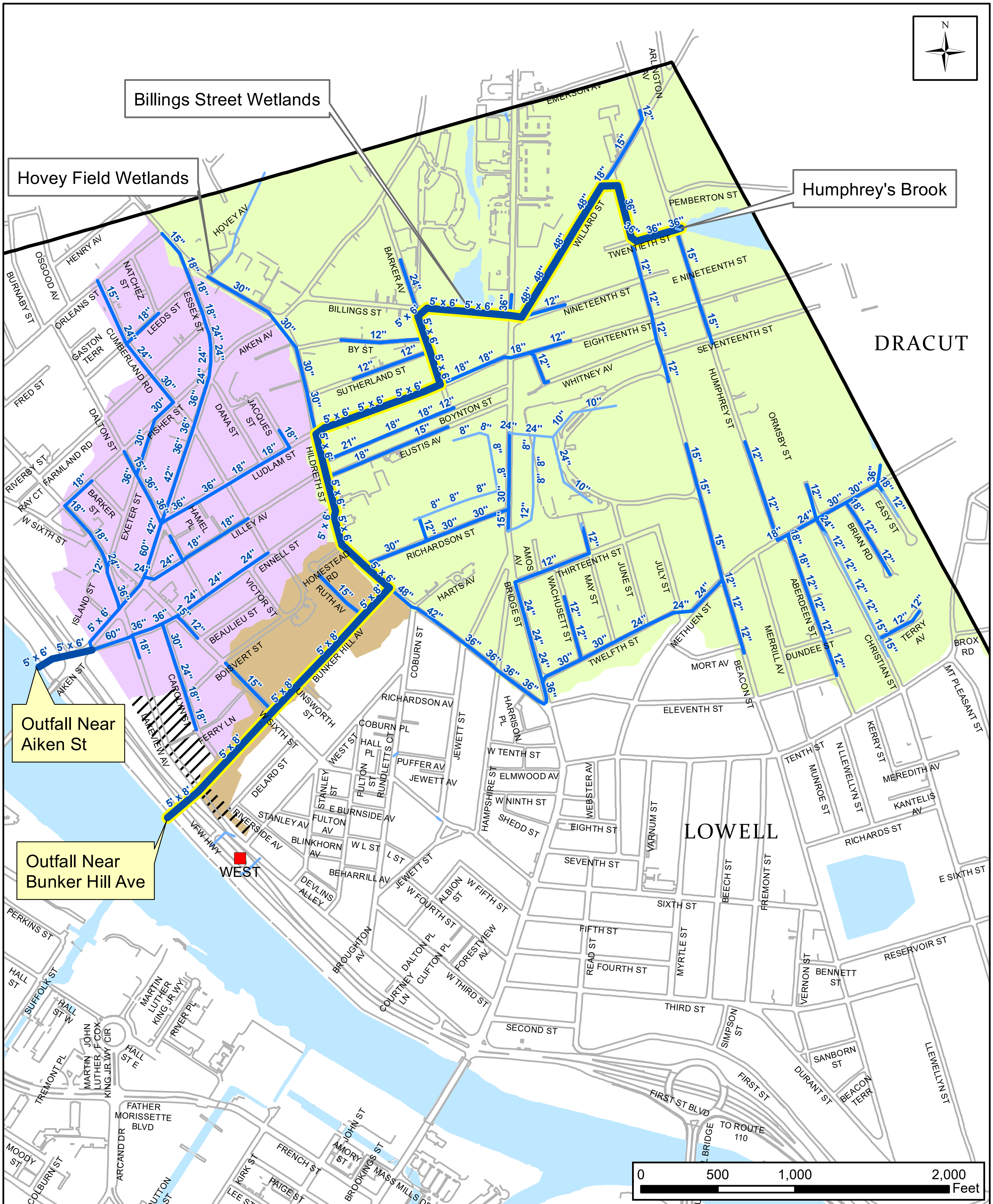
Based on the considerations described in Section 8.2, it is recommended that the work be completed under three construction contracts, with Phase 1 work representing a single construction contract and Phase 2 work divided into two construction contracts. **Table 8.1** summarizes the estimated linear footage for Phase 1, Phase 2A, and Phase 2B work and **Figure 8.1** shows the delineation of the three phases of work.

Table 8.1 Linear Footage Summary Per Pipe Size

Pipe Size	Linear Feet		
	Phase 1	Phase 2A	Phase 2B
8"-12"	0	1,000	7,000
15"-24"	450	5,700	7,000
>24"	1,950	3,900	7,400
Box Culvert	5,200	1,100	0
Total	**7,600**	**11,700**	**21,400**

Table 8.2 presents the Opinion of Probable Construction Cost (OPCC) for each phase of work. Note that the Phase 1 cost includes the cost for construction of the Aiken Street Outfall. As noted in Section 6, MassDOT is initiating a significant repaving program for the VFW Highway; to facilitate this work, it is recommended that the Aiken Outfall from the riverbank to just beyond the VFW Highway be constructed as part of Phase 1 work, although pipes will not be connected to the new outfall until future phases of work.

Generally, there are construction management and coordination benefits to having fewer, larger construction contracts. However, competition for larger construction contracts could be more limited, as only general contractors with larger bonding and project execution capacities would be eligible to undertake the work. Given the nature of the work, Phase 1 work cannot easily be subdivided into multiple construction contracts; however, Phase 2 work can be subdivided into two areas of work, with Phase 2A representing Sewer Area 40 and Phase 2B representing the remaining portions of the Humphrey's Brook/Billings Drainage Area. Phase 2B represents a large construction contract; during final design, construction market conditions will be further assessed to determine if there are benefits to dividing Phase 2B work into two construction contracts.



Legend

- Mainline Conduit (Phase 1)
- Aiken Outfall (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- West CSO Diversion Station

Separation Areas Phase

- 1 - Bunker Hill Ave
- 2A - Sewer Area 40
- 2B - Drainage Area Associated with Mainline Conduit
- Areas Excluded (Topography/Hydraulic Risk)

Lowell, Massachusetts
Centralville Sewer Separation Revised PDR

Figure 8.1
Recommended Plan Implementation

Table 8.2 Cost Breakdown Per Phase

Description	Phase 1	Phase 2A	Phase 2B
Construction Cost	$ 33.3	$ 17.6	$ 30.0
CSS & Lateral Rehabilitation Allowance	$ 3.8	$ 6.3	$ 10.9
Engineering (20%)	$ 7.4	$ 4.8	$ 8.2
Project Contingency (35%)	$ 13.0	$ 8.4	$ 14.3
Total Cost	**$ 57.5**	**$ 37.0**	**$ 63.4**

Notes:

1. Phase 1 includes Centralville Mainline Conduit, Bunker Hill Ave, and Aiken Street Outfall and VFW Highway Crossing
2. Phase 2A includes Sewer Area 40
3. Phase 2B includes Methuen, Middle Branches, Northern Branches, and Hovey Connection Areas

Figure 8.2 shows the recommended schedule to complete the work in accordance with the CD milestone dates. The CD deadline for completion of Phase I construction is December 31, 2027. It is expected that final design of the Phase 1 Mainline conduit will be completed by March 2025, with construction bids received in May 2025 and a construction contract execution by July 2025. The City will submit a State Revolving Fund (SRF) program application for Phase 1 work in October 2024. including design drawings and specifications. A construction period of 30 months is assumed for planning purposes.

It is recommended that Phase 2 design/permitting work begin in January 2025 to provide sufficient time for design, bidding, and construction phase work to be completed before the December 31, 2031 Consent Decree deadline for Phase 2 work. Additional time may be required for paving the next season after a freeze/thaw.

Phase 2B has significantly more pipeline that the other phases, which is reflected in the design and construction durations presented in Figure 8.2. It is anticipated that construction of Phase 2A work will begin in July 2027 with a 3-year construction duration, and construction of Phase 2B will begin in July 2028 with a 3.5-year duration. The schedule presented in Figure 8.2 also considers key SRF dates to provide for continuity of funding throughout the eight-year schedule.

Figure 8.2 Implementation Schedule

Project/Construction Contract *	Centralville Sewer Separation Project Schedule							
	2024 Jul - Dec	2025	2026	2027	2028	2029	2030	2031
Phase 1 - Main Line Project - Removal of Humphrey's Brook flows from City's combined sewer system, including surface flow from Town of Dracut (approx. 7,300 lf)								
Design/Permitting								
Bidding								
Construction								
Phase 2 - Separation of the sewer and storm drain system in the Humphrey's Brook/Billings Brook and Hovey drainage area								
Phase 2A Contract - Area 40 ***(approx. 11,700 lf)***								
Survey/Geotechnical/System Rehab Evaluations/Wetland Flagging								
Design/Permitting								
Bidding								
Construction								
Phase 2B Contract - Humphrey's Brook/Billings Drainage Area ***(approx. 21,400 lf)***								
Survey/Geotechnical/System Rehab Evaluations/Wetland Flagging								
Design/Permitting								
Bidding								
Construction								

* Each project will include any sewer rehabilitation required.

Notes:

- Consent Decree Milestone
- Project Evaluation Form (PEF) Submission Deadline
- State Revolving Fund (SRF) Loan Application Deadline
- SRF Contract Execution Deadline