Southwest Interceptor
Local Sewer System Evaluation Study
(SWI-LSSES)

City of Berea
Community Report

Final

Prepared For

Northeast Ohio Regional Sewer District

February 2022

Wade Trim | Brown and Caldwell

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Local Sewer System Evaluation Study
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TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES (bookmarked PDF file)

LIST OF ACRONYMS

AGOL	ArcGIS Online
BBU	Basement Back-up
CCBH	Cuyahoga County Board of Health
CCDPW	Cuyahoga County Department of Public Works
CCTV	Closed-circuit (Sewer) Televising
cfs	cubic feet per second
CSO	Combined Sewer Overflow
CT	Common Trench
ft	feet or foot
HGL	Hydraulic Grade Line
HSTS	Home Sewage Treatment System (septic system)
I/I	Infiltration/Inflow
GPAD	Gallons per Acre per Day
GPDIM	Gallons per Day per Inch Diameter Mile
LF	Linear Feet
MCIP	Member Community Infrastructure Program
MG	Million Gallons
MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
NASSCO	National Association of Sewer Service Companies
NEORSD	Northeast Ohio Regional Sewer District
NPDES	National Pollutant Discharge Elimination System
OEP	Operational Evaluation Project
O,M&R	Operation, Maintenance and Repair
PACP	Pipeline Assessment and Certification Program
PFL	Peak Flow Limitation
PFA	Peak Flow Rate Area
RIDE	Regional Intercommunity Drainage Evaluation Study
ROW	Right of Way
SSO	Sanitary Sewer Overflow
SWI-LSSES	Southwest Interceptor-Local Sewer System Evaluation Study
TY	Typical Year
WQIS	Water Quality and Industrial Surveillance

EXECUTIVE SUMMARY

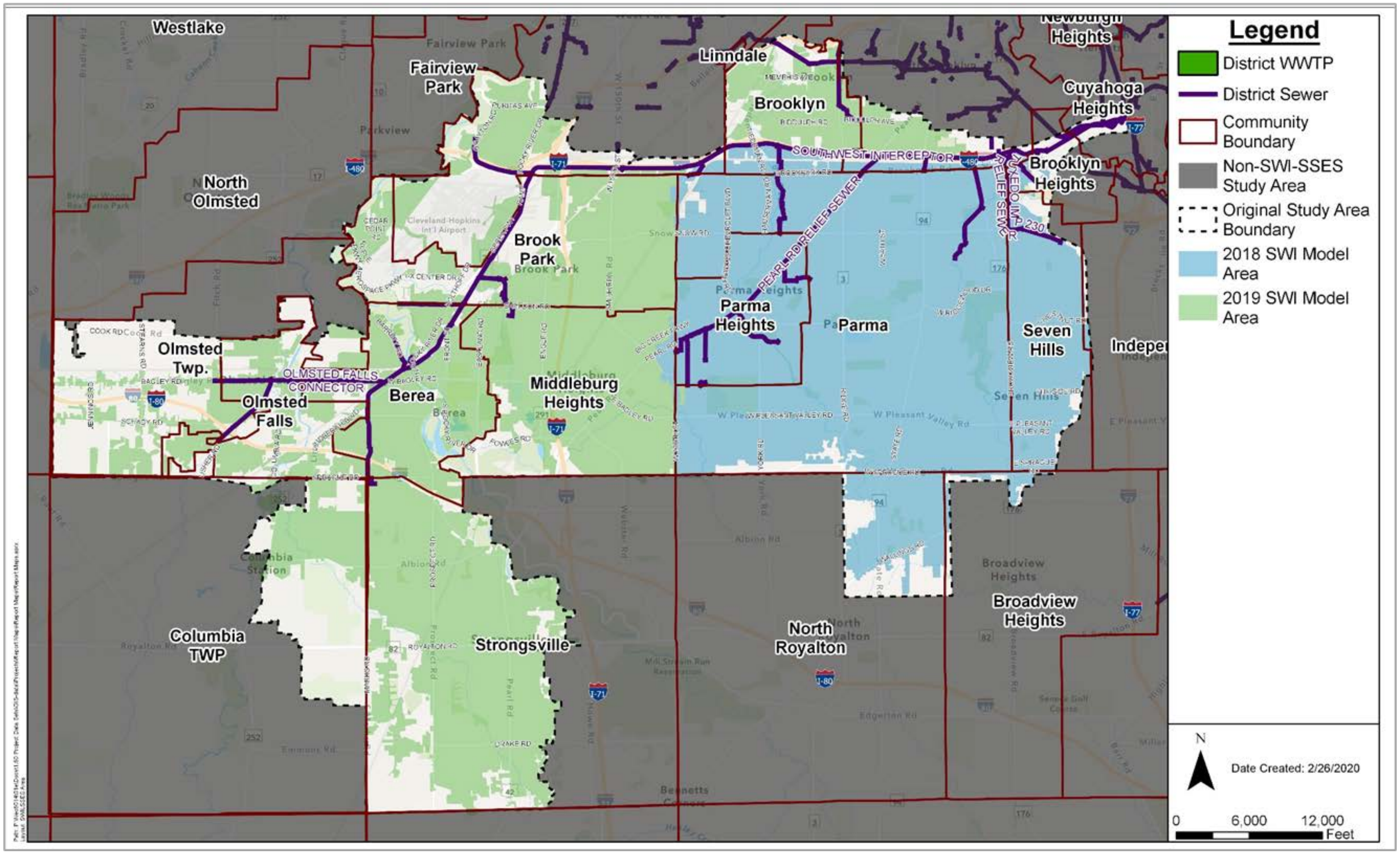
The Northeast Ohio Regional Sewer District (District) completed the Southwest Interceptor-Local Sewer System Evaluation Study (SWI-LSSES) as the third of four regional SSES projects to address sewer infrastructure problems that adversely affect human health and the environment. The LSSES projects are large-scale planning studies using hydraulic modeling and traditional Sewer System Evaluation *Survey* tools such as dyed water testing, sewer televising and smoke testing to identify existing sanitary sewer system problems and potential solutions in prioritized areas. Typical problems include sanitary sewer overflows (SSOs), sanitary sewer system basement backups (BBUs), common trench sewer crossflows, illicit discharges to separate storm sewers, and failing home sewage treatment systems (HSTSs, or septic tanks).

The LSSES projects provide technical guidance to the member communities in the form of Community Reports and ArcGIS Online (AGOL) information. The Community Reports summarize reported and projected problems, solution alternatives considered, and feasible sewer system improvements that may be implemented by the communities, either on their own, or with District assistance, if available, via the Member Community Infrastructure Program (MCIP) to address system problems. The LSSES projects also considered related sewer system policy, operations, and maintenance issues.

The SWI-LSSES area was divided into two parts to prioritize areas with the most severe problems and to balance field activities, such as flow monitoring and system physical inspection, for model development. Sewer system monitoring, inspection, modeling, and problem analysis of the second phase of the study area, which included the City of Berea, was conducted in 2019 and 2020 to produce this report and supporting information. **Figure ES-1** shows the SWI-LSSES project area and 2018 and 2019 model areas.

This report summarizes potential solutions to mitigate reported and projected problems. Sewer system improvements and infiltration/inflow (I/I) reduction measures may include sewer system rehabilitation, sewer separation/replacement, flow redirection, capacity improvements, inline storage, and I/I reduction improvements on private property. Some sewer system improvements may be integrated with District Stormwater Master Plan (SWMP) potential improvements or other infrastructure projects to reduce overall cost.

Figure ES-1. SWI-LSSES Project Area



Sewer System Overview

The City of Berea is served by a separate sanitary sewer system composed of 9% common trench and 91% separate trench sewers with a total sanitary sewer system length of 383,600 linear feet (LF). The common trench sewers in Berea are believed to be constructed entirely with common trench standard manhole (common standard) configuration. The sewer system serves a population of approximately 18,609[1] in a total area of 5.8 square miles. Sewer system trench types and lengths are summarized in **Table ES-1.**

Table ES-1. Berea Sanitary Sewer System Trench Types

Trench Type	Length (LF)	Proportion
Separate Trench	349,400	91%
Common Trench Standard Manhole	34,200	9%
Total	383,600	100%

Common Trench Sewers

Common trench sewer systems were primarily constructed prior to 1960 and likely represent the largest single cause of problems in the SWI area. **Figure ES-2** shows the common trench standard manhole configuration. Other common trench configurations, including over/under (invert plate) and dividing wall, are not known to exist in Berea. Leaky common trench sewers may:

- Contribute large amounts of sanitary sewer stormwater infiltration and inflow (I/I) which can cause surcharging, SSOs, and potential BBUs.
- Allow crossflow of sanitary sewage and storm sewer flows, which can contaminate stormwater.
- Contribute to solids deposition in sanitary sewers and allow undetected dry weather overflows.
- Make sewer system operation, maintenance, and repairs (O,M&R) more difficult.

[1] US Census Bureau, Quick Facts Berea, OH, July 1, 2019, population estimate; https://www.census.gov/quickfacts/bereacityohio

Common Trench Standard Manhole Systems (Common Standard)

The common standard sewer configuration constructed the storm sewer above and offset laterally from the sanitary sewer in the same trench as shown in **Figure ES-2**. Two separate manholes provide independent access to the storm and sanitary sewers. Although there is no direct hydraulic connection in the common standard system, there is an increased potential for stormwater exfiltration entering the sanitary sewer due to the proximity and relative elevations of the storm and sanitary sewers. **Figure ES-3** shows locations of the modeled sanitary sewers and associated trench types for Berea.

Figure ES-2. Common Trench Standard Manholes

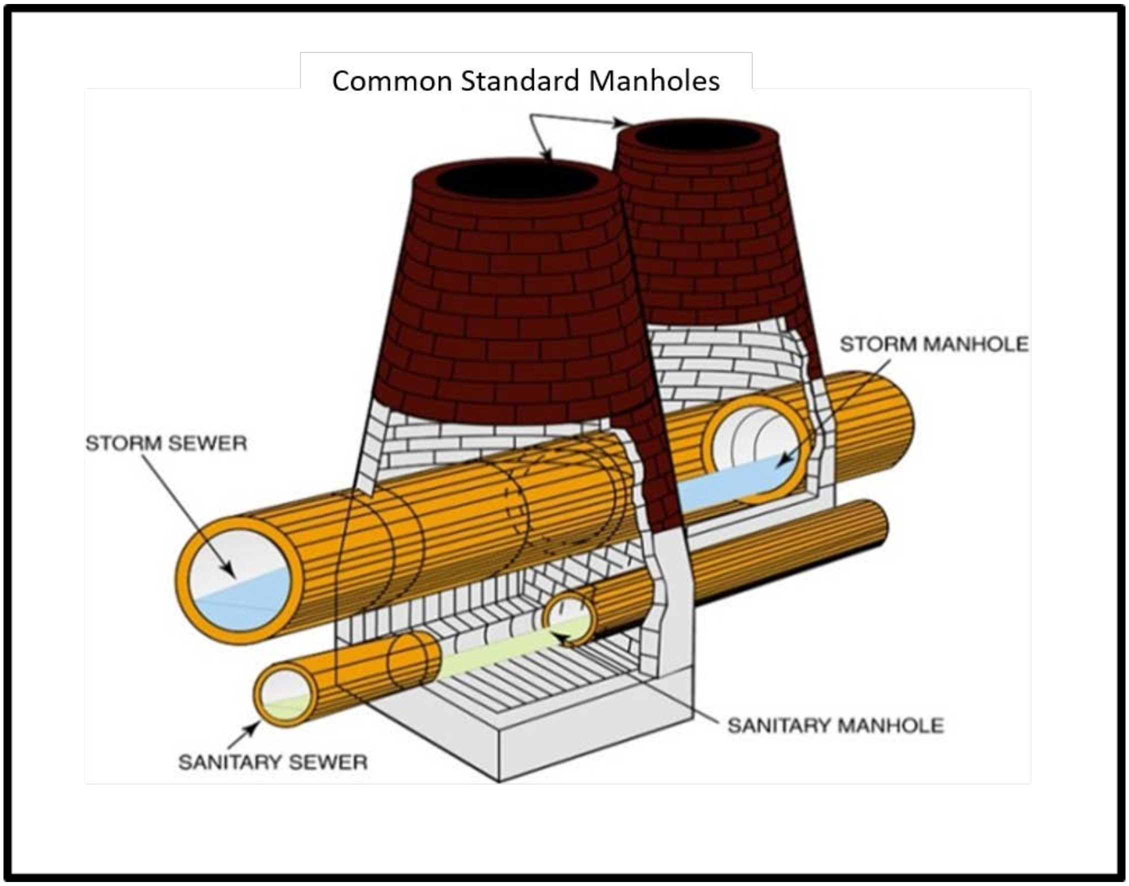
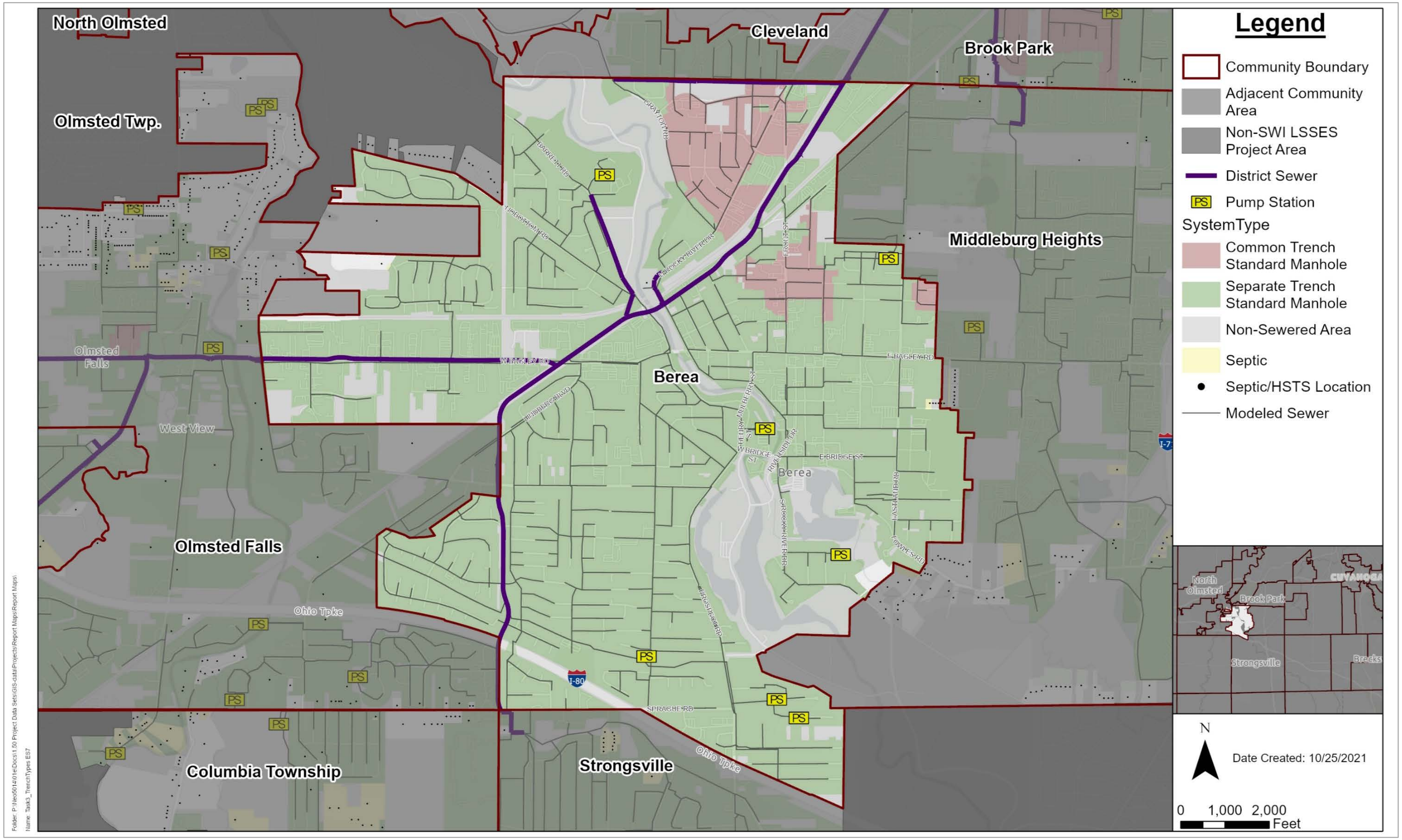


Figure ES-3. Sewer System Trench Types



Peak Flow Rate Areas

This study used peak flow rate areas (PFAs) as the basis for analyzing system performance and presenting potential improvements. PFAs are defined by the sewer subsystems in each community that discharge independently to the District SWI system, or in some cases, to an adjacent community. PFAs were selected as the basis for discussion of problems and solutions because the independent discharge to District sewers typically allows consideration of these PFA sewer systems apart from the systems in neighboring PFAs.

Reported and Projected Problems in Berea

The Berea sanitary sewer system was modeled using a calibrated InfoWorks ICM hydrologic/hydraulic model to simulate flow and hydraulic grade line (HGL) conditions associated with the 5-year, 1-hour design rainfall (1.46 inches in 1 hour using 15-minute rainfall increments). The storm sewer was not modeled. Although the original SWI system basis of design used a 1-year, 1-hour rainfall, subsequent analysis in the 1998 SWI Operational Evaluation Project (OEP) found that the District SWI system likely has capacity for at least a 5-year rainfall. The 5-year, 1-hour rainfall was used as the basis for analysis in the other LSSES projects and is used for the SWI-LSSES project as well. The 10-year, 1-hour rainfall (1.63 inches) was also analyzed for comparison. Both rainfalls are based on the District's *Hydrologic and Hydraulic Modeling Standards, Version 4.*

The local community storm sewer systems were not modeled in this analysis, but the District's regional SWMP projects modeled and analyzed the downstream regional systems. The Berea local system is tributary to the Rocky River SWMP project areas. A summary of the projected performance issues in the Berea system follows.

Sanitary Sewer Overflows

The SWI-LSSES project confirmed physical status of known constructed SSOs via field investigation and used the calibrated InfoWorks model to project SSO activity for the 5- and 10-year, 1-hour, design rainfalls and for the District's Typical Year[2] rainfalls. Constructed SSOs are typically piped connections at manholes intended to allow the sanitary sewer system to overflow to a storm sewer or local surface water if surcharge occurs. A manhole overflow at grade is an example of a non-constructed SSO.

The status of existing SSOs and projected volumes for active SSOs in Berea are shown in **Table ES-2** for 5-year, 1-hour, and Typical Year rainfalls. **Figure ES-4** show the SSO locations and status. Of the nine SSOs, three are projected to be controlled and six SSOs are projected to be active during the 5-year, 1-hour rainfall. Model-projected SSO volumes are relatively small and are expected to produce minimal water quality impacts.

[2] A synthetic Typical Year rainfall time series was developed in 1995 as part of the District's CSO facilities planning effort. This synthetic Typical Year consists of 121 representative events compiled predominantly from recorded rainfall that occurred in 1991 and 1993.

SSOs generally provide hydraulic relief points for sanitary sewers, but in some cases may worsen rather than reduce sanitary sewer problems by allowing inflow of stormwater from surcharged storm sewers into sanitary sewers. While the 5-year, 1-hour rainfall should be considered the minimum level of control, communities should consider further control and potential elimination of SSOs during planning of improvements. Communities may wish to consider additional longer-term flow monitoring or SSO activation monitoring using tethered blocks or level sensors to confirm SSO activations vs. rainfall prior to design and construction of improvements.

The status of SWI area SSOs is documented for the project in the *Sanitary Sewer Overflow (SSO) Investigation and Status Report, Revision 4, February 2021*. Additional detail regarding SSO frequency and volume is included in **Section 3.2**.

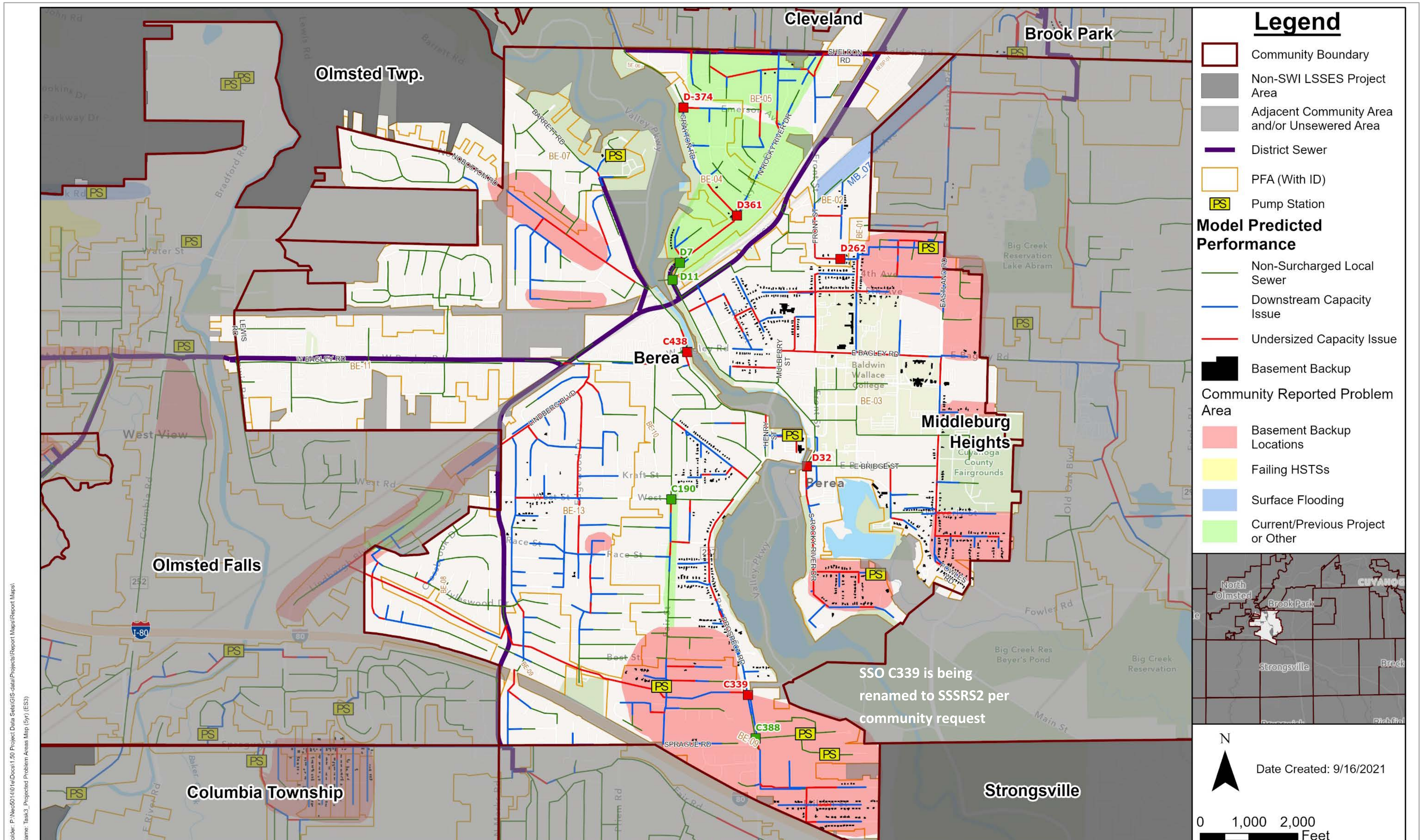
Table ES-2. Existing SSOs Modeled Status and Overflow Volumes

SSO ID	Location	Peak Flow Area (PFA) ID	Modeled Status (5-Yr Rainfall)	5-Yr, 1-Hr (15 Min) Overflow Volume (MG)	Typical Year Overflow Volume (MG)	# of Activations in Typical Year
C190	West/Fair	BE-10	Controlled	0	0	0
C339*	Prospect at CEI Easement**	BE-09	Active	0.013	0	0
C438	Bagley/Barrett	BE-10	Active	0.172	0.526	8
D7	North Rocky River Drive	BE-04	Controlled	0	0	0
D11	North Rocky River Southwest of D7**	BE-04	Controlled	0	0	0
D32	East Bridge Street/Riverside	BE-03	Active	0.072	0	0
D262	Third/Pearl	BE-02	Active	0.031	0	0
D361	North Rocky River Drive/Grayton	BE-04	Active	0.006	0	0
D374	Emerson Avenue at Grayton Road**	BE-04	Active	0.008	0	0
Total				0.302	0.526	8

** SSO C339 is being renamed to SSSRS2 as requested by the community.*

*** SSO identified during course of project.*

Figure ES-4. Reported and Projected Problem Areas (5-Year, 1-Hour Rainfall)



High Wet Weather Flows

Table ES-3 summarizes peak flow rates for Berea by PFA for the 5-year, 1-hour rainfall. The projected peak flow rates are provided at the PFA outlets in millions of gallons per day (MGD) and are also provided on per acre and per inch-diameter-mile of tributary area/sewers bases to assist in comparison of different areas. The per acre peak flows in gallons per acre per day (GPAD) are calculated by dividing the peak flow rates by the respective tributary sewered areas.

The peak flows in gallons per day per inch-diameter-mile (GPDIM) are calculated using the tributary sewer length in miles and associated sewer diameters in inches and includes the sanitary service laterals, which often comprise greater length than the mainline sewer system. This study and many other studies have shown that service laterals can produce as much or more wet weather infiltration/inflow (I/I) than the mainline sewer system.

The peak flows are aggregated for PFAs that have flow diversions in or out, and for areas that have upstream tributary PFAs to approximate the wet weather flow response generated in the contributing area. If the PFA outlet and net aggregated peak flow rates are the same, the area likely has little or no flow diversions in or out, or they may be cancelling each other.

Aggregated peak flows are calculated as follows:

Net aggregated peak flow = peak flow at PFA outlet + aggregated flows diverted out of PFA - aggregated flows diverted into PFA

SWI overall study area sanitary sewer peak 5-year, 1-hour flows in primarily separate trench sewer systems (at least 70% separate trench by length) were found to range from 1,800 to 233,500 GPAD (2,600 to 535,000 GPDIM), with an area-weighted average of 10,100 GPAD (21,800 GPDIM). Peak 5-year flows in primarily common trench systems (at least 70% common trench length) were found to range from 3,900 to 229,700 (6,600 to 496,500 GPDIM), with an area-weighted average of 28,000 GPAD (43,600 GPDIM). For the purposes of this study, excessive I/I areas are identified for I/I reduction measures when peak flow rates exceed 50,000 GPAD (or 70,000 GPDIM).

Berea’s sewer system consists of 9% common standard trench configuration. Data collected from this study indicates that, within Berea, there are 12 PFAs exhibiting a higher degree of I/I than the average predominately separate trench configuration GPAD (10,100 GPAD). One PFA exhibits an excessive degree of I/I (over 50,000 GPAD), with a GPAD of 117,000. The PFA comprises approximately 7 acres (0.2%) of Berea’s area tributary to SWI; it is predominately served by a separate trench system. For comparison, typical separate trench sanitary sewer peak wet weather flows in urban, single-family, residential areas are in the range of 5,000 to 10,000 GPAD for older systems with moderate I/I.

Table ES-3. Model-Projected Peak Flow Rates (Routed in Pipe)					
		Projected Peak Flow Rates (5-Year, 1-Hour Rainfall)			
PFA ID	PFA Type	PFA Outlet, MGD	Net Aggregated Flow, MGD	Net Aggregated Flow, GPAD	Net Aggregated Flow, GPDIM
BE-01	Inter-Community	0.14	0.14	32,791	98,601
BE-02	District Connection	3.75	1.97	26,658	42,347
BE-03	District Connection	17.84	21.79	30,890	52,285
BE-04	District Connection	3.13	4.19	40,523	73,984
BE-05	District Connection	5.83	5.83	23,843	37,473
BE-06	District Connection	0.87	0.87	116,892	174,395
BE-07	District Connection	2.12	2.12	20,733	36,022
BE-08	Inter-Community	1.80	1.80	10,577	20,944
BE-09	District Connection	9.73	10.14	18,016	31,288
BE-10	District Connection	10.68	11.87	23,191	30,903
BE-11	District Connection	1.28	1.28	6,023	10,623
BE-12	District Connection	0.84	0.84	5,122	9,052
BE-13	District Connection	5.13	5.13	16,034	23,247
BEBP-01	Inter-Community	0.59	0.59	13,782	27,731
Area-weighted Average (Berea)				21,259	34,453
Area-weighted Average (SWI)				14,121	27,920
Area-weighted Average (SWI Primarily Common Trench)				27,663	43,494
Area-weighted Average (SWI Primarily Separate Trench)				10,091	21,849

Private Property Testing

Private property infiltration/inflow (I/I) testing conducted across SWI-LSSES communities found rapid transfer of dyed water from downspouts to sanitary sewers, with 33% of downspouts tested showing rapid infiltration of dyed water, and downspout infiltration of varying rates at over 67% of properties tested. Testing results for properties in Berea are lower; 7% of tested properties had rapid transfer of dyed water at downspouts and 93% of properties tested had no downspout I/I observed during testing.

Sewer System Surcharging, BBUs, and Common Trench Crossflows

Berea reported eight areas with recurring BBUs. Nearly 51% of the modeled Berea sanitary sewer system is projected to operate in a surcharge condition (water surface above sewer crown) for the 5-year, 1-hour design rainfall, and nearly 12.7% or 840 of the estimated 6,590 buildings with basements are projected to experience BBUs during that same rainfall event.

In many areas, common trench storm to sanitary crossflows in both the public sewers and private service leads are believed to be a primary cause of wet weather sanitary sewer surcharging. Investigations from this project and other District LSSES projects have indicated that sewage and stormwater crossflows are likely to occur in common trench systems, leading to high sanitary sewer I/I rates and stormwater contamination. Other potential causes of surcharging include inadequate sewer system capacity and/or bottlenecks and flow increases due to upstream development and/or improperly-connected direct inflow sources. Sewer system capacity issues may be related to sewer slope, size, solids deposition, structural defects, and/or other design and construction issues.

In some areas, projected BBUs are more severe than have been reported. Exfiltration of sewer surcharge flows into the common trench volume surrounding the sewers and service laterals allows for storage of wet weather flows and is believed to be a primary reason why actual surcharging and BBUs may not be as frequent or severe as projected. These inconsistencies likely arise from the approximate nature of the sewer system model, particularly in common trench areas, where the numerous sanitary/storm sewer crossflows and parallel storm sewers are not being explicitly modeled.

Stormwater Management Program

The District's Regional Stormwater Management Program (RSMP) project studied stormwater-related problems throughout the SWI-LSSES area. Berea is included in the Rocky River SWMP project area. **Section 3.2.2** contains additional details on the locations of the SWMP problems relative to the sanitary system problems identified in this study. Including sewer system improvements and I/I reduction measures in coordination with the RSMP projects may help reduce overall project cost to improve sanitary and storm sewer system performance. More information on the results of the RSMP efforts and potential projects can be requested from the District Watershed Team Leader.

Table ES-4 and **Figure ES-4** summarize sanitary sewer system performance by PFA, including reported and model-projected problem areas in Berea. **Tables B2** through **B4** in **Appendix B** provide additional detail regarding system performance and problems by PFA.

Table ES-4. Sanitary Sewer System Performance by PFA

PFA ID	PFA Area. Acres	Sewer Type					Sewer Surcharge			Sanitary Sewer Overflows			Projected Basement Backups		Failing Home Sewage Treatment Systems, # Units	Net Aggregated[3] 5yr-1hr (15-min) Peak Flow, Gallons Per Acre per Day, GPAD	Net Aggregated[3] 5yr-1hr (15-min) Peak Flow, Gallons per Day per Inch Diameter Mile, GPDIM	Community Identified Problem Areas
		Total Length of Sanitary Sewer, LF	Total Length of Common Trench Sewer, LF	% of Common Trench Sewer	Total Length of Separate Trench Sewer, LF	% of Separate Trench Sewer	Total Sanitary Sewer Modeled, LF	Total Modeled Sanitary Sewer Surcharged, LF	% of Modeled Sewer Surcharged	SSOs	Active SSOs	SSO Volume, MG	Model Projected Basement Flooding, # Units	% of Buildings in PFA with Basement Flooding				
BE-01	2	163	0	0%	163	100%	0	0	0%	N/A	N/A	N/A	0	0%	0	32,791	98,601	N/A
BE-02	93	7,833	2,691	34%	5,142	66%	7,932	3,449	43%	D262	D262	0.03	18	19%	0	26,658	42,347	MB_07
BE-03	843	91,129	8,289	9%	82,840	91%	76,765	47,449	62%	D32	D32	0.07	510	36%	3	30,890	52,285	BR_04, BR_05, BR_06 & BR_10
BE-04	114	14,645	7,565	52%	7,080	48%	11,814	7,585	64%	D11 & D7 & D361 & D-374	D361 & D-374	0.01	11	4%	0	40,523	73,984	BR_08
BE-05	151	20,203	15,668	78%	4,535	22%	21,770	14,330	66%	N/A	N/A	N/A	3	2%	0	23,843	37,473	BR_07 & BR_08
BE-06	7	1,325	0	0%	1,325	100%	1,172	15	1%	N/A	N/A	N/A	0	0%	0	116,892	174,395	N/A
BE-07	132	14,936	0	0%	14,936	100%	12,453	2,671	21%	N/A	N/A	N/A	3	1%	0	20,733	36,022	BR_09
BE-08	130	18,361	0	0%	18,361	100%	15,356	4,930	32%	N/A	N/A	N/A	0	0%	0	10,577	20,944	OF_05 & OF_06
BE-09	387	54,207	0	0%	54,207	100%	46,083	32,197	70%	C339	C339	0.01	82	9%	0	18,016	31,288	BR_01, BR_02 & BR_03
BE-10	566	74,733	0	0%	74,733	100%	66,986	27,860	42%	C190 & C438	C438	0.17	180	13%	0	23,191	30,903	BR_02, BR_03, BR_09 & BR_12
BE-11	283	15,414	0	0%	15,414	100%	20,598	0	0%	N/A	N/A	N/A	0	0%	0	6,023	10,623	N/A
BE-12	197	23,759	0	0%	23,759	100%	17,737	2,166	12%	N/A	N/A	N/A	0	0%	7	5,122	9,052	BR_09
BE-13	313	45,436	0	0%	45,436	100%	38,119	30,527	80%	N/A	N/A	N/A	33	3%	0	16,034	23,247	BR_02 & BR_11
BEBP-01	36	1,470	0	0%	1,470	100%	3,605	1,470	41%	N/A	N/A	N/A	0	0%	0	13,782	27,731	N/A
TOTAL	**3,255**	**383,614**	**34,213**	**9%**	**349,401**	**91%**	**340,391**	**174,649**	**51%**	**9**	**6**	**0.30**	**840**	**13%**	**10**	**N/A**	**N/A**	

Potential Improvements and Prioritization

Planning-level solutions were developed to solve the projected problems and optimized using cost and non-cost criteria. The proposed improvements in Berea include sewer rehabilitation capacity improvements, new flow connections, and private property I/I reduction at a total projected planning level/class 5 cost of $72.3 million, including design and construction engineering and administration. An additional project definition cost of $0.8 million is suggested to complete additional pre-design investigations in common trench rehabilitation areas to better define the significant system defects and sources of I/I. The improvements are prioritized into three tiers for community consideration as summarized below.

Tier 1 – Address Community-Reported Problem Areas and Active SSOs

Community-reported problem areas and SSOs projected to activate for the 5-year, 1-hour design rainfall are proposed to be addressed first. Berea reported 13 ongoing problem areas and six SSOs are projected to be active for the 5-year, 1-hour design rainfall, which is considered the minimum level of control. However, communities should consider higher levels of control where feasible. The planning level total cost of these improvements is $16.9 million.

Tier 2 – Control Excessive Infiltration/Inflow

Tier 2 improvements are proposed to reduce peak wet weather flows in areas where modeled peak flow rates during the 5-year, 1-hour rainfall are projected to be excessive (greater than 50,000 GPAD or 70,000 GPDIM). The Tier 2 planning level total cost to address these areas in Berea is $52.9 million.

Tier 3 – Address Other Projected Problems

Projected system surcharging and BBUs in other portions of the system may ultimately be controlled by reducing I/I in the public sewer system and/or on private property. In some areas, capacity improvements may also be indicated. The planning level total cost of suggested Tier 3 improvements in Berea is $2.5 million.

Table ES-5 and **Figure ES-5** summarize the proposed improvements to provide acceptable performance during the 5-year, 1-hour rainfall. Further detail is provided in **Sections 4** and **5** of this report.

Table ES-5. Potential Improvements and Project Costs by Tier			
Tier	Problem Summary	Potential Improvements	Project Cost, $ Millions
1	Community-Reported Problem Areas and Active SSOs	Public rehab for 3,000 LF of common trench sewers, rehab for 22,334 LF of separate trench sewers, 882 LF of replaced/capacity enhanced sewers, 508 LF of new sewers, and 46 parcels with private rehab.	16.9
2	Control Excessive I/I	Public rehab for 7,753 LF and 74,172 LF of common and separate trench sewers, respectively.	52.9
3	Other Projected Problems	657 LF of replaced/capacity enhanced sewers, and 380 LF of new sewers.	2.5
Project Cost Subtotal			72.3
Common Trench Areas Project Definition Cost (included in above)			0.8
All Improvements and Project Definition			72.3

Summary of Recommended Rehabilitation Levels

Field investigations conducted include closed-circuit television (CCTV) inspection of selected sewers in prioritized field work order areas. The results and recommended sewer rehabilitation levels were detailed in a technical memorandum provided to the District and communities entitled, *1485 Southwest Interceptor - Local Sanitary Sewer Evaluation Study (SWI-LSSES) Task 2 – Local System Inspection and Condition Assessment, July 2021*. This memorandum included pipe condition assessments based on NASSCO[3] guidelines and associated typical recommended rehabilitation levels based on the assessment.

The suggested rehabilitation levels are summarized in **Figure ES-6** and are also available on the District's ArcGIS Online (AGOL) website. The condition assessment of Berea sewers was limited and when planning for future system improvement and/or rehabilitation projects, both the condition assessment information and the overall performance improvements described subsequently in this community report should be considered and re-assessed in planning and design phases of those improvements. **Figure A3** in **Appendix A** summarizes the field investigations and findings that support the recommended rehabilitation levels

[3] National Association of Sewer Service Companies

Figure ES-5. Overall Potential Solutions Summary Map (5-Year, 1-Hour Rainfall)

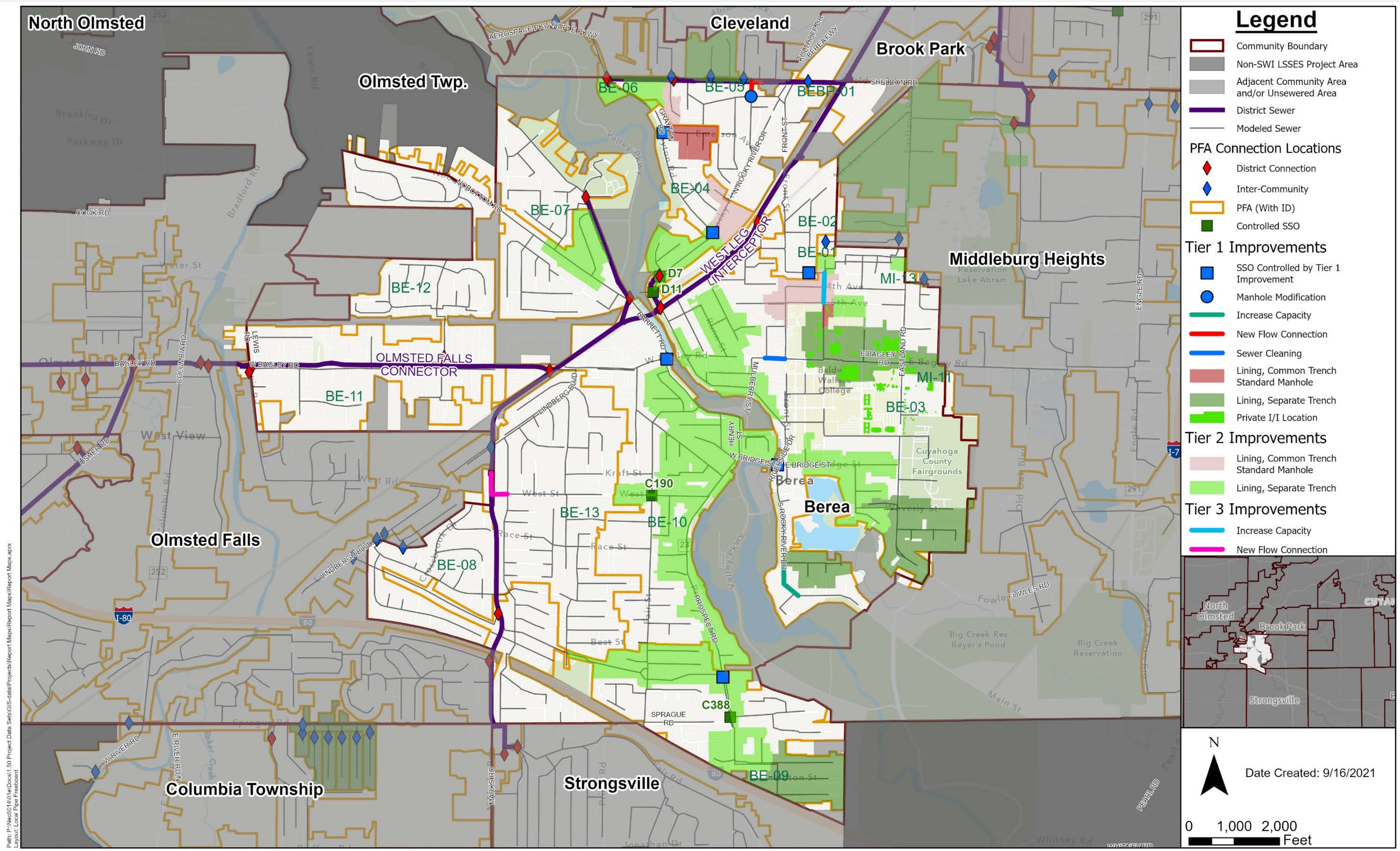
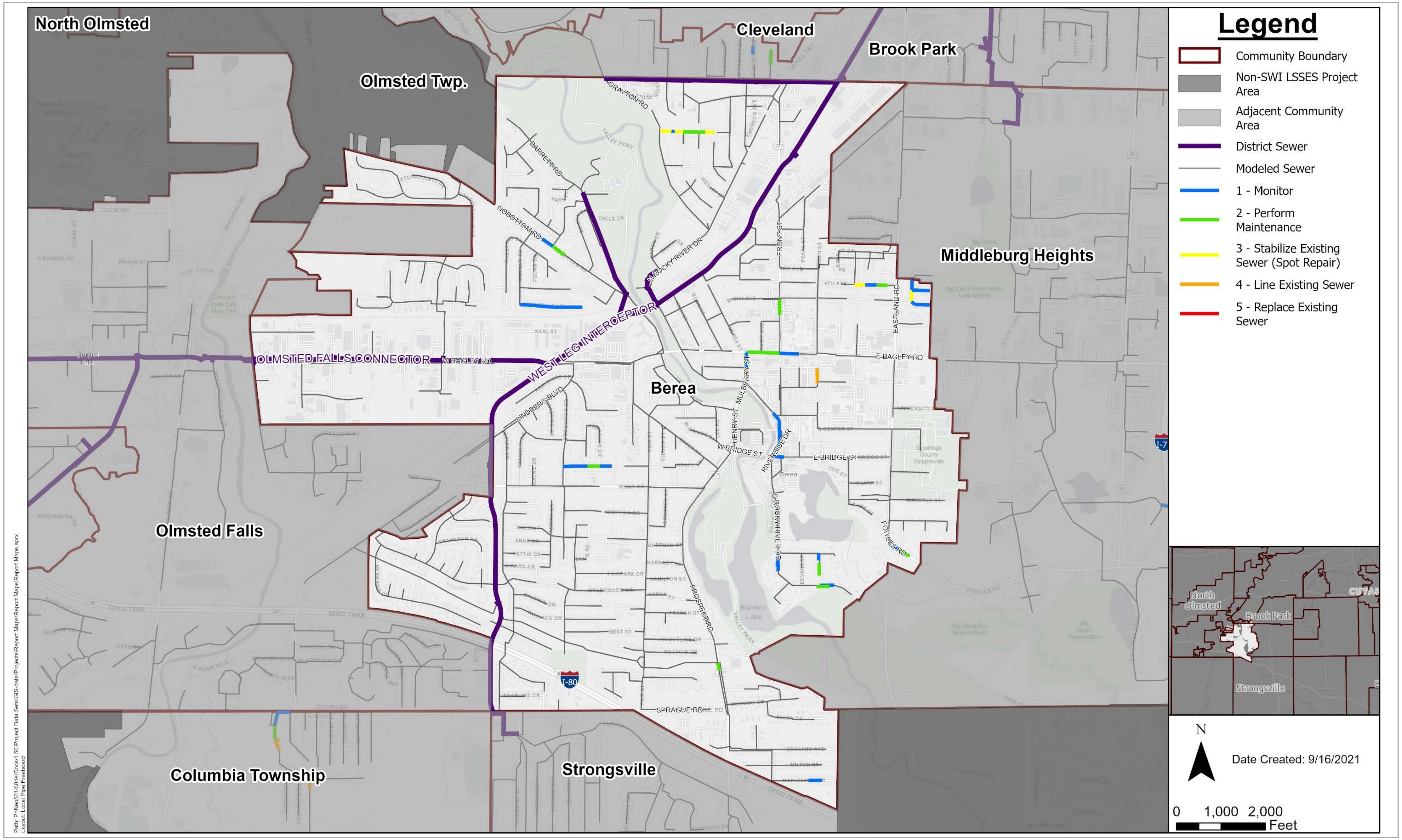


Figure ES-6. Summary of Sewer Rehabilitation Recommendation Levels Based on Project CCTV Inspection



Potential Solutions for 10-Year, 1-Hour Rainfall

The project also analyzed model-projected performance for the 10-year, 1-hour rainfall (1.63 inches). The analysis considered performance results for existing conditions and improved conditions developed for the 5-year, 1-hour rainfall problem areas. Results are summarized in **Section 5.3** and **Appendix G**. The spreadsheet provided as **Attachment 1** includes a tab comparing the 5- and 10-year rainfall results.

In the HHI-LSSES project, a similar analysis found that for most problem areas and communities generally, this resulted in additional work totaling less than a 10% increase over the projected total cost for the proposed improvements associated with the 5-year, 1-hour design rainfall. The primary conclusion from this analysis is that in many instances where improvements are proposed, a relatively small amount of additional improvement cost may provide a significant improvement in performance for larger rainfalls. This should be considered during planning and design of improvements to identify the most cost-effective improvements.

Future Conditions Modeling

A future conditions model was developed to evaluate system capacity for potential future development. Planning-level estimates of future flows were developed assuming full build-out on undeveloped land and the connection of all septic areas in the SWI service area. This analysis identified 101 acres of either future development or existing septic area to be connected under future conditions.

Future residential and commercial/industrial dry and wet weather flows were estimated based on similar, recently-developed areas within the SWI service area. Multiple areas with similar land uses and lot sizes developed since 1990 were selected to determine representative flows. Area-weighted dry and wet weather flow parameters were then developed for each land use.

Each area was added to the base model, assigned the estimated dry and wet weather flow parameters, and connected to the nearest modeled node. Existing and future development conditions were then run for the 5-year, 1-hour design event for three models: base system condition with no improvements, base system model with Tier 1 improvements, and base system model with Tier 1, Tier 2, and Tier 3 improvements. The model results are summarized in **Table ES-6**.

Table ES-6. Existing vs. Future Conditions Results Summary				
Sewer System Improvements Completed (sewer system model version)	**Development Scenario**	**Model-Projected Sewer System Performance**		
		Surcharged Pipes	**Flooded Manholes**	**BBUs**
Base system model (no improvements)	Existing[1]	738	12	836
	Future	760	12	851
Tier 1 Improvements Completed	Existing	638	7	491
	Future	666	7	503
Tiers 1-3 Improvements Completed	Existing	431	2	22
	Future	462	3	32

[1] *Development of study area existing during 2018/2019 model calibration flow monitoring periods*

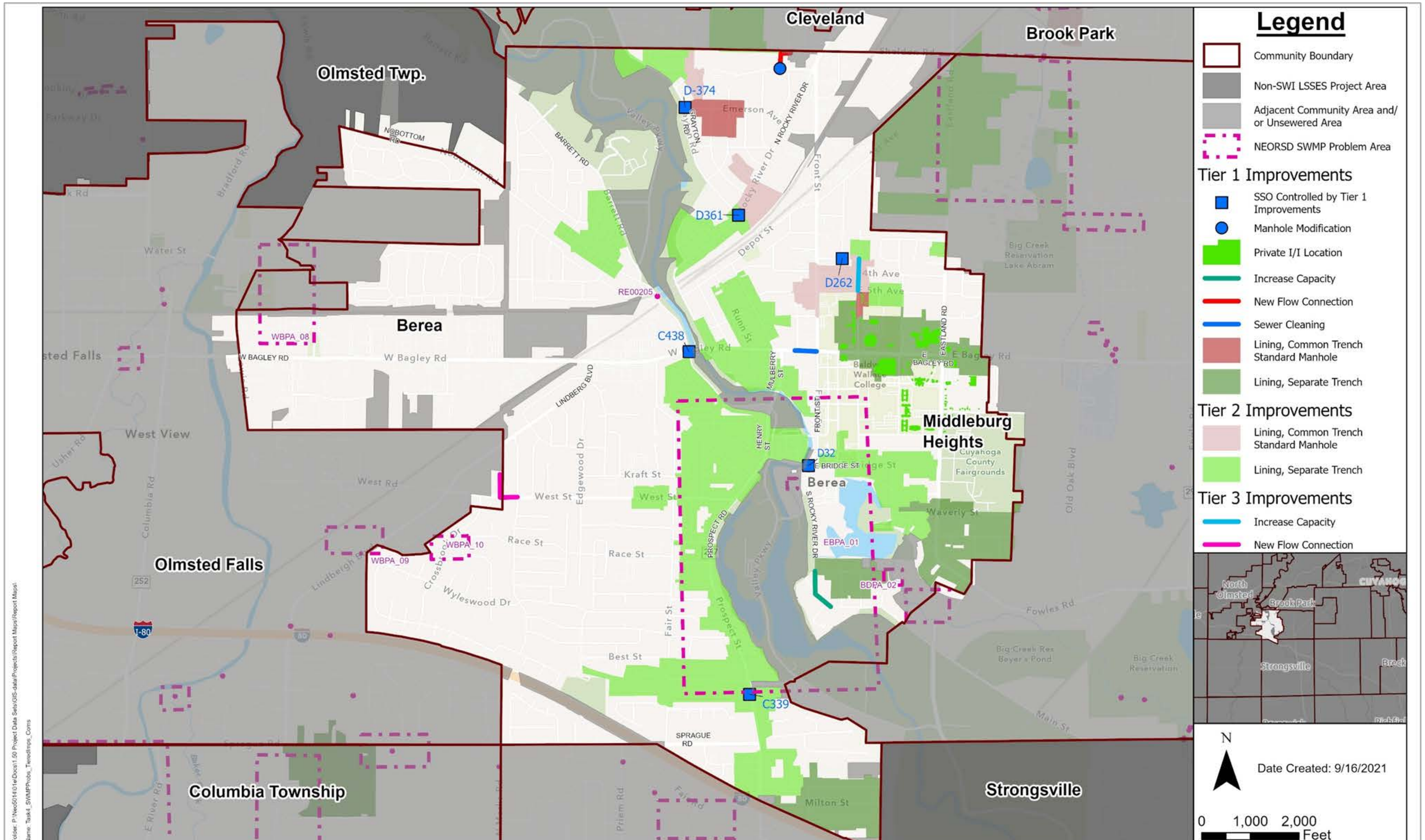
Table ES-6 indicates that the model-projected BBUs increase by less than 3% under the future development scenario for both the base system model and the system with Tier 1 improvements completed as compared to the existing development scenario. The table also shows that implementation of Tier 1 through 3 sewer system improvements reduces the number of projected BBUs by 96% under the future development scenario compared to the base system model.

Section 5.4 and **Appendix H** provide additional detail regarding the future conditions analysis completed. The suggested Tier 1, 2, and 3 improvements were not adjusted based on the future conditions modeling results. Communities should consider potential future development flow increases during design of sewer system improvements. Future condition information is also available on the District AGOL website in the SWI-LSSES Community Report Viewer.

Stormwater Master Planning

The SWI-LSSES project identified SWMP problem areas with respect to where potential opportunities may exist for coordinated sanitary and storm projects that could be considered by the community. These overlapped locations indicate areas where additional investigation of storm sewer related problems may be impacting the sanitary system if the storm sewer and/or sanitary systems are not relatively watertight. Communities may want to evaluate the SWMP recommendations with respect to where the LSSES has identified potential improvements to the sanitary sewer system for coordinated projects that may improve performance of both systems and reduce overall project costs. More detailed information on specific collected data, identified problems and the potential recommended projects from the SWMP can be obtained from the District. **Figure ES-7** provides an overview of the SWMP identified problem areas with the LSSES potential improvements.

Figure ES-7. SWI-LSSES Potential Improvements Near District SWMP Problem Areas



Arc GIS Online (AGOL)

The District has developed an online geographic information system (GIS) for the SWI-LSSES area as part of this project to document information gathered, field investigation results, existing system record drawings, modeling analysis results, and suggested potential improvements. As refinements of the AGOL system continue, communities are encouraged to visit the site periodically as needed to obtain information. Contact the District to obtain access. **Appendix D** provides instructions for accessing the District's AGOL platform and Community Report Viewer.

Community Meetings

A Berea virtual meeting was held on June 25, 2020, to review preliminary findings of the field work, preliminary capacity analysis, and problem identification to date. Attendees included Berea's Director of Public Works, the City Engineer and Assistant City Engineer, District staff, and consultant team members.

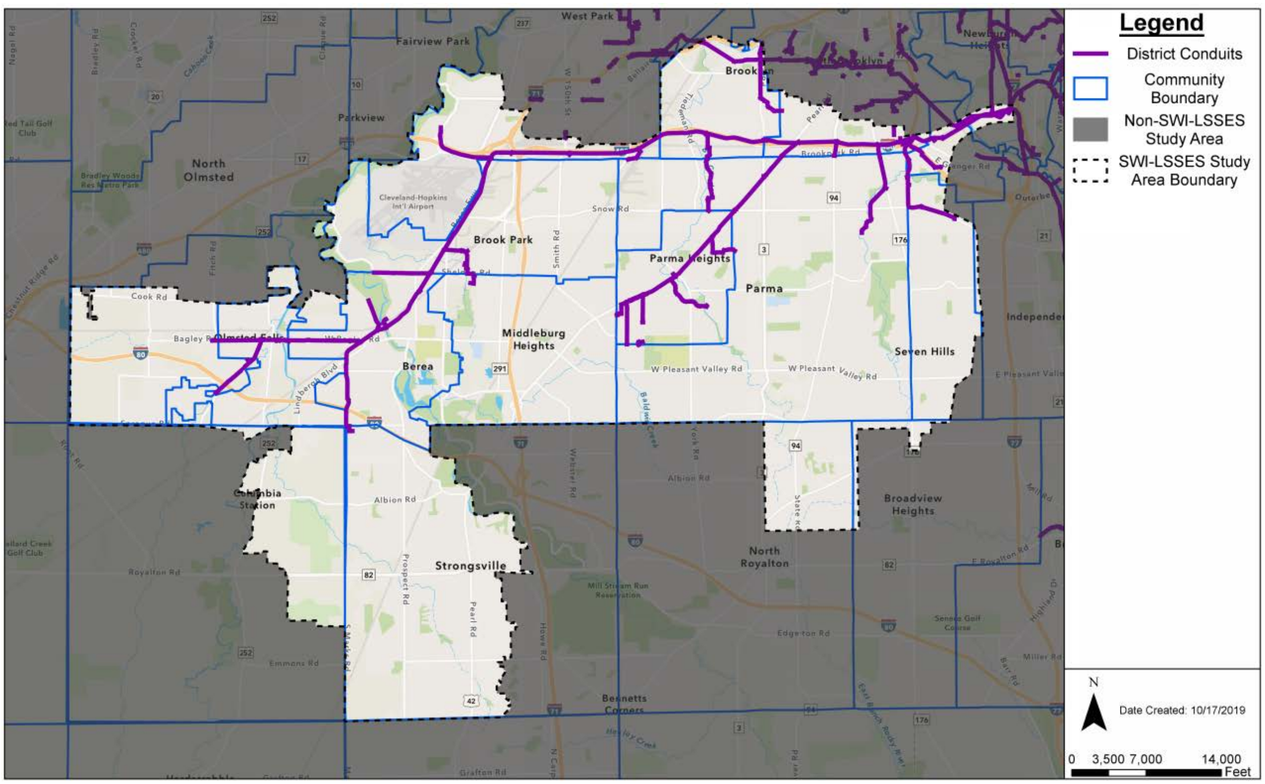
Subsequent meetings were held on March 25, 2021, and January 6, 2022. The meetings provided an overview of the LSSES project and summarized findings and potential solutions using PowerPoint slides and the District's AGOL platform showing field and model-projected results. Meeting slides and follow-up notes are provided in **Appendix I**.

1.0 INTRODUCTION

The Northeast Ohio Regional Sewer District (District) completed the Southwest Interceptor-Local Sewer System Evaluation Study (SWI-LSSES) as the third of four regional SSES projects to address sanitary sewer infrastructure problems that adversely affect human health and the environment. Typical problems include sanitary sewer overflows (SSOs), basement backups (BBUs), leaky common trench sewer crossflows, illicit discharges to separate storm sewers, and failing home sewage treatment systems (HSTSs, or septic tanks).

The SWI-LSSES project focused on the local sanitary sewer systems serving the 15 communities tributary to the SWI system, and portions of the Cities of Brooklyn and Cleveland south of Big Creek that are tributary to the Big Creek Interceptor. The project identified existing and projected problems in the study area and determine the underlying causes, analyzed potential alternatives, and identified feasible planning-level solutions to address the problems. The LSSES projects also considered related sewer system policy, and operations and maintenance issues. **Figure 1-1** shows the SWI-LSSES project area and the District sewer system serving the area.

Figure 1-1. SWI-LSSES Project Area



1.1 PROJECT TASKS

The SWI-LSSES project completed four primary tasks:

- Task 1 – Local System Assessment Strategy
- Task 2 – Local System Inspection and Condition Assessment
- Task 3 – Local System Evaluation (monitoring/modeling/analysis/problem identification)
- Task 4 – Prioritized Capital Solutions and Maintenance and Policy Recommendations

1.2 REPORT OVERVIEW

This report combines findings from initial project tasks to summarize the SWI-LSSES analysis for the City of Berea local sewer system. Section 1 summarizes the primary SWI-LSSES project submittals. **Sections 2** and **3** summarize how the local system was investigated and analyzed, and the resulting performance and problems identified. **Sections 4** and **5** summarize ongoing and currently proposed system improvements and potential solutions that may be considered for MCIP application and upcoming alternatives analysis.

Proposed work quantities, planning-level costs, and projected benefits, such as BBU and peak wet weather flow reductions are included. Prioritization and implementation suggestions are also provided.

Appendices

This report includes 10 appendices in a bookmarked PDF file containing detailed information:

- **Appendix A** includes detailed system and performance information figures.
- **Appendix B** contains detailed information tables.
- **Appendix C** provides sewer system HGL profiles for select modeled sewer reaches.
- **Appendix D** provides instructions for accessing the District's AGOL platform.
- **Appendix E** provides modeling and alternatives analysis notes compiled as PDF slides to provide backup information supporting alternatives analysis.
- **Appendix F** provides the Project Cost Opinion Development for LSSES Improvement Alternatives Analysis Technical Memorandum, Revision 2, September 2018.
- **Appendix G** summarizes analysis results for the 5- and 10-year, 1-hour rainfalls.
- **Appendix H** provides improvement model results with future development.
- **Appendix I** provides the community meeting slides and notes.
- **Appendix J** provides a listing of funding sources for public water and wastewater projects in Ohio.

1.3 PREVIOUS SWI-LSSES PROJECT SUBMITTALS FOR COMMUNITY REVIEW

Other reports and technical memoranda completed during the project have been provided to the District and communities. The following items have been developed in support of the project:

Task 1 – Local System Assessment Strategy

- *Project Prioritization Approach, Memorandum, September 2018*
- Community field investigation work plans

Task 2 – Local System Inspection and Condition Assessment

- Field investigation work orders – provided as developed
- Record drawings
- Emergent field issues – provided as discovered
- Arc GIS Online (AGOL) data and results – updated periodically
- *Task 2 - Local System Inspection and Condition Assessment Report, July 2021*

Task 3- Local System Evaluation

- *City of Berea Community Report – Capacity Analysis and Problem Identification, Draft, January 2021*

Task 4 – Prioritized Capital Solutions and Maintenance and Policy Recommendations

- Community meeting materials as applicable for each community
- Community report for each community – this report

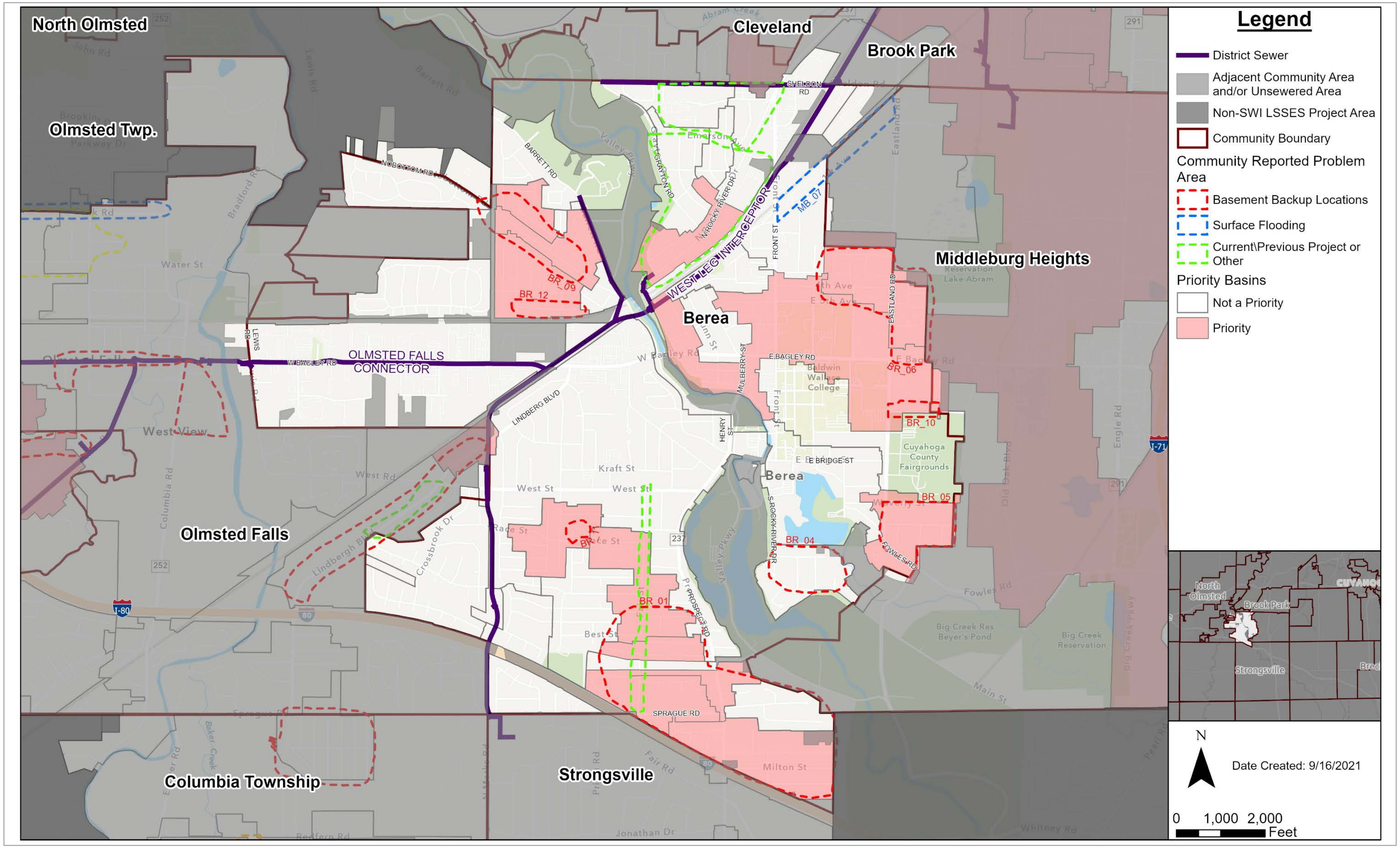
2.0 BACKGROUND AND LOCAL SYSTEM EVALUATION APPROACH

The SWI-LSSES project combined existing information from the District and communities with new field investigation results to update sewer system type and connectivity and assess sanitary sewer condition and potential for wet weather I/I. The new system information is based on field investigations including manhole inspections, smoke testing, dyed water testing, and closed-circuit sewer televising (CCTV) that have together targeted approximately 4,000 acres (about 7%) of the 59,000-acre SWI-LSSES service area.

Areas selected for investigation were prioritized based on several factors including reported BBUs, existing SSOs, high wet weather flows identified in previous projects, micromonitoring results, and existing common trench sewers. Short-term flow meters were installed for one or two significant rainfalls to check wet weather flow response. **Figure 2-1** shows the SWI-LSSES community-reported problem areas and field investigation prioritization areas in Berea. **Figure A3** in Appendix A shows the project monitoring locations.

Sanitary sewer system flow monitoring, rainfall monitoring, and development of a new SWI sewer system InfoWorks hydraulic/hydrologic model to include both the District and local sanitary sewers were completed to help define existing system performance and problems. Storm sewer monitoring was also conducted at selected locations to compare sanitary and storm sewer responses, particularly in common trench areas. The field investigations and projected performance information were used to develop, analyze, and optimize feasible solutions to remedy the reported and projected problems.

Figure 2-1. Field Work Prioritization Areas



2.1 PEAK FLOW RATE AREAS

This report summarizes the reported and model-projected sanitary sewer system problems and potential solutions using Peak Flow Rate Areas (PFAs) to divide community sewer systems into smaller subareas for analysis. PFAs are generally defined by the sewer subsystems in each community that discharge independently to the District SWI system, or in some cases, to an adjacent community. PFAs were selected as the basis for discussion of problems and solutions because their independent discharge to District sewers typically allows consideration of these PFA sewer systems apart from the systems in neighboring PFAs. **Figure A1** in **Appendix A** summarizes coverage areas for Berea including PFAs, the modeled sewer system, and locations of the respective discharges to the District sewer system. **Figures A2** through **A3** show the sewer system trench types, and field investigation summary information, respectively.

Potential solution alternatives were developed specific to a single PFA, or multiple PFAs as appropriate. Factors affecting how PFA solutions were combined include community preference and budgeting, PFA size/location, sewer system similarities, related problem cause and/or improvement(s), potential for hydraulic connection, and topography. Other PFA relationships may arise during community project planning and/or preliminary design investigations.

2.2 COMMUNITY-REPORTED PROBLEM AREAS

The District and SWI-LSSES project team worked with communities and their engineers and service directors to identify known problem areas. This information was used to help prioritize field investigation areas and flow monitoring locations and to compare to problems projected using the SWI-LSSES hydraulic/hydrologic model. **Table 2-1** summarizes the community-reported problem areas, which are discussed in more detail in **Section 3.2** and shown in associated maps provided in **Appendix A**.

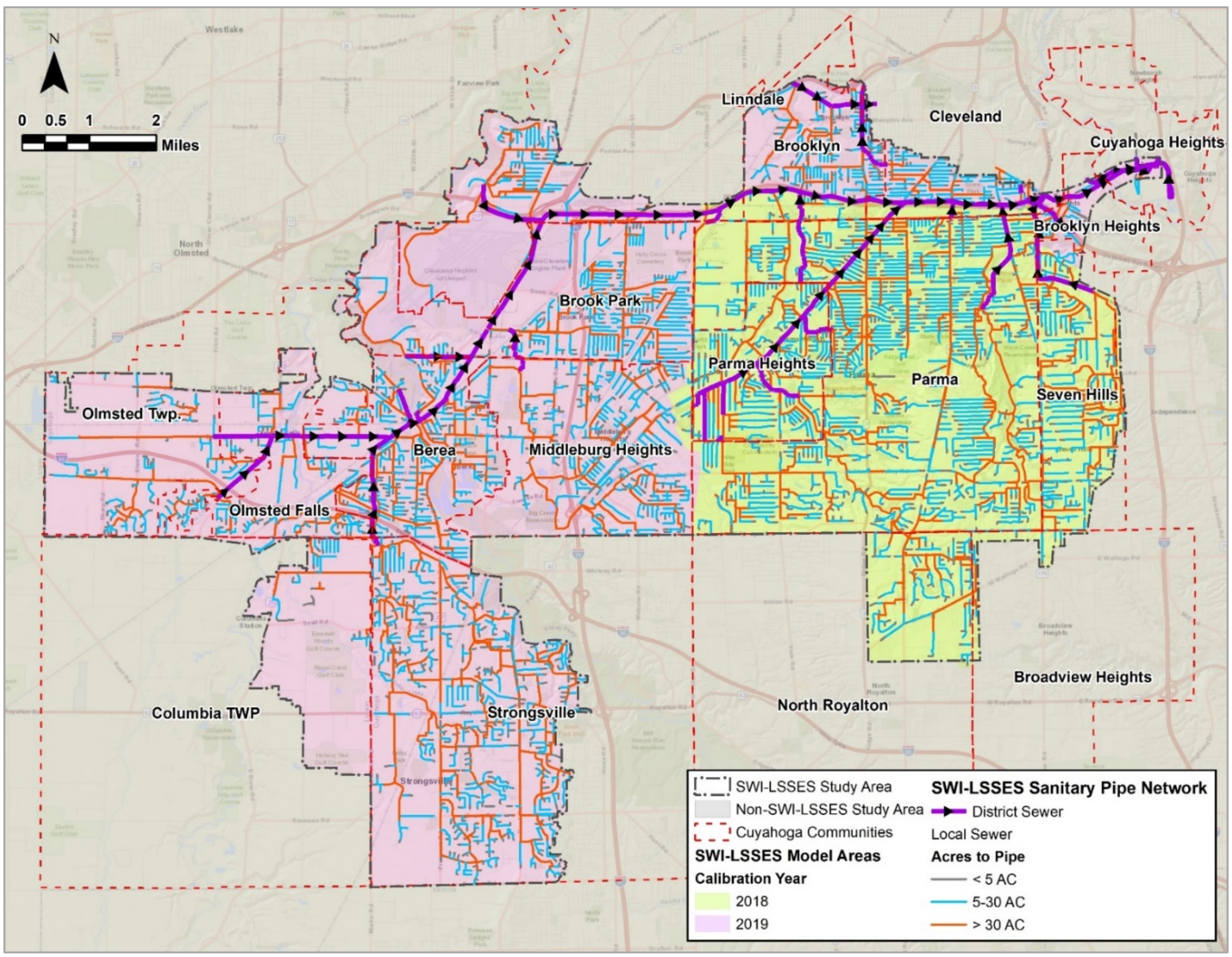
Table 2-1. Community-Reported Problem Areas		
Problem Area ID	Location	Reported Problem
BR-01/BR-02	• Dorland Avenue, Milton Street, and Maplelawn Drive • North of Sprague Road, West of Prospect Street, north to French Street and west to Fair Street including Best Street, Meadow Circle and Jananna Drive	BBUs
BR-03	Along Fair Street from Sprague Road to West Street	Other (sewer replacement project 2017)
BR-04	Monroe Street to S. Rocky River Drive	BBUs
BR-05	South of Cuyahoga County Fairgrounds to Fowles Road, Eastland Road and east to past Andrew Street	BBUs
BR-06	Barberry Drive south to E. 5th Avenue west of Eastland Road, east of Eastland Road, Wendy Drive to E. Bagley Road	BBUs
BR-07	Riveredge Parkway north to Sheldon Road, south to Emerson Avenue, including N. Rocky River Drive to the east	Other (Phase I of 2016 MCIP project to address I/I and BBUs)
BR-08	N. Rocky River Drive northeast of Karen Drive, north to Emerson Avenue and west to Grayton Road	Other (Phase II of 2016 MCIP project to address I/I and basement flooding)
BR-09	Lombardy Drive, Nobottom Road between Holly Drive and Cross Street, and Savage Street north of Chestnut to Hazel Drive	BBUs
BR-10	University Street west to Eastland Road and east to Pleasant Avenue	BBUs
BR-11	Fairwood Circle	BBUs
BR-12	Butternut Lane	BBUs
MB-07*	1st Avenue	Other (surface flooding)

** Problem area identified by neighboring community and overlaps into City of Berea.*

2.3 SEWER SYSTEM INFOWORKS ICM MODEL

The SWI system was modeled using the District's InfoWorks ICM hydraulic/hydrologic model (InfoWorks ICM Version 9.5.1.19011 April 2021). The model was developed from the updated District sewer system GIS based on existing record drawing information and field checks where required. This updated GIS has been made available on the District's AGOL platform. The model was generally extended into communities to include nearly all the local sanitary sewers 8 inches in diameter and larger, excluding the most upstream pipe segments serving areas of approximately 5 acres or less. **Figure 2-2** shows the model extents. **Figure A1** and other figures in **Appendix A** show the District and local Berea sewers included in the InfoWorks ICM model. The InfoWorks ICM model is available to communities upon request to the District Watershed Team Leader.

Figure 2-2. SWI-LSSES Sanitary Sewer System Model Overview



2.3.1 Modeled Rainfalls

Development and calibration of the model is described in the *Hydraulic Model Evaluation, Update, and Calibration 2018 and 2019 Model Areas Final Report, January 2022*. The projected performance and problems described in this report are based on the District's standard 5-year, 1-hour rainfall with 15-minute rainfall intervals (1.46 inches total) and a 5-minute model reporting interval, which is consistent with the 5-minute flow monitoring data interval used for model calibration. Although the original SWI system basis of design used a 1-year, 1-hour rainfall, subsequent analysis in the 1998 SWI Operational Evaluation Project (OEP) found that the District system likely has capacity for at least a 5-year rainfall. The 5-year, 1-hour rainfall was used as the basis for analysis in the other LSSES projects and was used for the SWI-LSSES project as well.

The project also analyzed model-projected performance for the 10-year, 1-hour rainfall (1.63 inches). The analysis considered performance results associated with the 10-year rainfall for existing conditions and for improved conditions developed for the 5-year, 1-hour rainfall problem areas. Results are summarized in **Section 5.3** and **Appendix G**. Both rainfalls are based on the District's *Hydrologic and Hydraulic Modeling Standards, Version 4*.

2.3.2 Modeled Pump Stations

Local pump stations were simulated in the existing conditions model to evaluate their performance as part of the hydraulic capacity assessment. The model included representations for 7 pump stations. **Table 2-2** summarizes the modeled pump stations and **Figure 2-3** shows locations and tributary areas.

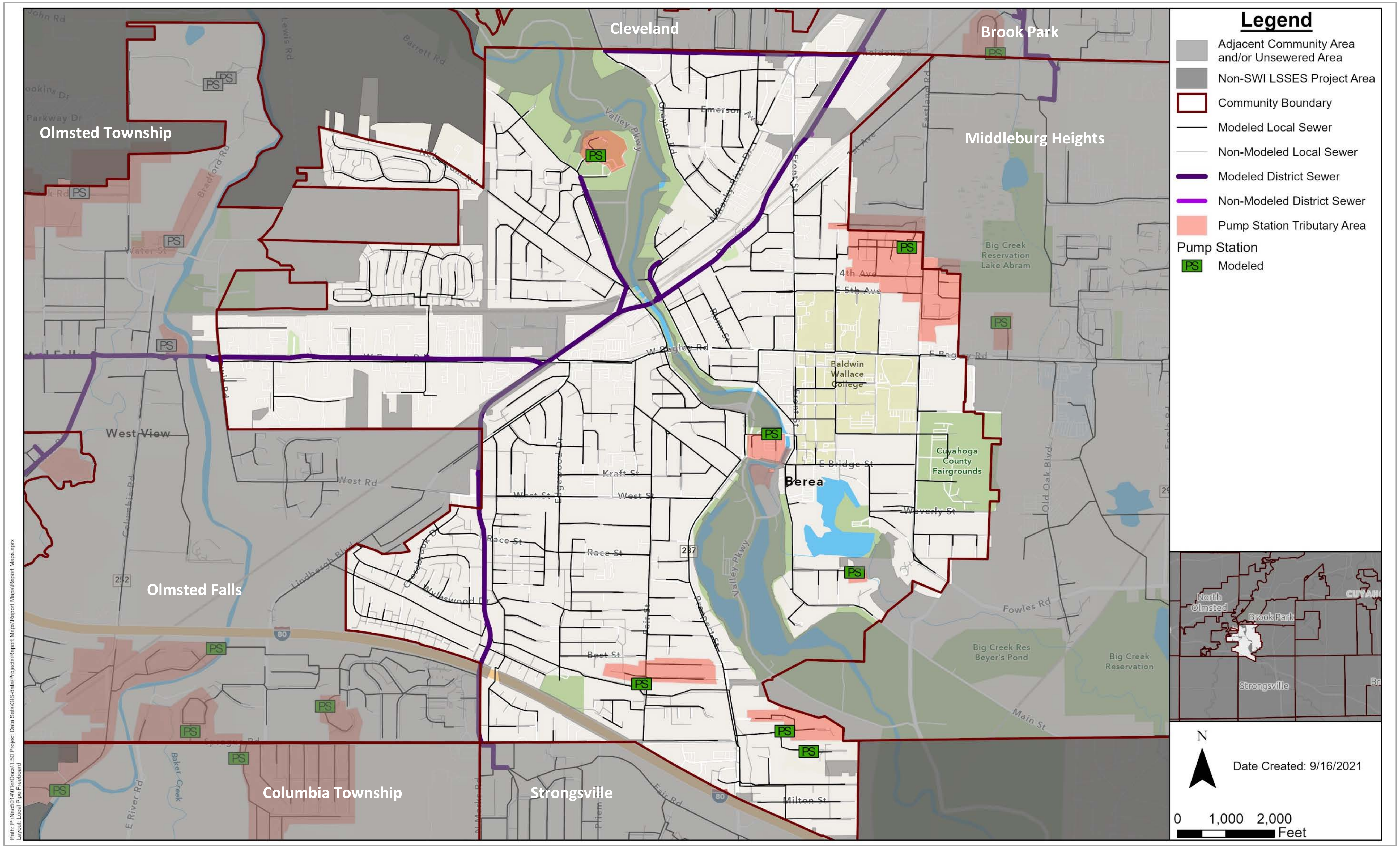
Table 2-2. Pump Stations within Berea

Pump Station Name	Ownership	Model Status*	No. Pumps	Modeled Station Capacity, MGD
Manning Pump Station (Ellen Dr.)	Unknown/Other	Modeled (Estimated)	1	0.15
Manning Pump Station (Manning Dr.)	Unknown/Other	Modeled (Estimated)	2	0.25
Fair St. Pump Station	Unknown/Other	Modeled (Estimated)	1	0.27
Old Town Pump Station (Monroe St.)	Community	Modeled (Verified)	2	0.10
Center Pump Station (W. Center St.)	Unknown/Other	Modeled (Estimated)	1	10.0
Barberry Pump Station (Barberry Dr.)	Community	Modeled (Verified)	2	2.0
Trailhead Pump Station (Trailhead Ln.)	Community	Modeled (Estimated)	1	0.45

* *Verified - Model representation based on available record data or operating parameters.*

The model representation for each pump station was based on available record data obtained at the time of the study. If record data was not available, the pump station operating parameters were assumed and are identified in the model documentation and notes. The community should note that if the pump station operating parameters have been adjusted or modified from the record data or are different from the assumed parameters, the model-projected BBUs and/or projected capacity analysis could vary from what is detailed in this report and associated maps. It is recommended the community verify the pump station operating parameters through testing or other means to re-evaluate the projected BBUs before improvements are finalized.

Figure 2-3. Modeled Pump Stations



2.3.3 Analysis of Common Trench Sewer Systems - Flow Limit Elements

In most common trench areas, the storm and sanitary sewers exhibit crossflows at joint defects and service lateral connections, and in some instances essentially function as a two-pipe combined sewer system. Because the SWI model does not include the storm sewer system and the innumerable interconnections, this interaction between the storm and sanitary sewer systems was approximated in some areas using “flow limit” model elements to achieve acceptable calibration to observed rainfalls. The flow limits consist of weirs, orifices, and storage used at select locations to mimic the real system. The flow limits allow the high I/I tributary to the system to escape or be stored (e.g. in the storm sewer, sewer trench, or basements) as the sanitary sewer becomes overwhelmed, thus approximating the real system’s operation as the sanitary sewer fills, and higher flows are conveyed in the storm sewer system or stored in the common trench or ultimately in basements. The flow limit locations and elevations are indicated as purple dashes at the respective manholes in the HGL profiles in **Appendix C**.

The flow limits were removed in the future conditions models that simulate performance in the improved systems. The flow limits were also removed during sensitivity testing and capacity assessment/problem identification in the existing system for 5-year, 1-hour, and larger rainfalls. Further detail regarding how and where the infiltration limits were used in the model, and the resulting effects on the existing conditions analysis are described in the *Hydraulic Model Evaluation, Update, and Calibration 2018 and 2019 Model Areas Final Report, January 2022.*

2.3.4 Model Routed Flow vs Model RDII Flow

Sanitary sewer system stormwater infiltration and inflow and are collectively referred to as rainfall dependent infiltration and Inflow (RDII). In many portions of the SWI-LSSES project area and particularly in common trench areas the sewer system hydrologic/hydraulic InfoWorks model was challenging to calibrate because RDII rates are relatively high, in many cases exceeding existing sewer system capacities for even moderate rainfalls. High RDII flows often result in sewer system surcharging (consistent with flow storage in manholes and sewer trench), BBUs and SSOs, particularly for larger rainfalls. This capacity limitation not only causes performance problems but can also limit the RDII entering the system. Other soil and sewer system defect parameters may also affect RDII peak flows for varying rainfall and soil moisture conditions.

As a result of this capacity limitation, the RDII generated in model subcatchments to calibrate the model for a range of rainfall events can be much higher than the projected/measured flow in the existing sewers, even though RDII does not include base wastewater flows. This implies that if the existing system had more capacity, e.g. via pipe size increases, the peak wet weather flows in the sewer system could increase significantly. Another implication is that if the sewer system were to provide adequate capacity for all peak flow rates (e.g. no surcharging, BBUs or overflows), the peak flows routed through the system and peak model subcatchment RDII flows would be similar.

This study provides and uses results for both the model routed flows and model RDII flows. The routed flows were used as a measure of what is flowing in the existing system and is ultimately passed downstream to the District or other communities. The RDII flows have been used in this study by the modeling team to differentiate wet weather response of model subcatchments based on the nearest calibration flow meter. This RDII wet weather response was also used to identify areas that should be considered for I/I reduction via sewer system rehabilitation and/or replacement to meet the District's 50,000 GPAD (70,000 GPDIM) excessive wet weather flow guideline. Although these excessive flow guidelines were developed for use with model RDII flows, if model routed (sewer system) flows exceed these guidelines, they would also be considered excessive and would likely indicate even higher RDII flows.

2.3.5 RDII Peak Flow Rates vs Volumes

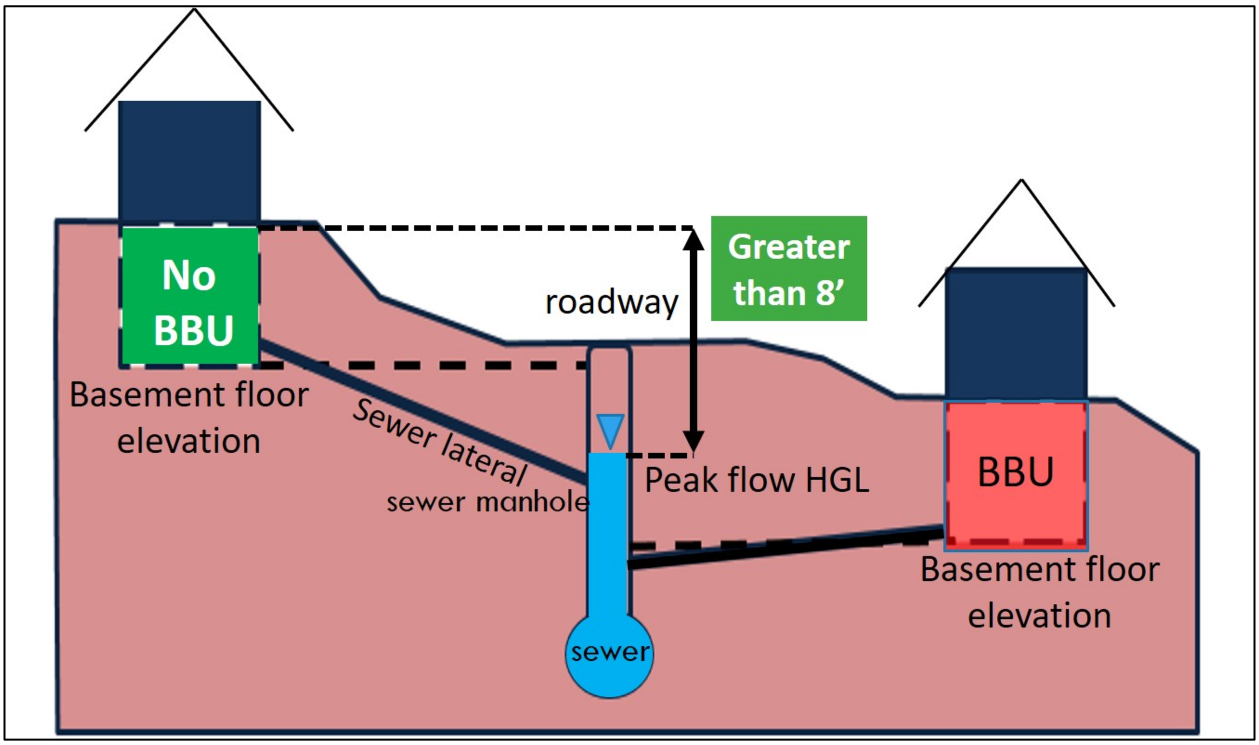
RDII can be measured as both a flow rate and a volume. For this study peak flow rates are documented in MGD, GPAD and GPDIM. The latter two are included to allow comparison of peak rates from varying size model subcatchments and PFAs. The peak rates are related to sewer system capacity and performance parameters such as surcharging, BBUs and SSOs. High peak rates also affect downstream community and District infrastructure by using conveyance and treatment capacity that would otherwise be available to treat flows for larger rainfall events and/or increased sewage flows from new development.

RDII volume is measured as rainfall capture, which is the portion (volume %) of rainfall falling on an area that drains to the sanitary sewer system. Sewer systems with high RDII flow rates often also have high rainfall capture volumes, but the two parameters are not always correlated. High RDII capture volumes indicate that excessive stormwater is entering the sanitary sewer system and draining to District treatment plants, resulting in increased treatment costs. This study has found that rainfall capture volumes above approximately 5% are often associated with sewer system problems such as BBUs. Problems may exist in lower capture areas, particularly if sewer system capacities are low, or if O&M or structural problems exist. **Section 3.1** discusses rainfall capture in more detail.

2.4 BBU PROJECTIONS

The model was used to project peak flow rates and corresponding maximum HGL profiles in the system. This information was combined with the District's 2017 Digital Elevation Model (DEM) and GIS building footprints to identify buildings likely to have basements at risk of backups during the 5-year, 1-hour rainfall due to excess wet weather flows and/or sanitary sewer capacity deficiencies. Buildings are projected to be at risk if the model maximum HGL elevation is within 8 feet of grade at a building along a modeled pipe as shown in **Figure 2-4**. This analysis assumes basement floor elevations are 8 feet below the highest ground elevation at each structure with a basement. Results are summarized in **Section 3**.

Figure 2-4. BBU Projection Approach Based on Grade Elevation



2.5 SSOS AND OTHER WATER QUALITY IMPACTS

The SWI-LSSES project has estimated SSO activations and other water quality impacts of common trench sewers, known failing HSTSs, and suspected illicit discharges in the tributary communities. This information is summarized for the SWI-LSSES project area in the overall project summary report. The status of SWI area SSOs is documented for the project in the *SSO Investigation and Status Report, Final, February 2021*. Relevant findings for the City of Berea SSOs, including model-projected overflows for the 5-year, 1-hour rainfall, are summarized in **Section 3.2**.

3.0 LOCAL SYSTEM INVESTIGATION AND ANALYSIS RESULTS

This section summarizes study results including field investigation results and model-projected problems associated with the 5-year, 1-hour rainfall. The City is served by a separate sewer system composed of 9% common trench standard (common standard) and 91% separate trench sewers, with a total sanitary sewer length of 383,600 LF. **Figure A1** in **Appendix A** summarizes the local sanitary sewer system within the SWI service area, the PFA polygons and associated PFA discharge points to the District sewer system, and intercommunity discharges to neighboring community sewers. **Figure A2** summarizes the sewer construction trench types and the location of known structural SSOs relative to the community-identified problem areas. **Figure A4** summarizes local sewer system projected performance under existing conditions including SSOs and BBUs, as well as community-reported problem areas.

3.1 SUMMARY OF FLOW MONITORING AND FIELD INVESTIGATION RESULTS

Flow monitoring in the Berea system included 25 model calibration sanitary sewer flow meters, two level meters, and 61 micromonitoring locations. Berea sewer system capture coefficients (percentage of total rainfall entering the sanitary sewer system) calculated based on the calibration flow monitoring and approximately nine rainfall events range from 2% to 26%, with an area-weighted average of 7% for monitored areas including a mixture of common and separate trench areas. For comparison, capture coefficients calculated for predominantly separate trench sewer systems in the SWI study area demonstrated an area-weighted average of capture of approximately 2%. The weighted average for separate trench sewers in Berea is 7% and 12% for common trench sewers.

This study has found that rainfall captures above approximately 5% are often associated with sewer system problems such as BBUs. Problems may exist in lower capture areas, particularly if sewer system capacities are low, or if O&M or structural problems exist. **Figure 3-1** shows the approximate distribution of SWI-LSSES capture coefficients based on calibration flow monitoring locations.

Figure 3-1. SWI-LSSES Calibration Meter Capture Coefficient Distribution

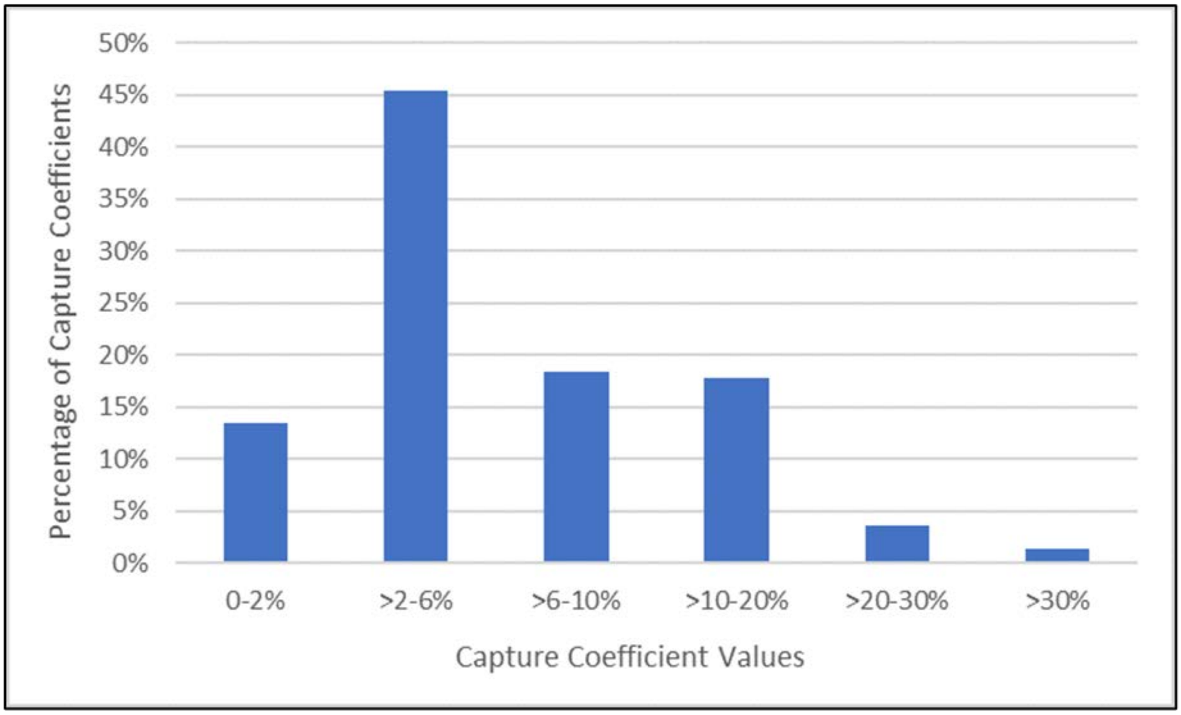
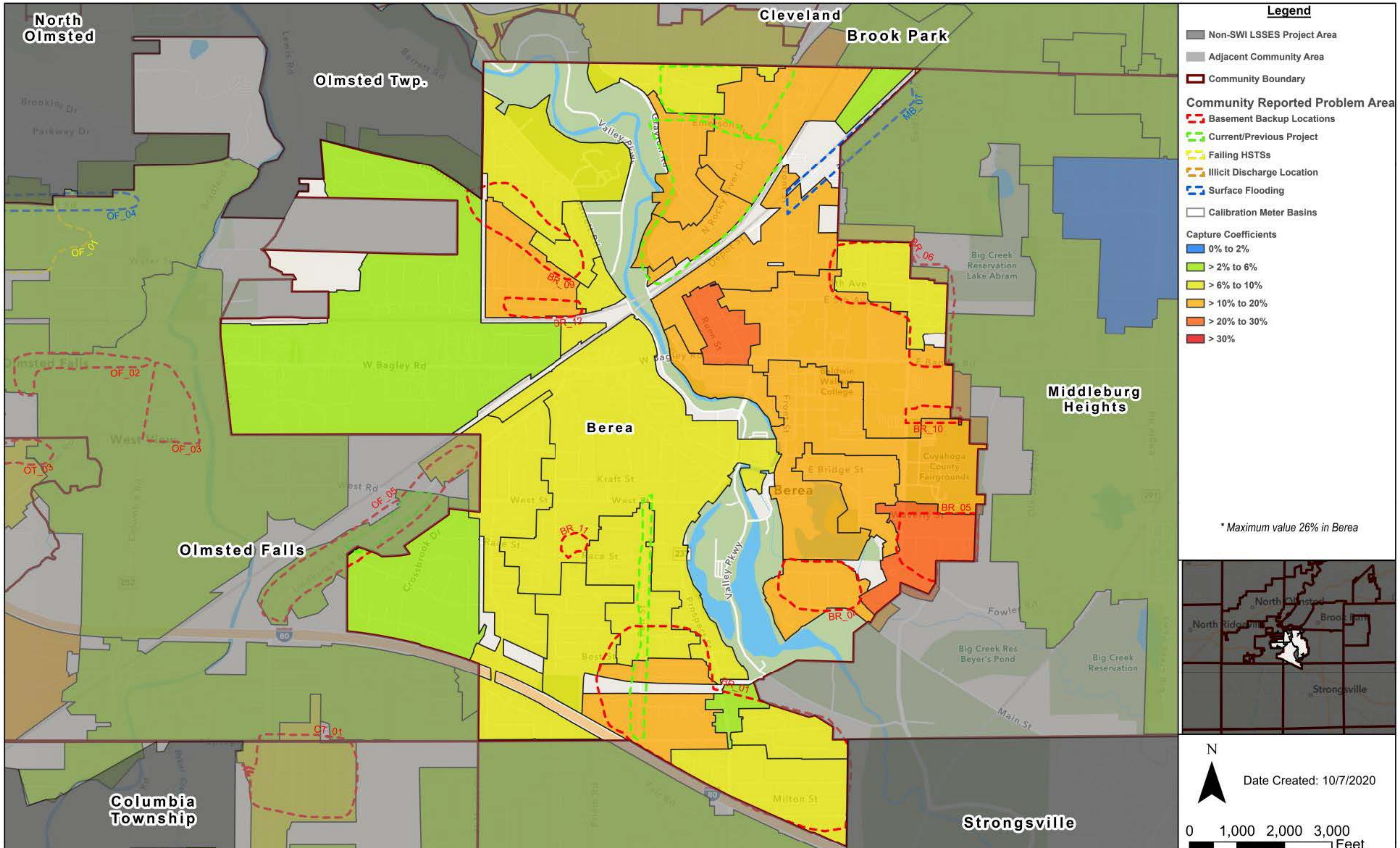


Figure 3-2 presents the SWI system monitoring capture coefficients for the calibration monitoring catchment areas. Additional information on the SWI system model is documented in **Section 2.3** and in the *Hydraulic Model Evaluation, Update, and Calibration 2018 and 2019 Model Areas Final Report, January 2022*.

A fieldwork screening analysis based on micromonitoring results is summarized in **Table B1** in **Appendix B** of this report. This analysis details how calibration and micromonitoring data were used to screen areas for proposed field work orders. **Figure A3** in **Appendix A** shows the monitoring and other fieldwork locations.

Figure 3-2. Calibration Flow Monitoring Area Capture Coefficients



3.1.1 Field Work Orders

Field investigations completed in Berea included 17 field work orders to conduct investigations including smoke testing, public right-of-way (ROW) and private dyed water testing, manhole investigations, SSO confirmation, and sewer system CCTV investigations. The field work orders are summarized in **Table 3-1**. **Figure A3** in **Appendix A** summarizes significant findings from the condition assessment and I/I investigation work orders conducted in the Berea system.

Table 3-1. Berea Field Work Orders

Work Order #	PFA ID(s)	Streets	Purpose and Activities
1	Various	Various	SSO investigation
4	Various	Various	Flow divider investigation
17	Various	Various	Manhole inspection
25	BE-03	Beech St, 4th Ave	Private property I/I testing, CCTV
40	BE-09	Maplelawn Dr, Edwards St, Milton St, Dorland Ave, S Point Trl, Prospect St, Greenfield Ct, Fair St, Whitehall Dr, Carteret Ct, Downing Ct, Walwick Ct, Jananna Dr, Kaye St, Vivian Dr, Sprague Rd, Prospect St, Lindbergh Blvd	Smoke testing
41	BE-07, BE-10	Savage St, Butternut Ln, Nobottom Rd, Lombardy Dr, Hemlock Dr, Laurel Dr, Larchwood Dr, Holly Dr, Sheldon Rd, W Vancey Dr, N Vamcey Dr, E Vancey Dr, Grayfriar Dr	Smoke testing, dyed water testing, catch basin testing, CCTV
48	BE-03	Riverside Dr, Front St, Bagley Rd	CCTV, manhole inspection
50	BE-09	Prospect St, Maplelawn Dr	Dyed water testing, catch basin testing, CCTV, connectivity investigation
54	BE-03	Andrew St, Fuller St, Franklin St, Austin St, Fowles Rd, Old Reservoir Rd, Main St, Monroe St, Bevans St, Stanmary Dr, Olde Town Trl, Waverly St, Quarry Stone Ln, S Rocky River Dr, Eastland Rd	Smoke testing

Table 3-1. Berea Field Work Orders

Work Order #	PFA ID(s)	Streets	Purpose and Activities
55	BE-09, BE-10, BE-13	Kempton Dr, Race St, Anne Dr, Pattie Dr, Girard Dr, Fairpark Dr, Wyleswood Dr, Baldwin Dr, Wallace Dr, Best St, Adrian Dr, Edgewood Cir, Fairwood Cir, Lynn Rd, Woodmere Dr, Glenwood Dr, Glenwood Cir	Smoke testing
56	BE-01, BE-02, BE-03	Louis Dr, Janice Dr, Wendy Dr, Eastland Rd, 4th Ave, Westmoor Ln, Bond Pkwy, Bishop Pl, E 15th Ave, Orchard Grv, Maple Ave, Barberry Dr, Woodlawn Cir, University St, Beech St	Smoke testing, dyed water testing, catch basin testing, CCTV
64	BE-09, BE-13	Wayne Dr, West St, Beeler Dr, Baldwin Dr, Lapaz Blvd, Tampico Ct	Smoke testing
73	BE-03, BE-04, BE-08	Grayton Rd, Longfellow Dr, The Burns, The Mall, Wesley Dr, Emerson Dr, Race St, Crossbrook Dr, Brockton Cir, Adams St, Veterans St, Clark St, E Bridge St, Seminary St, Spring St, Beech St, Jacob St, E Grand St, E Center St	Smoke testing, dyed water testing, catch basin testing, CCTV
82A	BE-03	Waverly St, Fowles Rd	Private property I/I testing, dyed water testing, catch basin testing, CCTV
82B	BE-03	S Rocky River Dr, Stanmary Dr	Private property I/I testing, CCTV
93	BE-13	Kraft St	Private property I/I testing, CCTV
99	BE-03	W. Bagley Rd, Front St, W. 5th Ave, Mulberry St	CCTV, catch basin testing

3.1.2 Sewer System Dyed Water Testing

Dyed water testing found significant I/I in both the public ROW sewers, and from private property sources. In Berea, dyed water testing was conducted in 23 sewer reaches totaling approximately 5,550 LF, through Work Order 93. In this length, 25 infiltration defects were found, with five pipe defects classified as rapid infiltration, and one rapid infiltration lateral connection defect. An example of a rapid storm sewer exfiltration/sanitary sewer infiltration is where existing industry standard codes from the National Association of Sewer Service Companies (NASSCO) do not adequately describe the severity of infiltration. Future infiltration reduction efforts should consider addressing these defects as a high priority. **Figure 3-3** provides a sketch of the dyed water testing setup and **Figure 3-4** shows an example service lateral with a high infiltration rate during mainline dyed water testing. **Figure A3** in **Appendix A** indicate pipes with positive crossflow infiltration tests highlighted in yellow. This information is also provided in the District's AGOL website for this project.

Figure 3-3. Example of Dyed Water Testing Setup

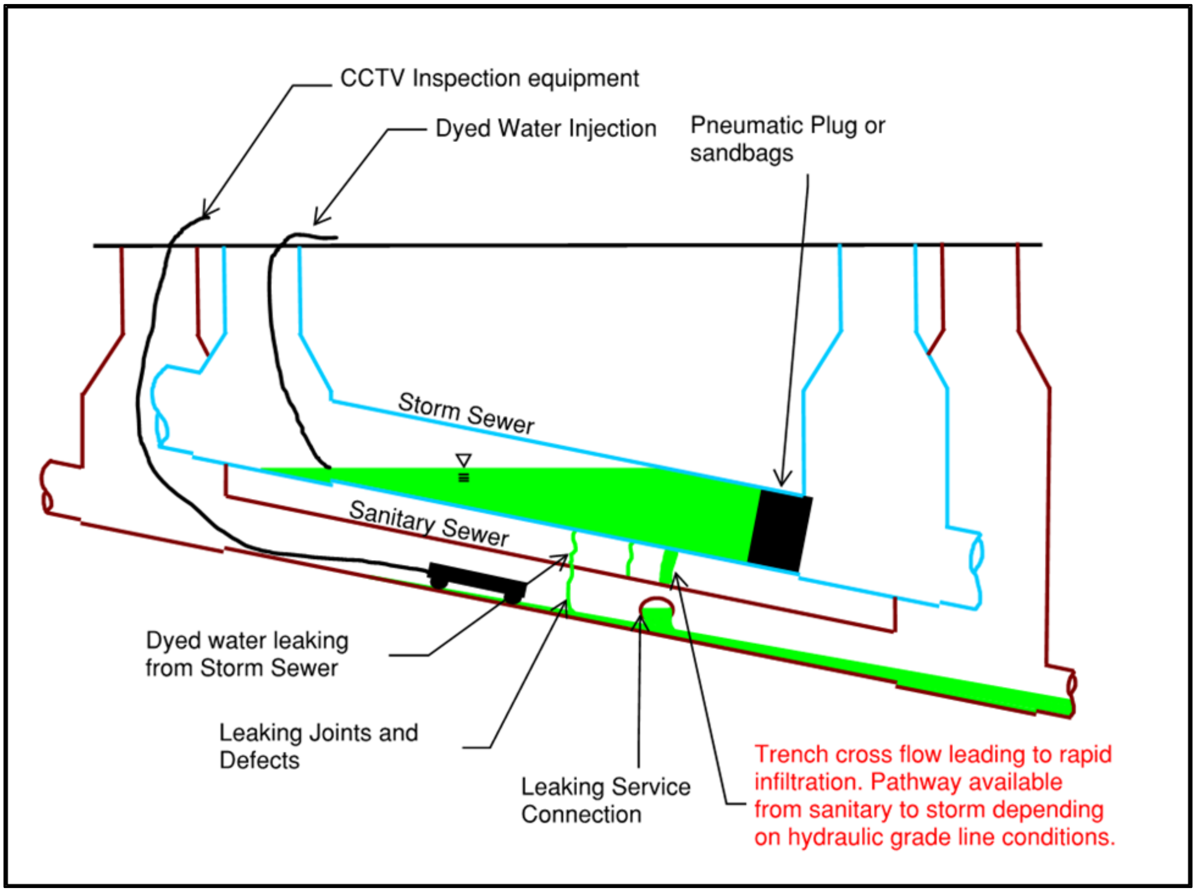


Figure 3-4. Infiltration from Storm Sewer to Mainline Sewer at Sanitary Service Lateral

Other Work Order Findings

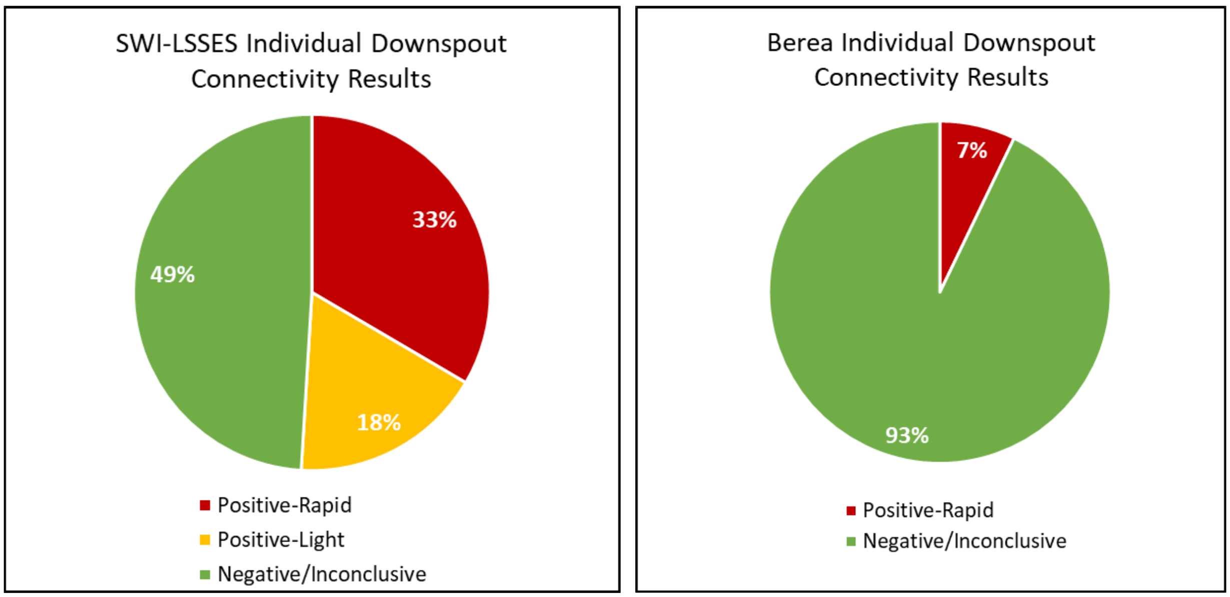
Critical sewer system structural and/or field follow-up conditions were provided in detail to respective communities for follow-up repairs or additional inspection. Some of the work orders, listed in **Table 3-1**, were completed to verify manhole configuration and trench types. The information related to the Berea field activities is summarized in **Figure A3** in **Appendix A** and on the District's AGOL platform. Additional detailed information is available from the District Watershed Team Leader upon request.

3.1.3 Private Property Testing Results

Individual Downspout Results

Private property I/I sources were tested at more than 400 properties as part of the SWI-LSSES efforts, including 17 properties in Berea. As shown in **Figure 3-5**, across the SWI-LSSES area, 49% of downspout tests did not find dyed water entering the sanitary lateral, 33% showed a rapid response during dyed water testing, and 18% showed a delayed/light response. A rapid response may be attributed to a direct connection or significant defects in the underground downspout plumbing or laterals. Slower responses may be attributed to minor defects in plumbing. In Berea, 7% of the downspouts tested were observed with a positive-rapid response, which is approximately 26% lower than the rest of the tests completed for the SWI-LSSES area.

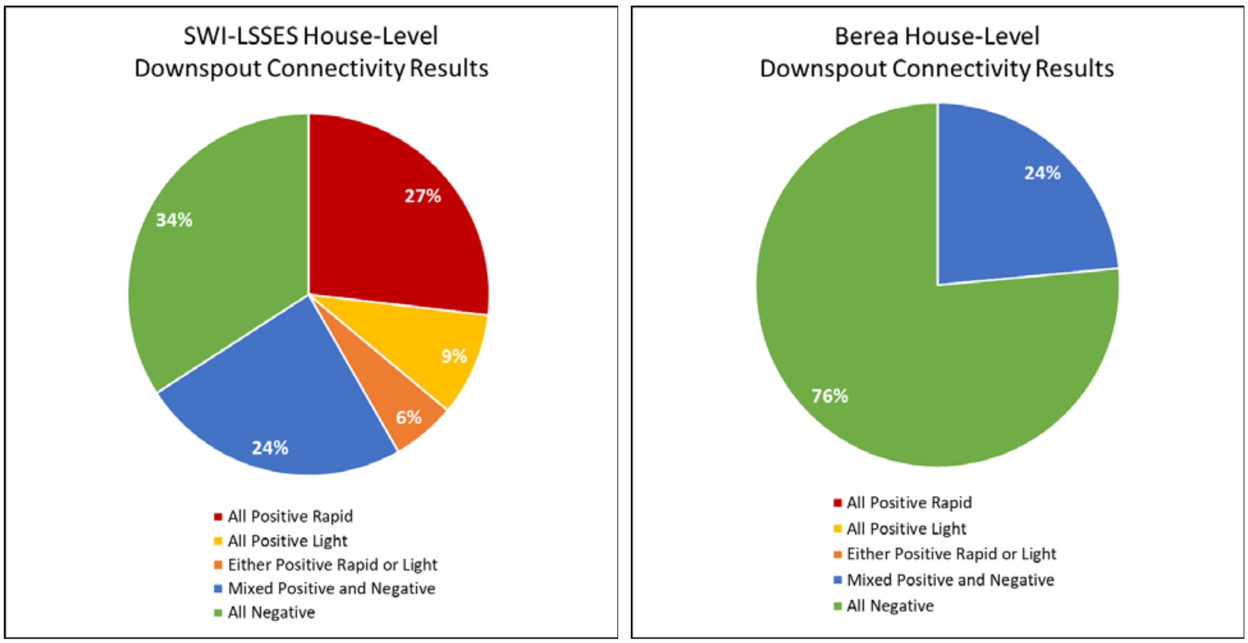
Figure 3-5. Individual Downspout Testing Connectivity Results



House Level Results

Results were also assessed at the house level. Most houses have multiple downspouts. The house level assessment indicates the percentage of houses that have at least one positive downspout test. Testing completed for the SWI-LSSES found no evidence of dyed water in the sanitary lateral at 34% of houses, and the other 66% had some dye transfer. In Berea, 76% of houses had no evidence of dyed water and the remaining 24% had some transfer as shown in **Figure 3-6**. In Berea, no residences tested had every downspout show a positive dyed water response in the sanitary sewer. The typical test setup utilizes a CCTV camera to monitor the sanitary sewer service connection for dyed water.

Figure 3-6. House-Level Downspout Testing Results



Test Results Based on Building Age

Private property investigations were also compared against building age for the study area. Approximately 67% of buildings tested throughout the study area were constructed between 1945 and 1967 (post-WWII). The other buildings that were tested were constructed in the 1800s (<1%), between 1900 and 1944 (14%, pre-WWII), between 1968 and 1990 (15%, post-WWII), and post-1990 (3%). The results presented in **Figure 3-7** show that SWI-LSSES buildings constructed between 1900 and 1944 (pre-WWII) had more positive I/I tests than other eras. It is unknown whether this is due strictly to age/deterioration of the piping, or if materials and/or construction methods vary significantly during the different periods. Unlike the overall SWI-LSSES area, buildings in Berea that were constructed between 1945 and 1967 (post-WWII) had more positive I/I tests (mixed positive and negative) compared to those constructed in other eras. **Figure 3-7** does not show test results for one home in the study area (and Berea) that was built in the 1800s (mixed positive and negative) or 12 homes tested that were constructed after 1990 (all negative).

Figure 3-8 shows building construction periods in the Berea study area. Building information was obtained from Cuyahoga County.

Figure 3-7. Downspout Test Results with Structure Age (SWI-LSSES and Berea)

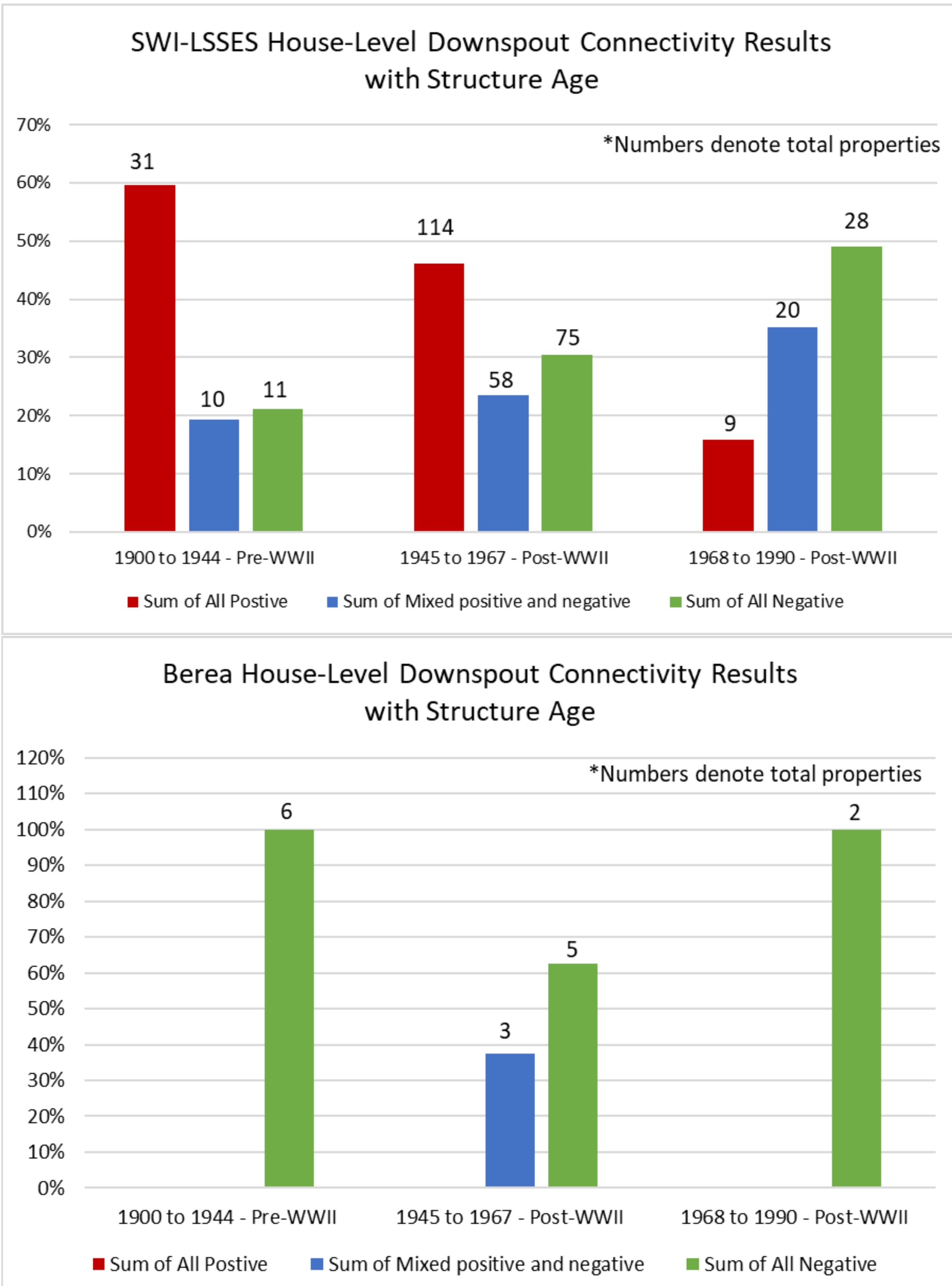


Figure 3-8. Building Construction Periods

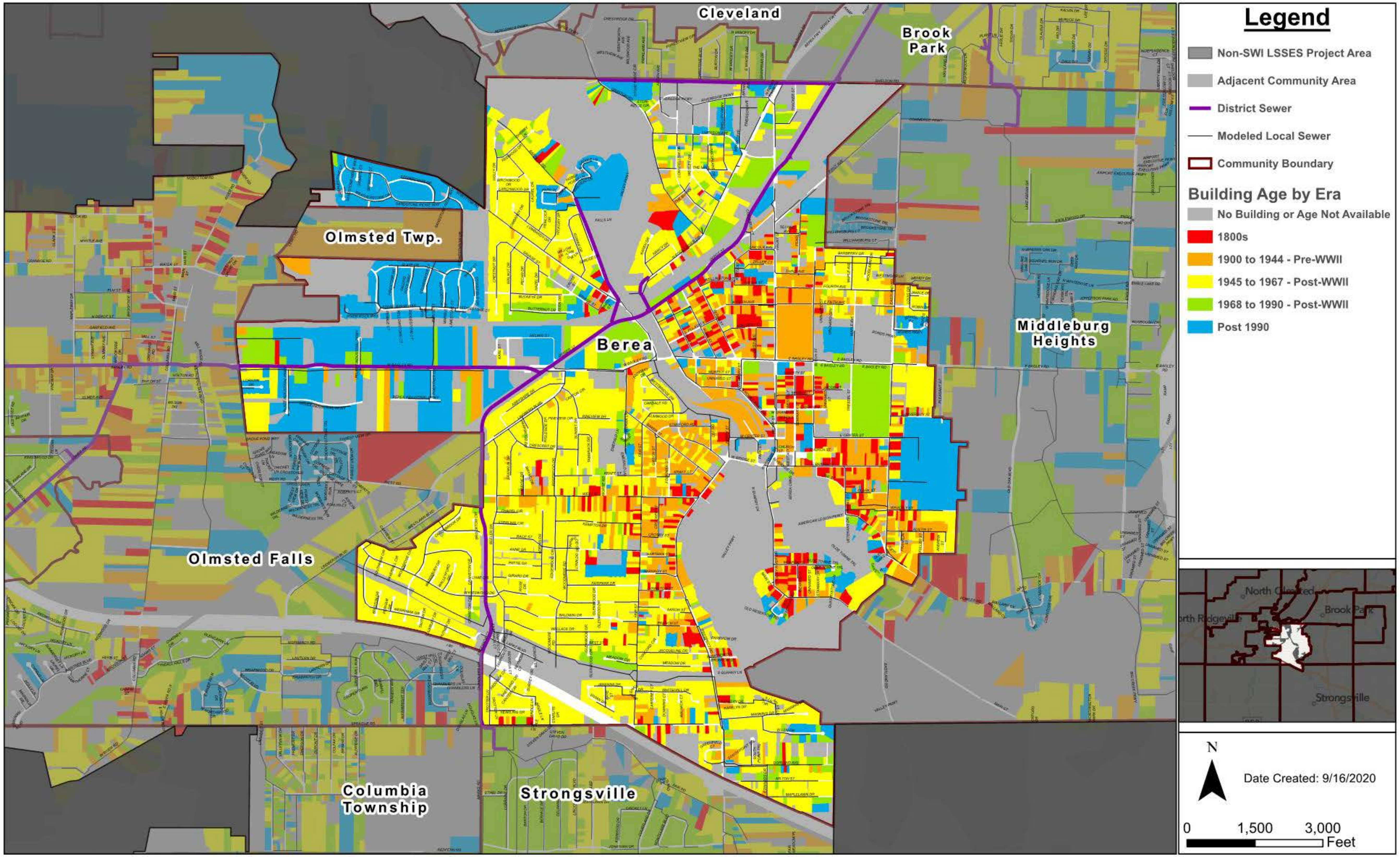


Figure 3-9 shows an example of rapid response observed in the sanitary lateral during private property investigations. Dyed water introduced to the stormwater lateral via the downspout can be seen infiltrating the sanitary lateral at the visible joint at the 3 o'clock and 9 o'clock positions. Note that there is no direct connection from the stormwater lateral system. When the dyed water entry point was visible, a defect, rather than a direct connection, was indicated to be the source of the infiltration.

Locating leaks from the private stormwater lateral to the private sanitary lateral may require progressive investigation. When the dye entry point into the sanitary sewer can be located, point repairs may be suitable to address the observed leak. As an example, in the photo shown in **Figure 3-9**, all the downspouts had a rapid response to the sanitary sewer. In this case, the camera was able to capture that all the positive tests entered the sanitary lateral at the same defect. However, as explained in the following paragraph, additional leaks may also exist.

Not all Defects are Visible

Point repairs at specific lateral locations, such as those shown in **Figure 3-9**, may or may not eliminate I/I from the property. Upstream or downstream defects in the laterals may also leak if the known infiltration defects are repaired. Furthermore, the rainfall simulated during testing is small compared to rain events that utilize a significant portion of the service lateral capacity, i.e. the small amount of water from the testing hose does not fill the stormwater lateral as much as a rainfall event. Therefore, defects that are located further upstream, or at higher elevations (e.g. at pipe crown or at downspout riser) may not be exposed during testing. These defects may only appear during rainfall events or they may activate if a visible defect is repaired. Repairing the known leaks found during testing via point repair may help the system but may not be a comprehensive solution such as full pipe lining, grouting of all joints, and/or separation of individual drains with direct or indirect connections.

Stormwater Lateral Obstruction

Stormwater laterals are also prone to obstruction by leaves and other debris that may wash off roofs or yard drain areas. If the stormwater lateral becomes obstructed, stormwater will tend to migrate to the closest, lowest outlet, which is often the sanitary service lateral, or the service lateral trench. Some stormwater laterals were originally constructed with traps to reduce odors and/or pest migration toward the home. The traps will tend to increase the risk of obstruction and make cleaning more difficult. The presence of these traps in Berea is unknown. However, if found to exist, the removal of existing traps and/or regular cleaning of stormwater service laterals is suggested to promote adequate drainage and minimize private property I/I.

Figure 3-9. Downspout Water Infiltration into Sanitary Lateral

3.2 PROJECTED EXISTING SYSTEM PERFORMANCE AND PROBLEM SUMMARY

Peak wet weather flows originating in the Berea PFAs were analyzed using two methods for calculating I/I: 1) gallons per day per inch diameter-mile (GPDIM), and 2) gallons per acre per day (GPAD). The GPDIM parameter is commonly used for assessing I/I contribution to a sewer system based on size and length of pipe upstream of a point in the system regardless of tributary area or population. The GPAD parameter considers the peak flow at a point in the system divided by the sewered area tributary to that point. The SWI-LSSES is also using an aggregated area approach that accounts for PFAs with upstream tributary PFAs and flow diversions in and out of the PFAs.

SWI overall study area sanitary sewer peak 5-year, 1-hour flows in primarily separate trench sewer systems (at least 70% separate trench) were found to range from 1,800 to 233,500 GPAD (2,600 to 535,000 GPDIM), with an area-weighted average of 10,100 GPAD (21,800 GPDIM).

In Berea, sanitary sewer peak 5-year, 1-hour flows in PFAs of primarily separate trench sewer systems (at least 70% separate trench) were found to range from 5,100 to 117,000 GPAD (9,000 to 175,000 GPDIM), with a weighted average of 21,300 GPAD (34,500 GPDIM), and there are no

PFAs that are at least 70% common trench. In comparison to the SWI study area, the majority of Berea PFAs were found to be within range to slightly higher on a per-acre basis. 13 of the 14 Berea PFAs (99.7% of 2,805 acres) do not exceed 50,000 GPAD (and 11 of the 14 PFAs, which is 96% or 2,690 acres, do not exceed 70,000 GPDIM). An approximate 110-acre area in the north part of Berea (east of the Rocky River East Branch, north of N. Rocky River Drive, then north to the City's border) has the highest peak rates. The peak flow rates in this area are in the range of 41,000 to 117,000 GPAD (up to 175,000 GPDIM). Most of this area (or about 103 acres) is part of the Phase 2 North End Sewer Rehabilitation 2020 MCIP project shown in **Figure 3-16**.

Figures 3-10 and **3-11** summarize the projected Berea sanitary sewer system routed flows for the 5-year, 1-hour rainfall using GPAD and GPDIM for each PFA based on the calibrated events. For rainfalls larger than the calibration events, limited sewer system capacity may reduce the peak rate measured in the system. **Figure 3-12** shows the locations and control status of the known SSOs in Berea (5-year, 1-hour rainfall).

- Previously known SSOs are shown in green if projected by the model to be controlled during the 5-year, 1-hour rainfall event.
- SSOs discovered during the SWI-LSSES fieldwork are shown in green with a black dot if projected to be controlled and projected active SSOs are shown in red with a black dot.
- Confirmed existing SSOs previously recorded as eliminated are shown as a green circle if they are projected to be controlled, and as a red circle if projected to be active during the 5-year, 1-hour rainfall.

Figure 3-13 shows the locations of HSTSs and illicit discharge investigation areas and status. The HSTSs are categorized as reported failing by CCBH evaluation, HSTSs greater than 20 years old and assumed as failing, or existing systems newer than 20 years and/or reported as passing by CCBH evaluation.

The following additional information is included in **Appendices A** through **C, E** and **G**.

Appendix A – Maps and Figures

Figure A4 in **Appendix A** shows the existing sanitary sewer system projected performance results and reported/projected problem areas, including:

- Reaches of modeled local sewer system surcharging above the sewer crown.
- Reaches shown in red indicate surcharging caused by the peak flow rate exceeding the local sewer capacity.
- Reaches shown in blue indicate surcharging caused by a backwater condition originating downstream.
- Buildings with basements projected to be at risk of flooding are shown in black (model HGL within 8 feet of grade elevation at building).

Appendix B – Tables

- **Table B2** summarizes projected system performance and SSO volumes for each PFA.
- **Table B3** summarizes SSO status and volumes for the 5-year, 1-hour rainfall and typical year of rainfall.
- **Table B4** summarizes reported and projected problems by PFA. Field work findings are also summarized.
- **Table B5** provides an inventory of all the HSTSs in Berea as provided by the Cuyahoga County Board of Health (CCBH).
- Illicit discharge investigation locations are listed in **Table B6**.
- Observations collected during field work are summarized in **Table B7**.

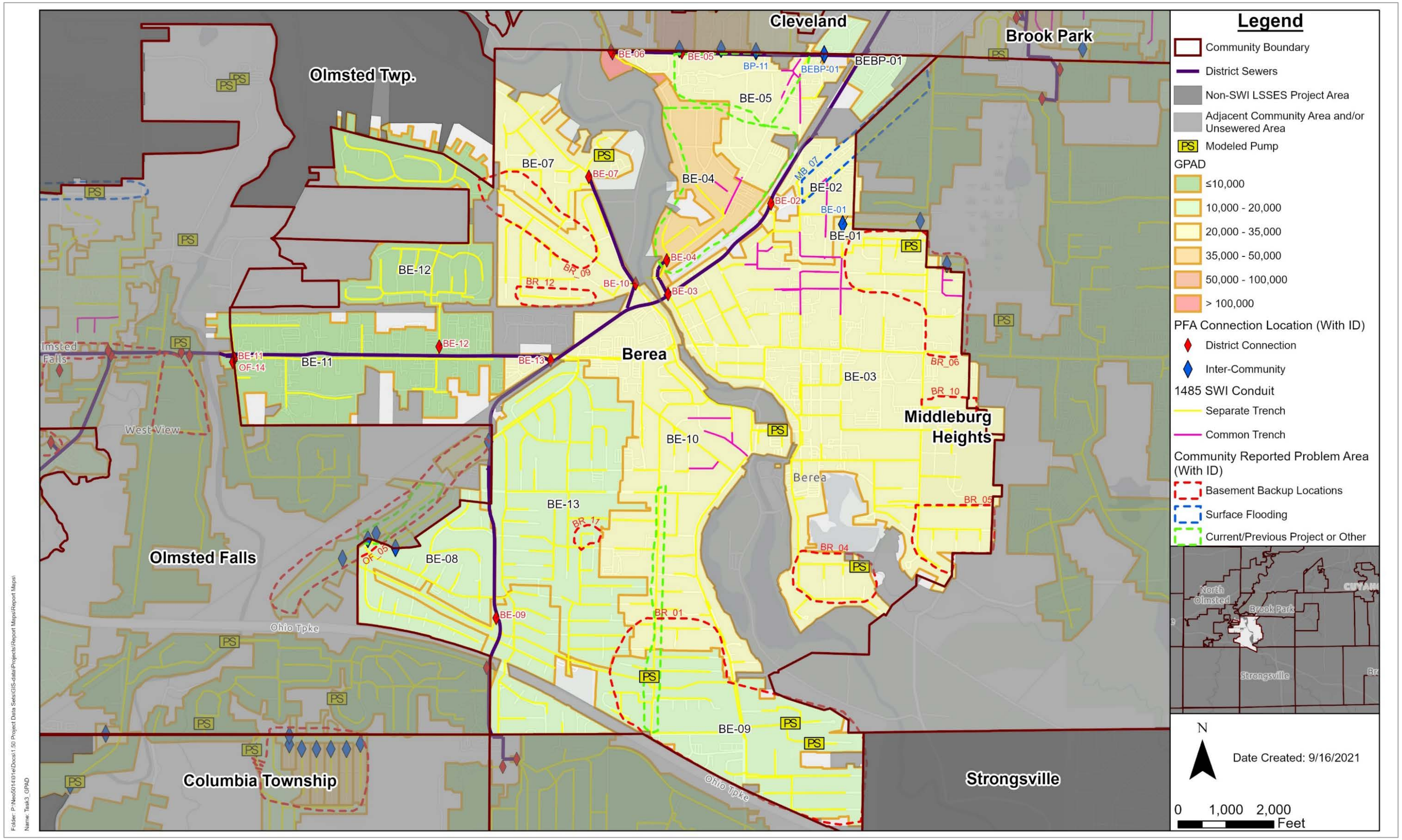
Appendix C – Local Sewer Hydraulic Profiles

Appendix C includes local sewer system profiles for the 5-year, and 10-year, 1-hour rainfalls under existing conditions.

Appendix E – Modeler Analysis Notes

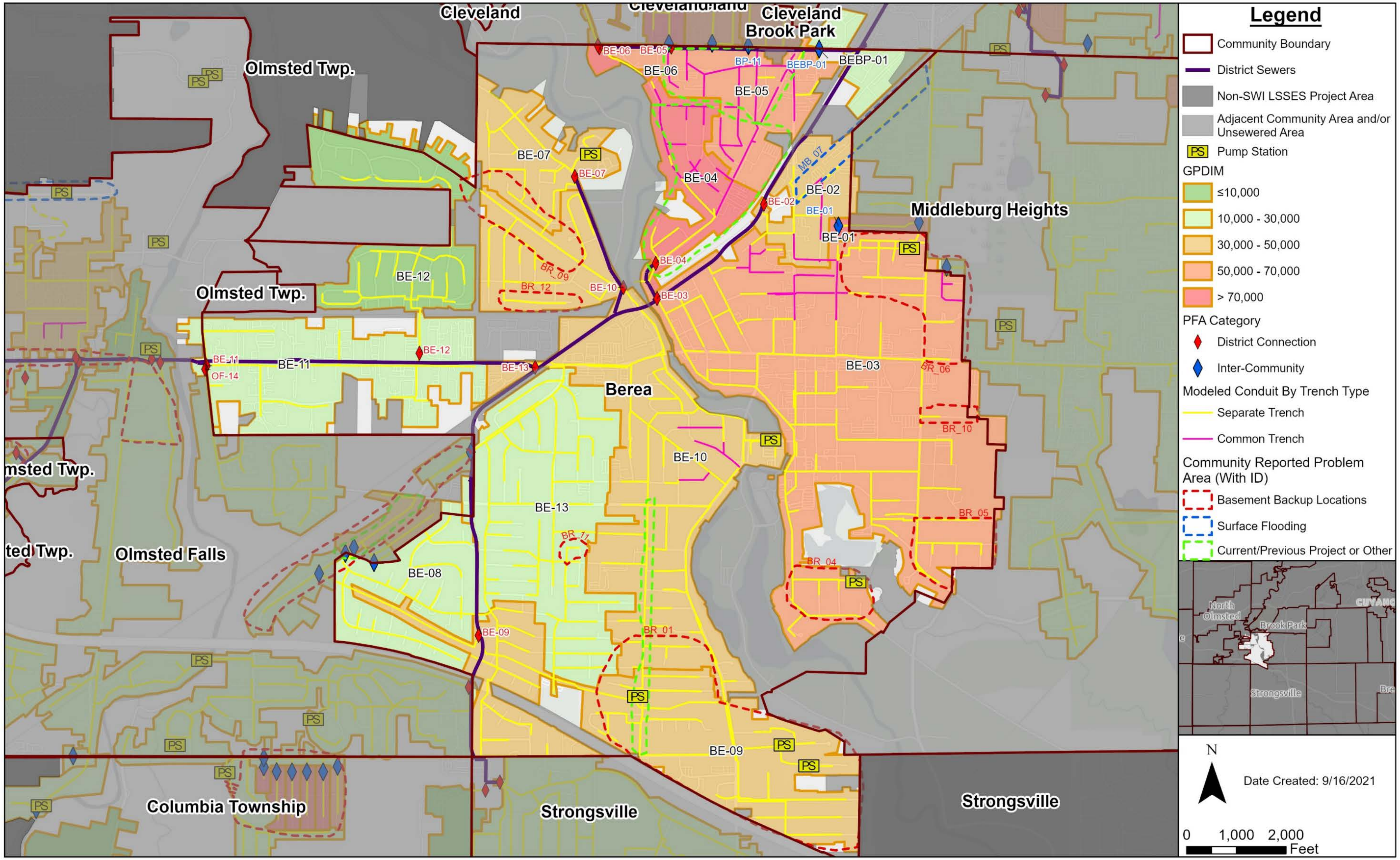
Appendix G – 5- and 10-Year Rainfall Performance Comparison

Figure 3-10. Peak Model Routed Sanitary System Flow Rates by PFA – 5-Year, 1-Hour Rainfall (GPAD)



GPAD: Gallons per acre per day

Figure 3-11. Peak Model Routed Sanitary System Flow Rates by PFA – 5-Year, 1-Hour Rainfall (GPDIM)



GPDIM: Gallons per day per sewer inch-diameter-mile

Figure 3-12. Modeled SSOs Projected Status – 5-Year, 1-Hour Rainfall

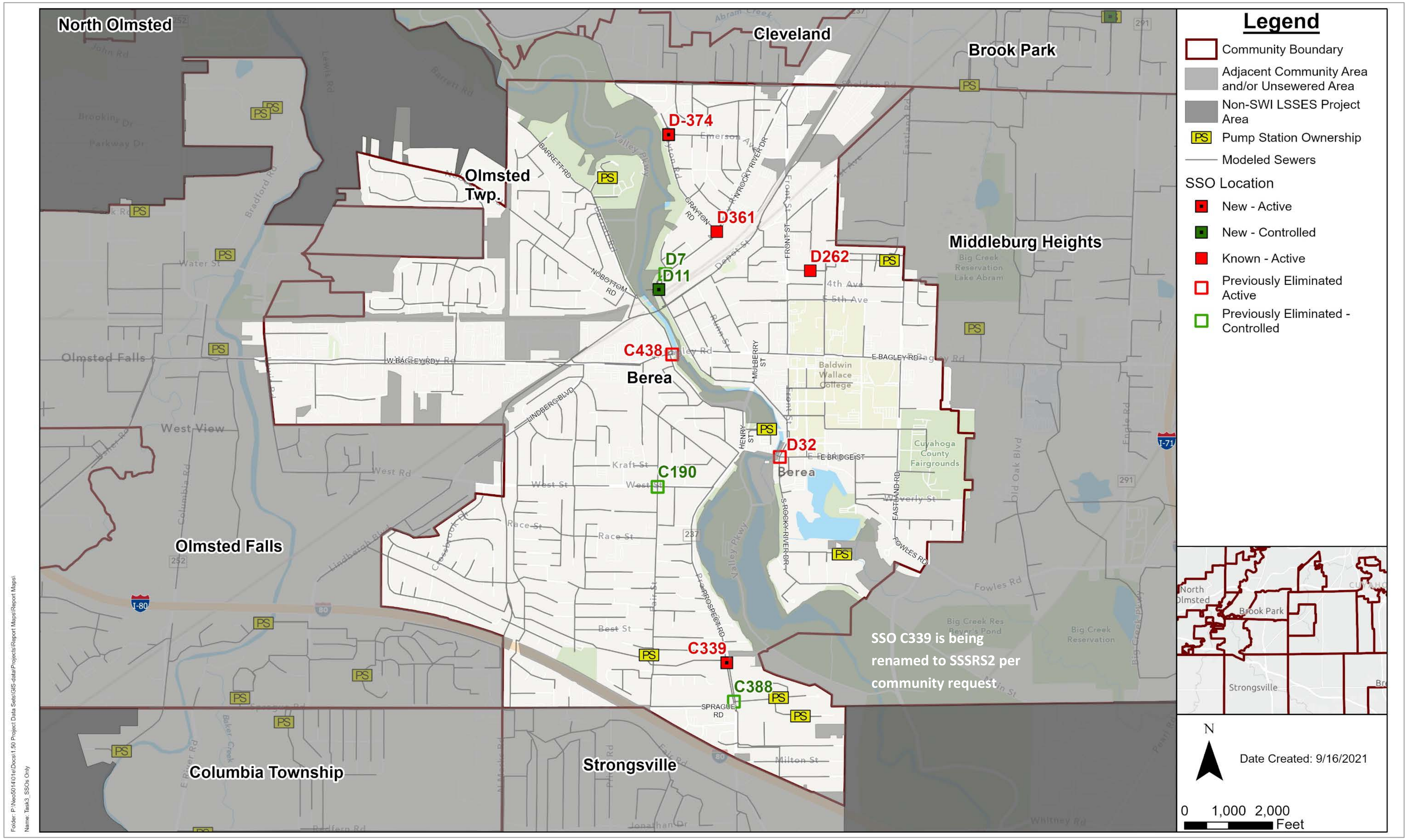
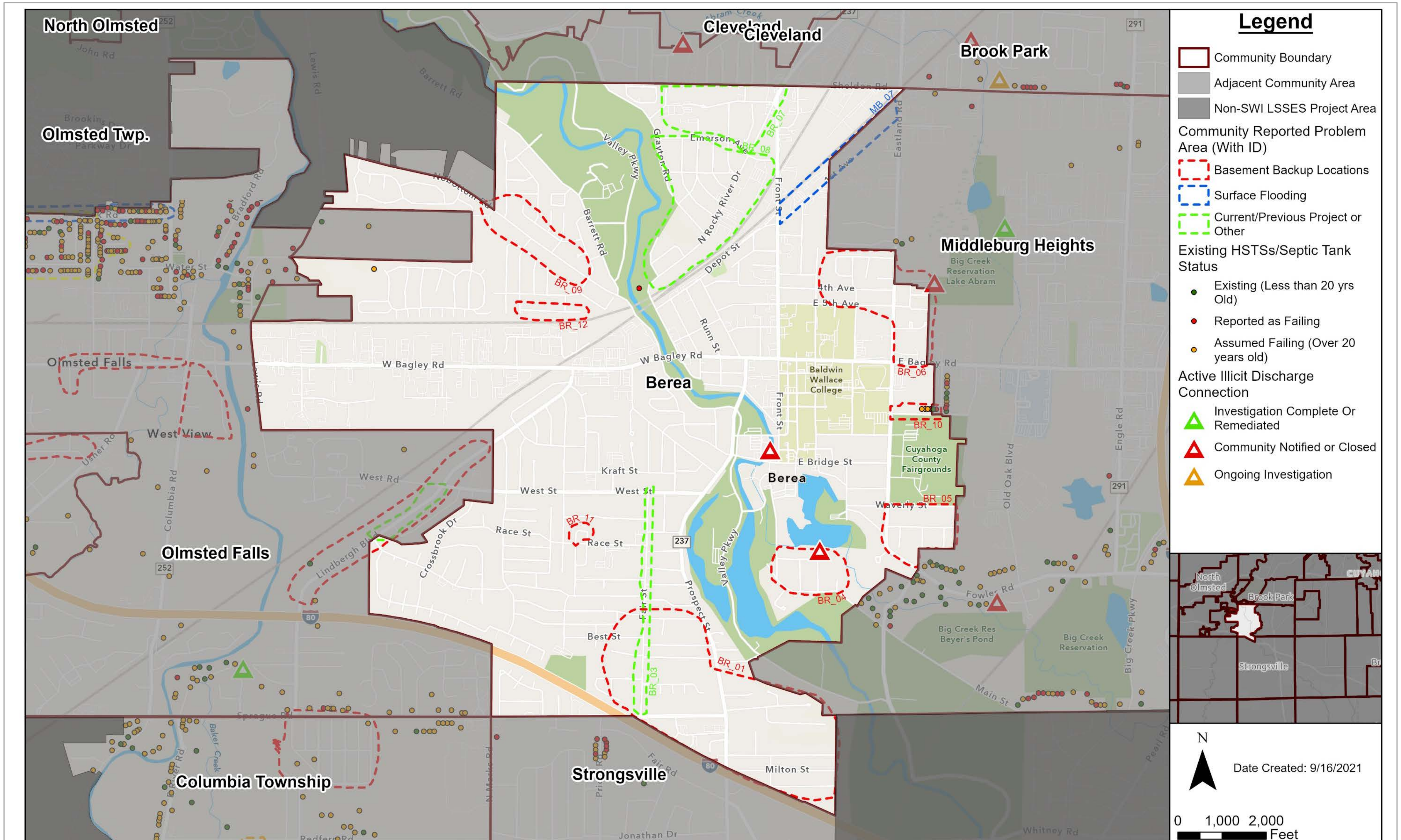


Figure 3-13. Berea IDDE and Failing HSTS Locations



IDDE: Illicit Discharge Detection and Elimination; HSTS: Home Sewage Treatment System

3.2.1 Reported vs. Projected Problem Areas

Berea reported 8 recurring BBU areas listed previously in **Table 2-1** and shown in **Figure 3-14**. Throughout the SWI-LSSES area, the reported problems often agree with other sources of information and analysis to help confirm the problems identified. In some instances, the analysis has projected performance problems where none have been reported, or the reported problems are not substantiated by the calibrated model projections. These inconsistencies likely arise from the approximate nature of the sewer system model, particularly in common trench areas, where the numerous sanitary/storm sewer crossflows and parallel storm sewers are not being explicitly modeled. Communities may wish to update the problem areas if additional reports are received by providing updated information to the District watershed team leader.

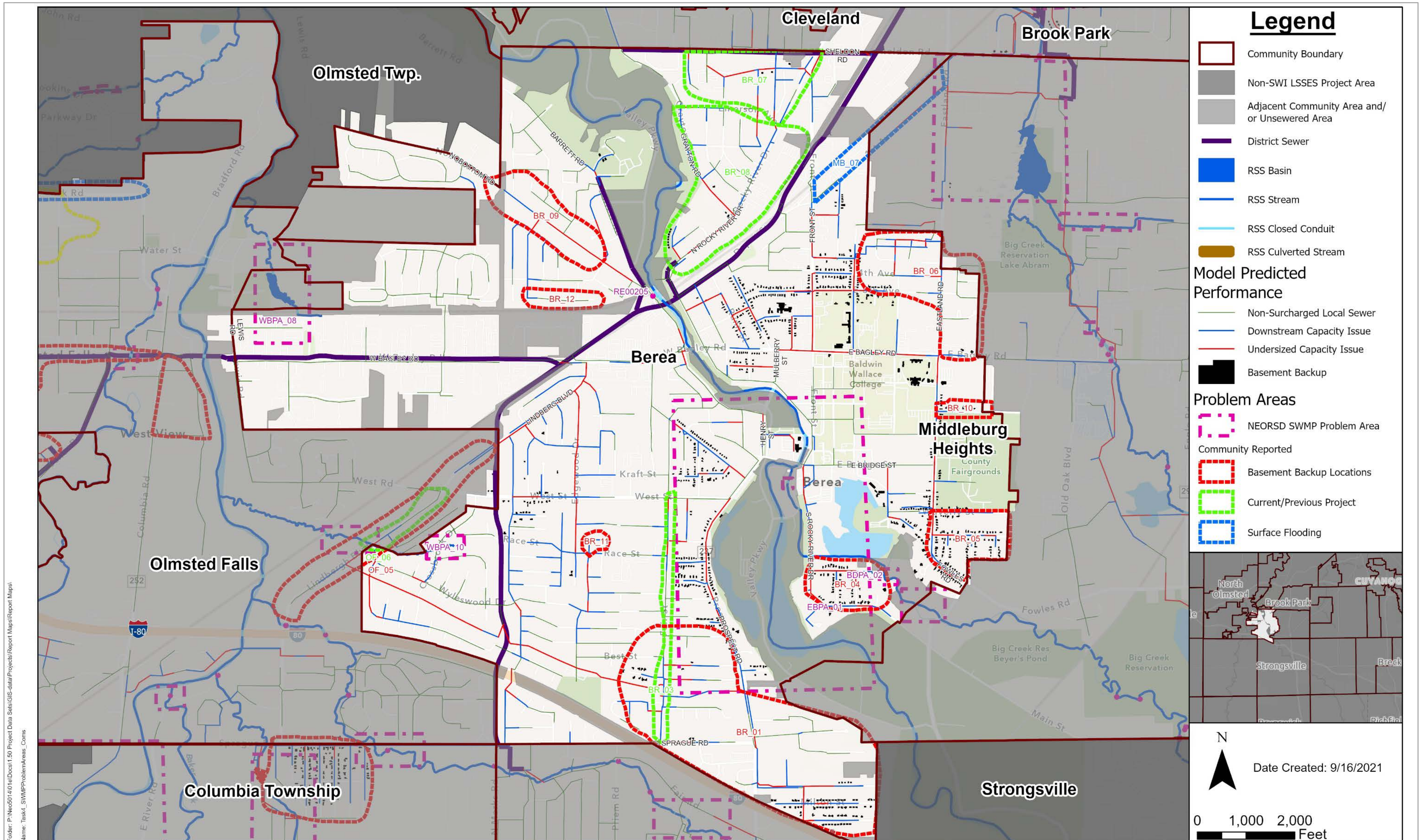
In common trench areas, it is suggested that the pipe system crossflows and the sewer and service lead exfiltration to pipe trenches may be providing a significant storage volume outside the pipe. This may be limiting actual peak wet weather HGLs experienced in the system and may be one reason why the modeled system may appear to react more severely to wet weather I/I than the actual system because the model does not account for this storage. This concept also suggests the following considerations:

- Preliminary design activities should perform testing to determine and quantify the sources of I/I, which may include direct infiltration and/or inflow sources on private property.
- Proposed improvements in problem areas that include new sanitary sewers or rehabilitation of existing sanitary sewers should remove I/I, provide adequate capacity or storage for peak flows, or some combination of these to avoid creating problems that could potentially arise from sealing the sanitary sewer when high wet weather flows may be originating on private property or in another upstream location.
- Reducing/controlling known BBUs and active SSOs and improving areas with significant I/I are generally considered to be the highest priorities for proposed improvements, but sewage/stormwater crossflows, while often not readily apparent, may be causing significant contamination of stormwater flows in some common trench systems. Preliminary design investigations for potential improvement projects should determine how the two systems interact to develop successful projects that cost-effectively improve both hydraulic performance and water quality.

3.2.2 Stormwater Master Planning

The District completed stormwater master planning (SWMP) studies as part of the Regional Stormwater Management Program (RSMP). Primary stormwater planning objectives included inventory of regional stormwater assets, identification of improvements to address structural issues, and development of conceptual plans for flooding relief where identified in the SWMP area. The program did not specifically address stormwater-related issues in the local community system but did evaluate the capacity of nearby regional stormwater assets to handle local stormwater flows for Berea. **Figure 3-14** provides an overview of the District's regional stormwater assets and SWMP problem areas relative to the LSSES reported problem areas and model-projected BBUs and surcharged sewers. Berea is included in the Rocky River SWMP project area. The SWI-LSSES project documented SWMP findings with respect to potential sanitary sewer system improvements to help identify opportunities for coordinated projects that may improve performance of both systems and reduce overall cost. Communities are also encouraged to review available SWMP information in conjunction with future local sewer system improvement projects to identify integrated planning opportunities.

Figure 3-14. SWI-LSSES Projected Problems Near District SWMP Problem Areas



3.2.3 Problem Summary

The Berea sewer system exhibits reported and model-projected performance problems including sewer surcharging and associated BBUs. The reported BBU areas generally coincide with model-projected surcharging/flooding areas. **Table B4** in **Appendix B** summarizes the reported and projected problems by PFA. **Figure 3-14 and Figure A4** in **Appendix A** provide an overview of these areas. Berea has 7 remaining active HSTSs, of which two are reported to be failing based on inspection, and the remaining six HSTSs installed prior to 1999 (greater than 20 years old) or listed as "unknown installation date" may also be at risk of failing. These are summarized in **Table B5**. **Table 3-2** summarizes system performance problems relative to the number of PFAs. **Table ES-4** in the executive summary and **Table B2** in **Appendix B** provide added detail for Berea PFAs.

Table 3-2. PFA Performance Problem Summary

Issue	# of PFAs Impacted	% of Total PFAs[3]	Comments
Community-Reported Problems	9	64%	Areas identified in meetings with City
Common Trench Sewers	6	43%	City served by primarily (18%) common trench standard sewer system
Active SSOs[1]	5	36%	6 of 10 existing SSOs are projected to be active SSOs during the 5-year, 1-hour rainfall
Model-Projected Surcharged Sewers[1, 2]	12	86%	Approximately 169,000 LF or 55% of total modeled sewers
Model-Projected BBUs[1, 2]	8	57%	10% or 700 of the approximate 6,700 buildings with basements (per the Cuyahoga County parcel records) are projected to be at risk
Illicit Discharges and Active Septic Areas	1	7%	Reference **Table B5** in **Appendix B** for a HSTS inventory, and **Table B6** for illicit discharge investigation locations
No Identified Issues	2	14%	These include: PFAs BE-01; BE-11

[1] *As projected by the hydraulic model for the 5-year, 1-hour rainfall*

[2] *Modeled sewers represent 82% (59 miles) of total local sewer length*

[3] *Based on 14 total PFAs*

3.2.4 Potential MCIP Candidate Project Areas

The District MCIP funding program is assisting member communities in addressing water quality and quantity issues associated with sewer infrastructure that adversely impact human health and the environment. Additional details are available at the following website.

https://www.neorsd.org/community/member-community-infrastructure-program-mcip/

The District issues an annual request for proposals (RFP) to communities interested in applying for grant funds. Design and construction of improvements to address problems identified in this report section are potential candidates for MCIP funding. Applications/proposals are typically due in late spring for a successive year start if awarded.

3.3 ADDITIONAL FIELD OBSERVATIONS

Sewer system CCTV inspection data developed by the SWI-LSSES project has been reviewed to summarize significant field observations. Relevant findings are highlighted in **Appendix A** of this report including maps that show inspected pipes identified with NASSCO PACP grade 3 or above condition code for roots, deposits, debris, or Fats, Oils and Grease (FOG). Examples include:

- Debris buildup including dirt, grit, gravel, and paper products
- Root intrusion through open pipe joints or structural cracks in the pipe, as well as from or within private house laterals
- Fats, Oils and Grease (FOG) buildup that can originate from Food Service Establishments or residences

The SWI-LSSES project recorded other field observations in the ArcGIS online system that were visible from the surface, such as buried or cracked manholes, clogged catch basins, and general cleaning needs. These observations are identified in **Figure A3** in **Appendix A** and summarized in **Table B7** in **Appendix B**. A complete summary of field observations is documented in the *Task 2 – Local System Inspection and Condition Assessment Report – July 2021*. The most current field observations from the project work orders are available for review in the District's ArcGIS Online platform.

3.4 ONGOING AND PROPOSED IMPROVEMENTS

Berea has been contracting with the Cuyahoga County Department of Public Works (CCDPW) to perform rehabilitation projects in the collection system. Projects include septic conversion projects, lining of mainline sewers, and lateral reinstatement in the right-of-way. Locations of recently completed projects are shown in **Figure 3-15**.

Berea completed a phased SSES project in the north end of the city, east of Grayton Road (east of the Rocky River East Branch) and north/northwest of N. Rocky River Drive. The City has completed rehabilitation on the local sanitary system for the Phase 1 portion of area as part of a 2017 MCIP project and is underway with Phase 2 of the work as part of a 2020 MCIP project. The Phase 1 portion is shown in **Figure 3-15** as a completed project and both areas are shown in **Figure 3-16**. Post-construction flow and rainfall monitoring in these project areas would support community and District understanding of the benefits of various types of system rehabilitation.

Figure 3-15. Previous Rehabilitation Work

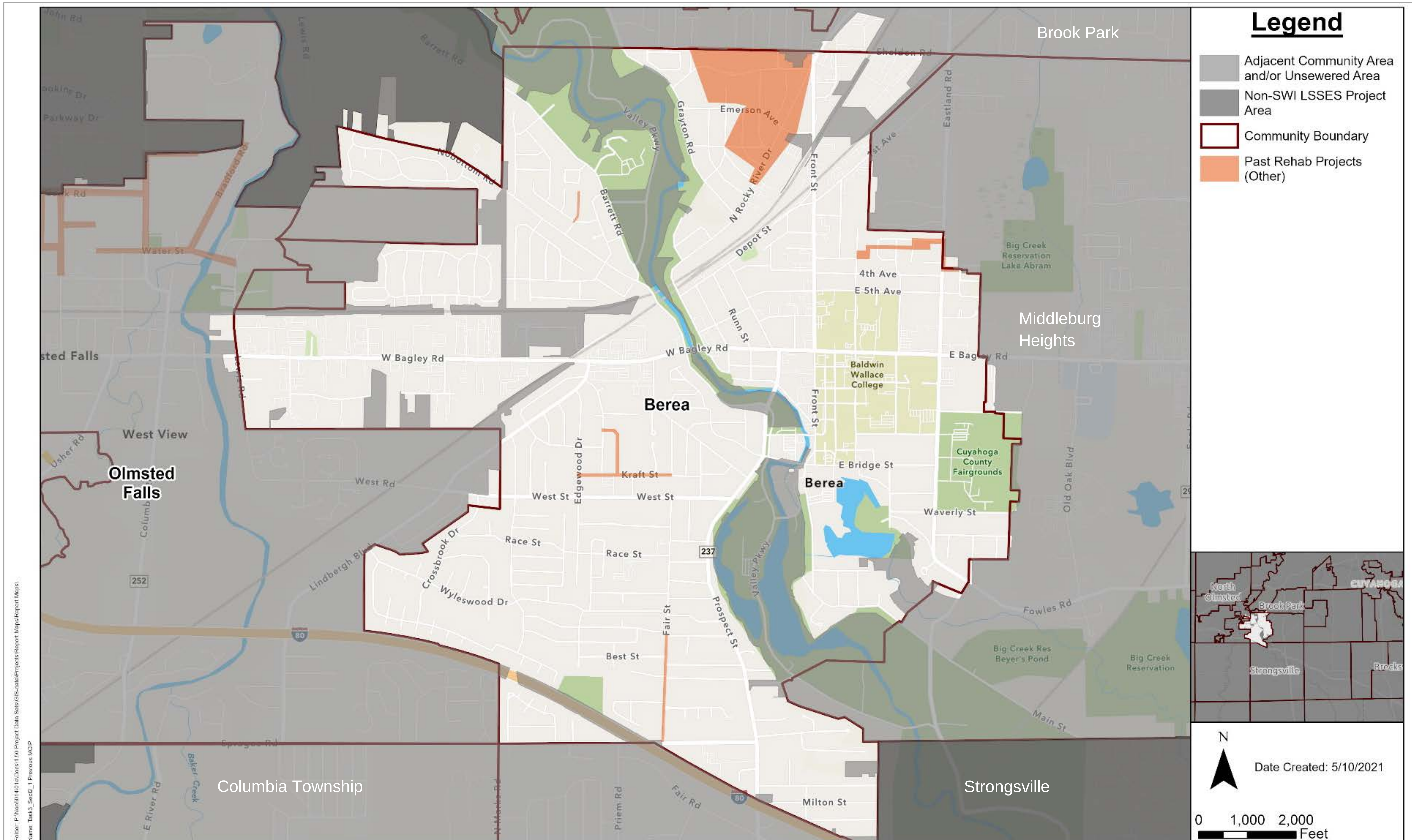
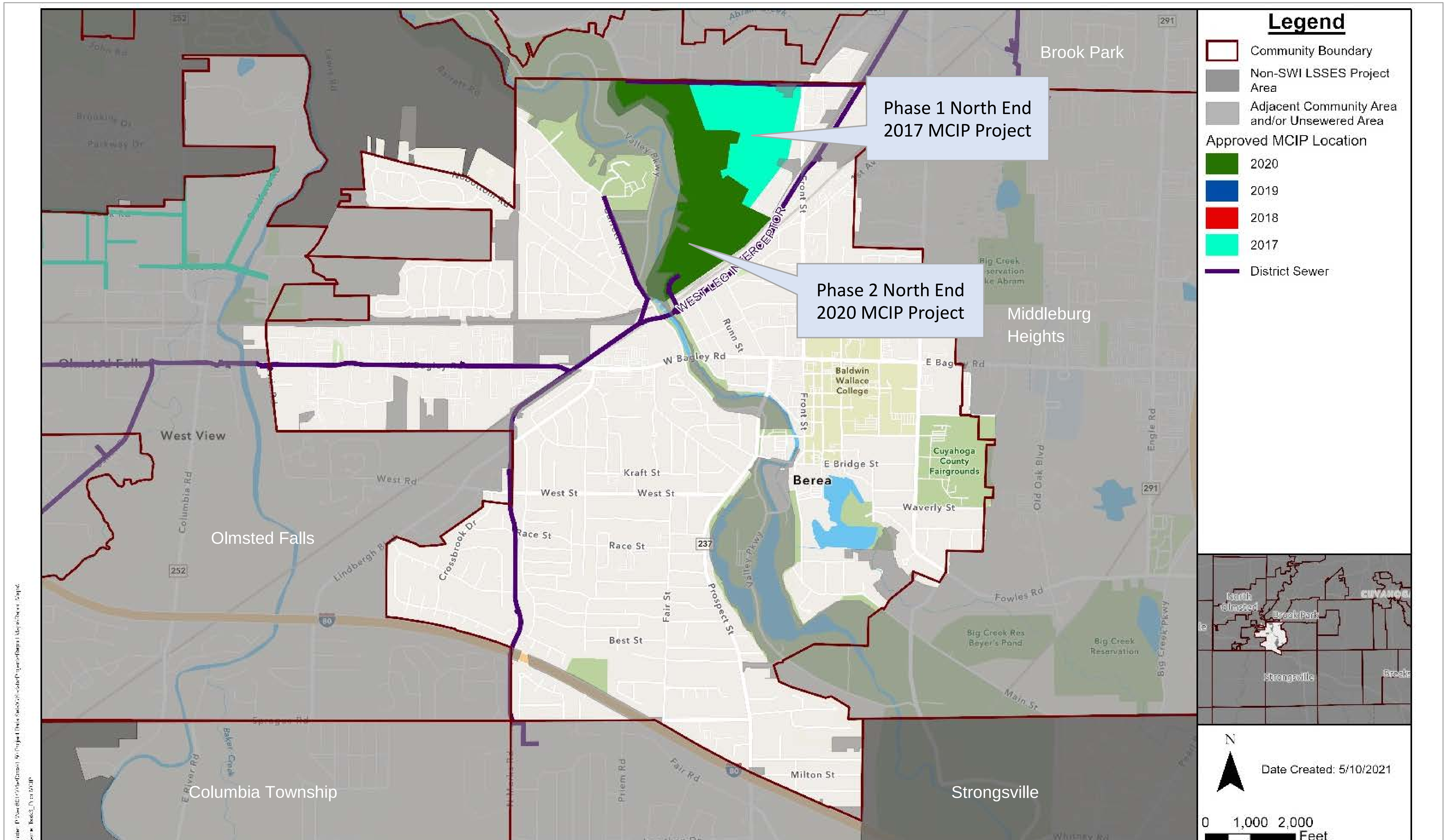


Figure 3-16. North End Phase 1 and Phase 2 MCIP Project Areas



4.0 ALTERNATIVES DEVELOPMENT AND OPTIMIZATION

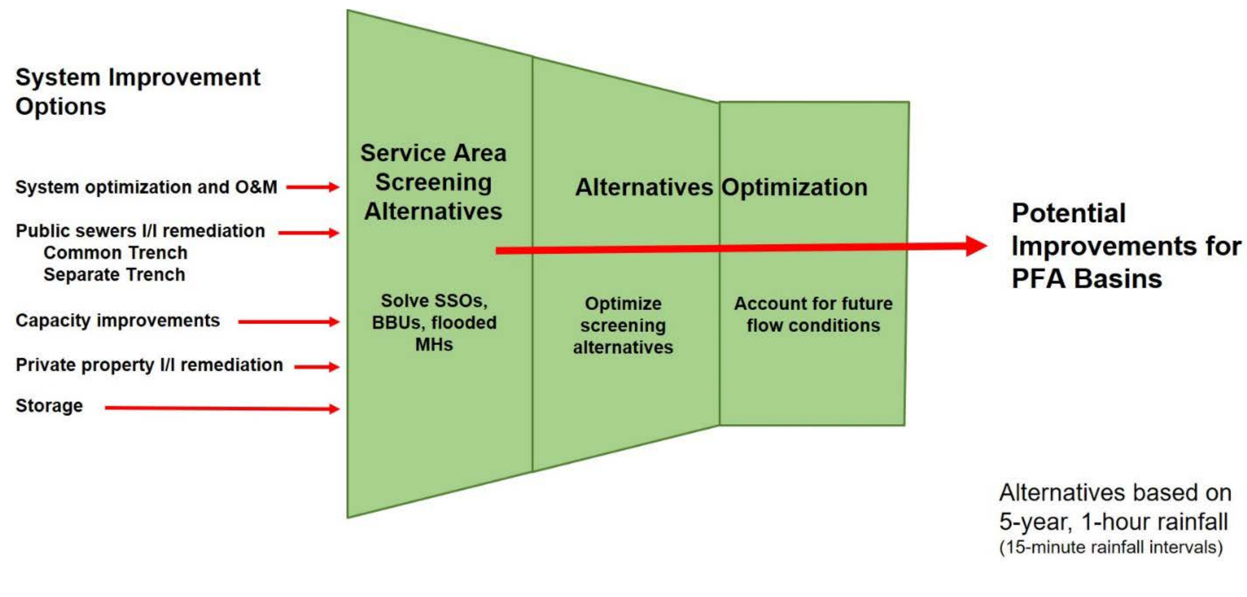
This section summarizes the approach for the development and analysis of sewer system improvement alternatives by PFAs, including the following:

- Alternatives Development and Optimization Approach
- System Improvement Options Considered
- Modeling of Sewer System Improvements
- Planning-Level Cost Development
- System and Community Screening Alternatives

4.1 ALTERNATIVES DEVELOPMENT AND OPTIMIZATION APPROACH

A progressive approach was used to develop potential solution alternatives that address the reported and projected problems identified in each community. The approach includes screening alternatives development, further optimization of those alternatives, and refinement of potential solutions to identify feasible, cost-effective planning-level improvements for each affected PFA. **Figure 4-1** illustrates the approach.

Figure 4-1. Alternatives Development and Optimization Approach



Screening Alternatives

The first step in this process was the development of three screening alternatives that control all reported and projected SSOs, BBUs, and flooded manholes within the study area for the 5-year, 1-hour rainfall. Screening alternatives include the following:

- Capacity improvements alone
- Sewer system rehabilitation in high I/I areas with capacity improvements where needed
- Sewer system rehabilitation in high I/I areas with private property I/I reduction and capacity improvements where needed.

In this step, system improvement options consistent with these base alternatives were applied where needed across the system to mitigate the reported and projected problems, and then checked with the calibrated hydrologic/hydraulic model to confirm performance. **Section 4.2** describes the system improvement options considered. The screening alternatives provided performance information, such as resulting peak flow rates and cost information for comparison and helped guide how the proposed improvements may be further combined and optimized in successive analysis. **Section 4.5** presents the screening alternatives in more detail.

Alternatives Optimization

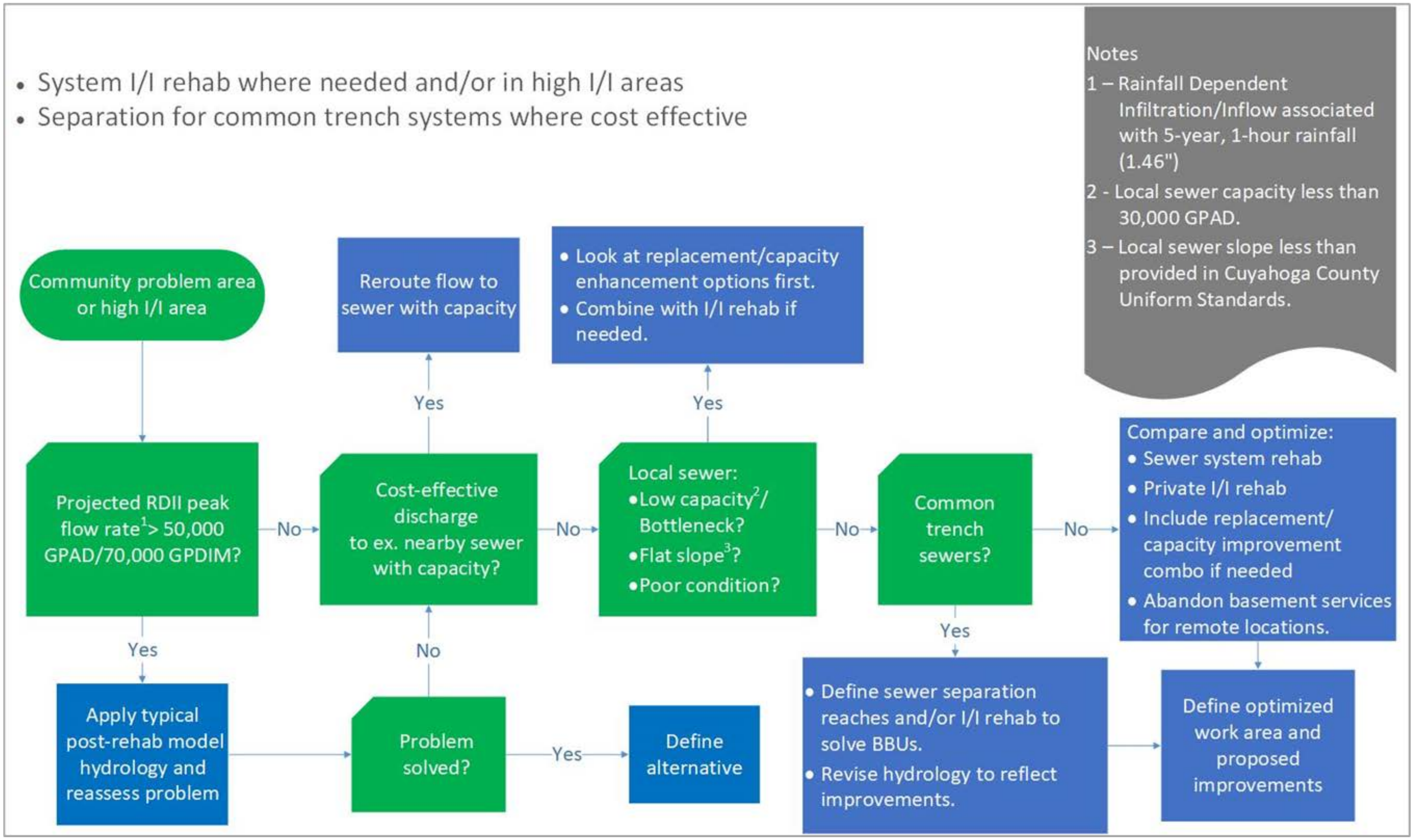
Subsequent analyses used the information developed during screening alternatives to further optimize the planning-level system improvements based on the following:

- Hydraulic performance parameters including peak flow rates and HGL levels were used with costs to compare effectiveness of various system improvement options described in the following section.
- Potential nearby existing spare capacity in local and/or District sewers was considered to minimize need for/length of relief sewers. For example, SSOs were routed to nearby District or other local sewers with spare capacity where feasible.
- Opportunities were considered to combine one or more neighboring PFAs in a common solution to reduce cost and/or disruption.
- Areas with excessive wet weather I/I flows were considered for public sewer and/or private property rehabilitation. Common trench systems were considered for replacement/separation, particularly if capacity improvements are needed.
- Areas of excessive I/I were considered for private property I/I reduction, particularly if the area tested positive, or is suspected to have high private I/I flows based on anecdotal information and/or building age.
- Private I/I reduction was also considered in areas where common trench rehabilitation/separation area available may not provide adequate performance improvement.

- Potential/planned community development to add or redistribute flows to District sewers were included to account for future flow changes.
- **Appendix E** includes PDF slide files created by the modelers as analysis notes that summarize alternative optimization considerations. The final improvements presented in this report may have been updated or adjusted during final optimization efforts and may not exactly match the analysis notes presented in **Appendix E**.

Figure 4-2 provides an overview of the process used to analyze and optimize proposed improvements in community PFAs.

Figure 4-2. Alternatives Optimization at PFA Level



4.2 SYSTEM IMPROVEMENT OPTIONS CONSIDERED

A range of system improvement options was considered to provide adequate capacity and/or reduce peak wet weather flows during the design rainfall, thereby controlling BBUs and SSOs. Typical system improvement options are discussed in approximate order of consideration. More detailed descriptions of many of the improvement options are provided in the *Project Cost Opinion Development for LSSES Improvement Alternatives Analysis Technical Memorandum, Revision 2, September 2018*, included as **Appendix F**.

Existing System Optimization

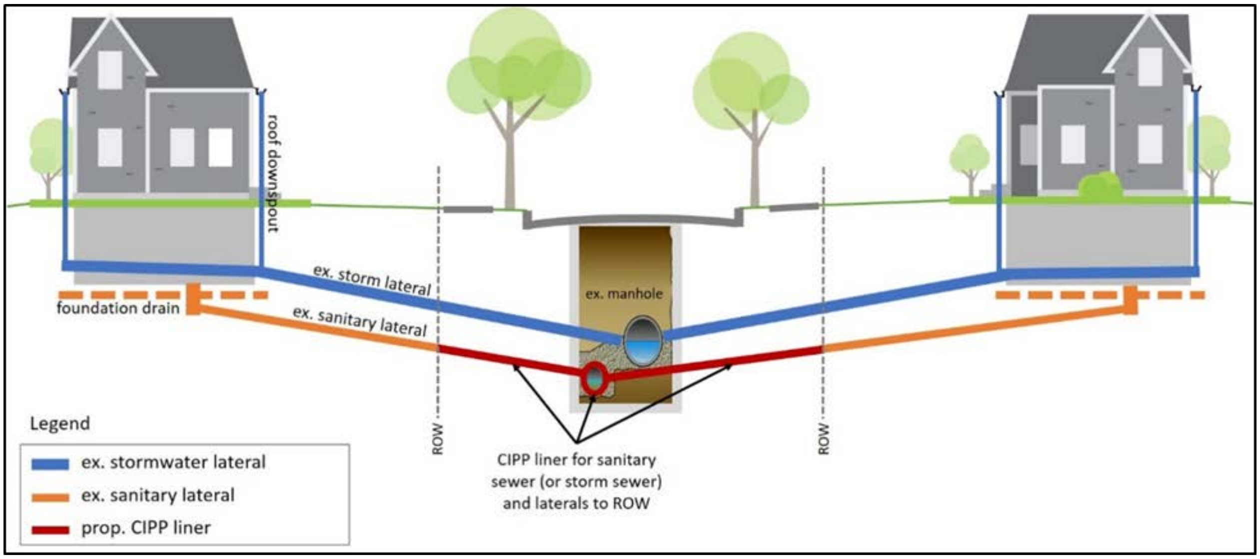
Optimization of the existing system looks for simple, low-cost improvements that control SSOs and/or BBUs and reduce pollution by either maximizing use of existing available capacity, or perhaps removing a localized bottleneck. Examples may include:

- O&M activities to remove roots or other obstructions or debris.
- Repairing system structural problems to improve reliability.
- Modifying an existing diversion structure to divert excess wet weather flow from a problem area to a portion of the system with available capacity.
- Raising SSO weir or activation pipe elevations to control activations during the 5-year, 1-hour rainfall while maintaining acceptable system HGL elevation. This can include modifying weir heights, offset pipes, or other diversion features, including at SSOs. These modifications are relatively simple and inexpensive and take advantage of available system hydraulic capacity.

Common Standard Manhole Trench Rehabilitation (Public ROW)

In high I/I common standard manhole systems in good structural condition, sewer system and service lateral rehabilitation using cured-in-place-pipe (CIPP) lining may be a feasible improvement option to reduce I/I in the public ROW. Rehabilitation may potentially target the sanitary or storm sewer system. If pre-design investigations determine that most of the I/I is originating in the public ROW, this may be the preferred option in these systems. This may be an important consideration, because if significant I/I is originating upstream of the pipe/service lead rehabilitation areas, making the system more watertight in the public ROW could potentially worsen any existing surcharging problem. This is because the existing system likely allows flows to exfiltrate, and the improved system would not. **Figure 4-3** shows a common trench sanitary sewer rehabilitation concept.

Figure 4-3. Common Trench Rehabilitation



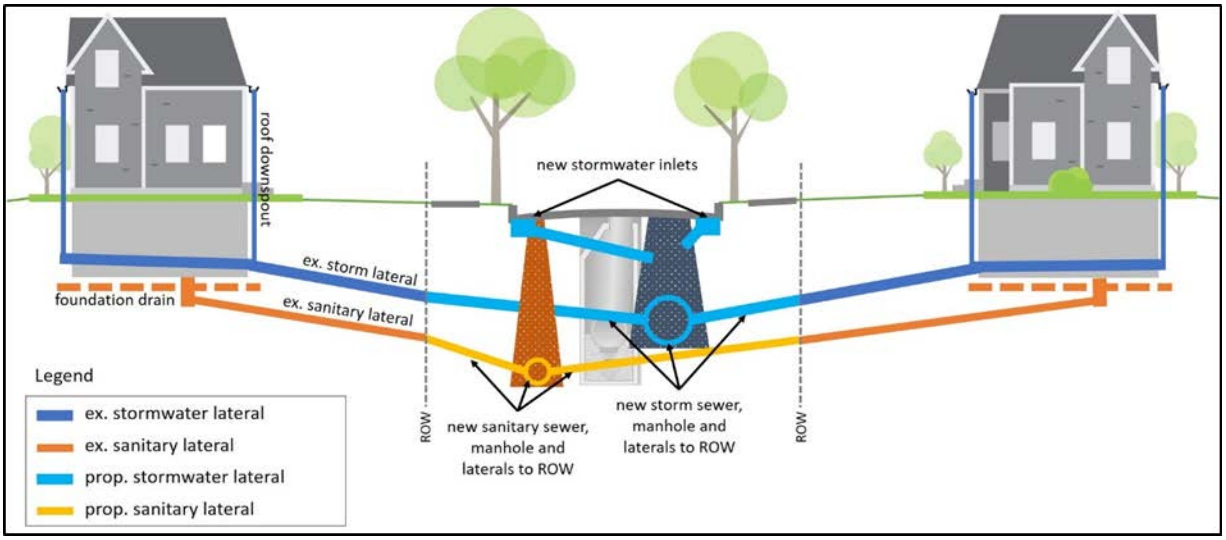
Common Trench Separation

Common trench separation may be indicated if either the storm or sanitary sewer is in poor structural condition, and common trench sewer rehabilitation is impractical. Two concepts have been identified for common trench separation.

Option 1- Replacement of Storm and Sanitary Sewers

The option to replace both storm and sanitary sewers and all service laterals in the public ROW has been implemented in several District communities with mixed success, presumably because a significant portion of sanitary sewer I/I is generated on private property. **Figure 4-4** shows the separation concept to replace all sanitary sewage and stormwater piping in the ROW. This option would be most applicable when the storm and/or sanitary sewers and service laterals are in poor condition and nearing the end of their useful life, or if sewer system rehabilitation is impractical for some other reason.

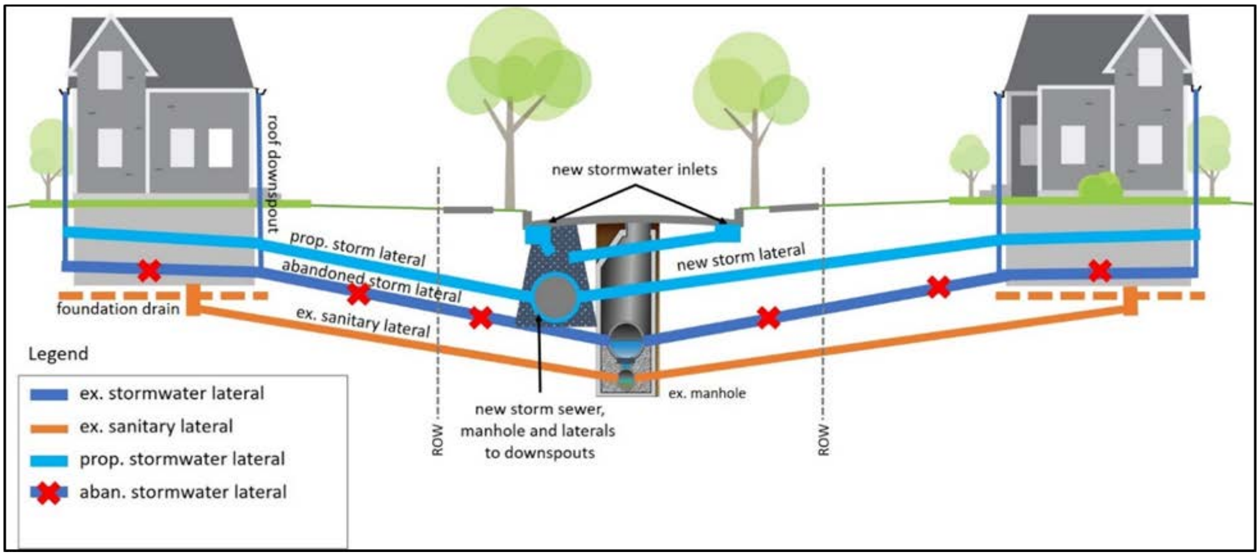
Figure 4-4. Replacement of Common Trench Sewers and Service Laterals



Option 2 – Stormwater Separation

Stormwater separation would construct a new storm sewer in the public ROW, and new stormwater service laterals in the public ROW and on private property to collect water from all roof downspouts as feasible. This option seeks to collect and transport stormwater without crossflow to the sanitary sewer system and to maintain new construction as shallow as feasible. The existing common trench system would remain as the sanitary sewer system. **Figure 4-5** shows the stormwater separation concept. This option would be applicable for common trench systems where the existing piping is in good structural condition, and where private property I/I is significant. It would also be appropriate in areas where stormwater drainage capacity is inadequate and would allow for construction of increased capacity where needed.

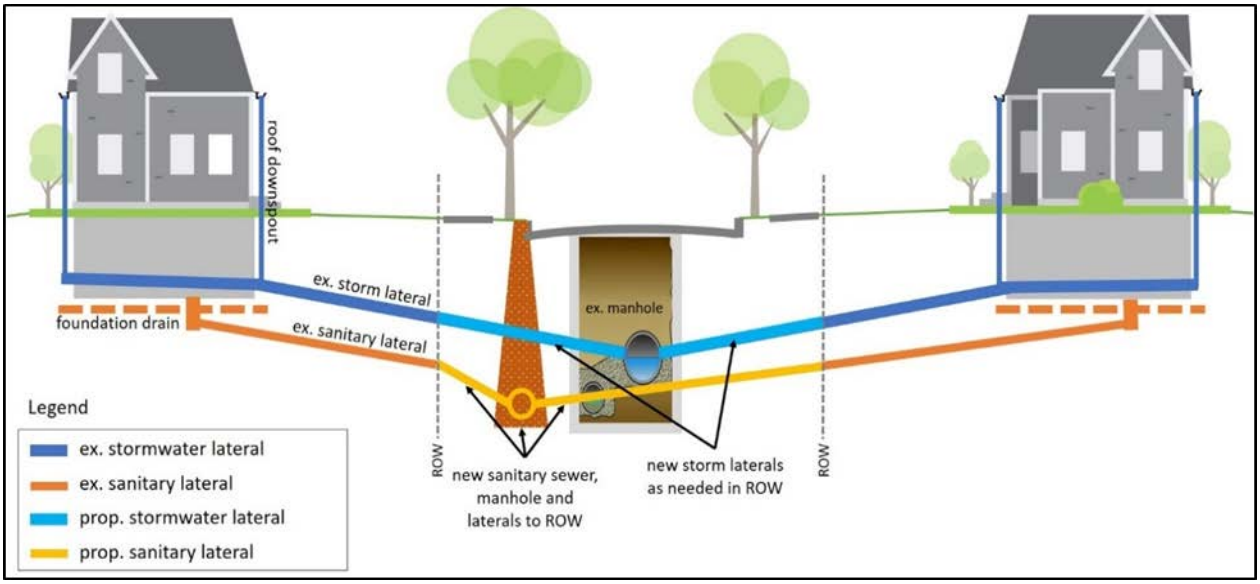
Figure 4-5. Stormwater Separation Concept for Common Trench Areas



Hydraulic Capacity Increase and/or New Flow Connection

In some areas, additional sanitary sewer capacity may be needed to prevent sewer system backups and/or SSOs even if system rehabilitation is completed. This may be most likely in areas where high private property I/I is infeasible to remove. In some PFAs, new sanitary sewers may also be indicated to reroute some or all the flow from one system that is overloaded to another with spare capacity. Increased sewer capacity can be constructed in conjunction with common trench remediation or on its own to relieve overloaded systems. **Figure 4-6** shows a new sanitary sewer improvement concept.

Figure 4-6. New Sanitary Sewer to Increase Capacity and/or Reroute Flow



Private Property I/I Remediation

Some areas have significant I/I that originates on private property. In these areas, the most cost-effective solution may involve reducing I/I on private property. Remediation of I/I on private property may require some communities to develop/adopt ordinances that require control of I/I on private property and allow for this work. Berea ordinances prohibit clean water discharges to the sanitary sewer system. Typical I/I control methods used on private property include pipe rehabilitation and replacement.

Suburban communities with larger lots may find low-cost options, such as discharging downspouts to grade, to be effective and acceptable. Other more densely-situated parcels in urban neighborhoods may not allow for this due to potential surface drainage problems. In these areas, I/I mitigation may likely involve replacement or trenchless rehabilitation of stormwater and/or sanitary service laterals to eliminate I/I. This work may need to be completed from the downspouts to the public sewers to be effective. If stormwater piping is replaced, new piping may often be constructed shallower than the existing stormwater lateral.

Conditions at each parcel may vary widely due to original construction quality, piping connectivity, materials, and owner maintenance. Private property dyed water testing and service lateral CCTV inspection are typically required at each property to assess presence and likely quantity of I/I, and to determine the cost-effective I/I control approach. Typical methods for reducing private property I/I include:

- New sanitary and/or stormwater service laterals - new shallower stormwater piping may help reduce cost and disruption
- Trenchless construction methods, such as pilot tube microtunneling, may be effective to install new service laterals with minimal disruption. More information is available online:
    - https://trenchlesstechnology.com/pilot-tube-microtunneling-catching-on-in-the-united-states/
    - https://www.ncpi.org/assets/PTMT%20D%20Gill-%20Rocky%20Mountain%20Trenchless%20Journal%202010.pdf
    - http://www.nadapacific.com/guided-boring.html
- Re-pitching eaves troughs may help redirect roof water to minimize trenching in heavily-landscaped areas
- CIPP lining of laterals if in acceptable condition
- Discharge of roof water to engineered rain gardens with shallow overflow piping or swales

Groundwater I/I

Anecdotal information from local engineers and plumbing contractors suggests that local SWI community groundwater levels are not typically problematic but may be significant in some areas. A plumbing contractor has indicated that in some SWI areas clay waterstops were used in the trench surrounding private service laterals to prevent sewer trench water from migrating toward building foundations during wet weather. Potential solutions need to consider local groundwater conditions in areas where prevailing groundwater levels are known to reach local sewer system and foundation drain elevations during wet weather conditions.

Defects in private stormwater laterals may also allow significant rainwater to migrate to sanitary service leads and/or foundation drains. In these instances, stormwater laterals may be rehabilitated or replaced as indicated by onsite inspection to eliminate the I/I sources.

Separate Sewer System I/I Remediation

Berea is served by primarily by separate trench and limited common trench sewers. Mitigation of high I/I flows and/or sewer system surcharge and BBU problems in separate trench areas, however, may involve rehabilitation of sanitary sewers and service laterals similar to that shown in **Figure 4-3**.

Storage of Peak Wet Weather Flows

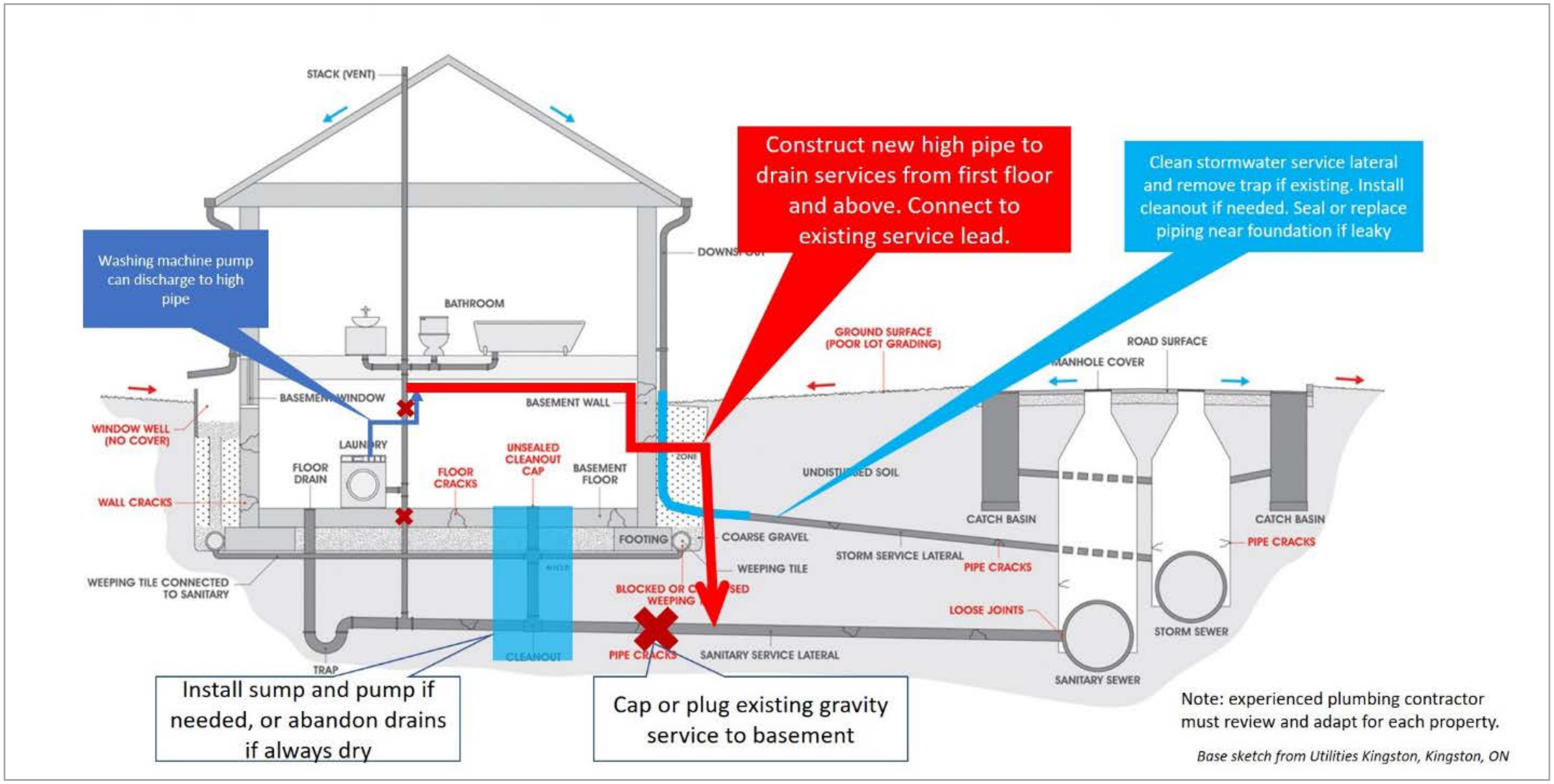
Inline or offline flow detention storage facilities may be considered where other alternatives, such as I/I reduction and/or capacity improvements, are infeasible or not cost-effective, or to provide increased level of service. Inline systems that are self-cleaning would typically be preferred over offline systems that may require pumping of influent or effluent flows and significant maintenance after wet weather events.

In cases where new piping is already proposed either to provide adequate capacity or repair failing infrastructure, inline storage in oversized pipes can provide a significant level of service improvement to attenuate peak flows during larger rainfall events. This concept typically requires additional grade flexibility and some added depth to allow use of the pipe storage volume without raising the local system design HGL.

Localized Basement Service Abandonment

In locations where one or more homes are experiencing chronic flooding due to mainline sewer surcharging that is not easily addressed with more systemic solutions, replumbing to abandon basement gravity stormwater drainage and/or sanitary service may provide a low-cost solution. **Figure 4-7** shows a building re-piping concept that can be adapted to specific locations.

Figure 4-7. Basement High Pipe Reconnection Example



Pumping

Increased pumping capacity or new pumping facilities may be considered in local systems to address flat or low areas subject to surcharging and BBUs, or to service remote parcels converting from septic tanks to sewer service. Life cycle maintenance and equipment replacement costs should be considered in comparison to other feasible alternatives.

Green Infrastructure (GI)

For local projects that construct sewer system improvements in the ROW and/or on private property, stormwater control measures, such as rain gardens and ROW bioretention, may be considered with the project where feasible to both reduce stormwater runoff and improve runoff water quality. Potential GI improvements should be located to direct stormwater away from the sanitary sewer system and building foundations.

For large projects that involve significant new stormwater drainage improvements, or in cases where existing stormwater capacity is low, larger stormwater detention facilities may be constructed in conjunction with the sanitary sewer system improvements to improve performance in both systems.

4.3 MODELING OF SEWER SYSTEM IMPROVEMENT OPTIONS

Investigations in and analysis of SWI local systems have concluded that most of the identified problem/priority areas have relatively high rates of I/I with sources that are widely distributed in both the public sewer system and on private property. The project also found that peak projected 5-year, 1-hour rainfall aggregated flow rates in areas with at least 70% common trench sewers are highly variable, ranging from 3,900 GPAD to 229,700 GPAD. The area-weighted average SWI peak 5-year, 1-hour aggregated flow rate in predominately common trench areas is approximately 27,700 GPAD. The area weighted average SWI peak PFA 5-year, 1-hour aggregated flow rate for all trench types is approximately 14,100 GPAD. This would range higher in areas with a large proportion of common trench sewers.

Separate Trench System Peak Flow Rates

In the SWI-LSSES area, sanitary sewer peak 5-year, 1-hour flows in primarily separate trench sewer systems (at least 70% separate trench) were found to range from 1,800 to 233,500 GPAD (small areas), with an area weighted average of 10,100 GPAD. For comparison, in other communities, typical separate sanitary sewer peak wet weather flows in urban, single-family, residential areas often range from 5,000 to 10,000 GPAD for older systems with moderate I/I, based on previous studies.

Modeling of I/I Flow Reductions in Typical Systems

In typical separate trench sanitary sewer system I/I improvement alternatives analysis, a percent reduction or explicit modeling of inflow sources and the tributary runoff area to be removed is often used to simulate the improved conditions after I/I control/capacity improvement projects.

Modeling of I/I Flow Reductions in SWI System

Based on SWI system conditions and a review of sewer system rehabilitation projects completed in the study area, the typical system analysis approach was determined to be infeasible. This is because I/I sources were found to be numerous and widely distributed, and because pre- and post-construction flow monitoring information was generally not available for completed sewer system rehabilitation and separation projects. The approach used instead was based on actual residual I/I responses observed using micromonitoring in the completed SWI and HHI-LSSES rehabilitation project areas.

Based on the local system monitoring in the improvement areas and nearby unimproved areas, and comparison of the range of responses, the following assumptions were made to simulate the system improvements in each community for the 5-year, 1-hour design rainfall:

- Existing separate trench sewers in primarily common trench areas generate an existing peak flow response of 20,000 GPAD.
- Common trench rehabilitation and/or separation in the public ROW reduces peak flows to 35,000 GPAD. For example, in an area with 100% common trench sewers, the peak flow rate is reduced to 35,000 GPAD.
- In areas with mixed common and separate trench sewers, the peak flow rate was reduced based on trench type percentages. For example, after rehabilitation in the public ROW, an area with 70% separate trench (assumed response of 20,000 GPAD) and 30% common trench (assumed response of 35,000 GPAD) would have a remaining peak flow of 24,500 GPAD. Conversely, an area with 30% separate trench and 70% common trench would have a remaining peak flow of 30,500 GPAD.
- Common trench areas with private property I/I remediation in addition to public system rehabilitation, or private property remediation in separate trench areas would reduce peak flows to 10,000 GPAD. The private property response rates did not need to vary between separate and common trench types since the value applied to both.

These assumptions are summarized in **Figure 4-8** and **Table 4-1**.

Figure 4-8. SWI-LSSES Hydrology Assumptions for Modeling of Improvements

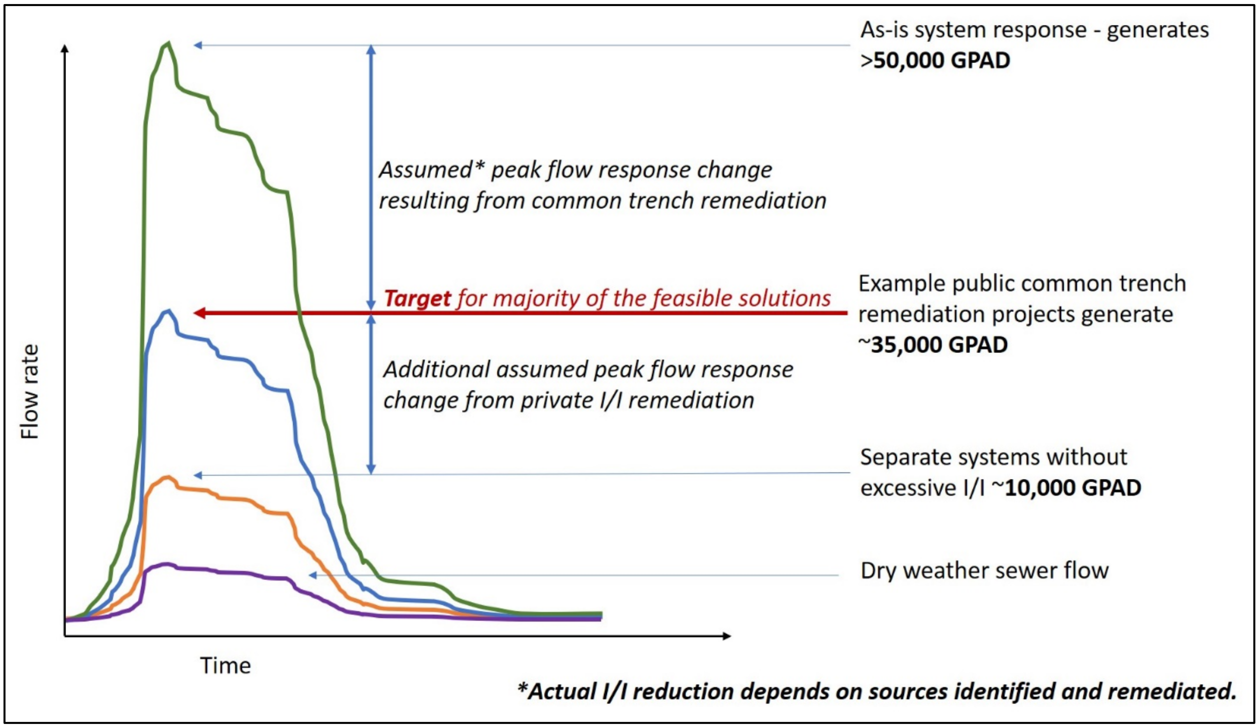


Table 4-1. Modeling Assumptions for Sewer System Improvements

System Condition	Common Trench Flow Response (GPAD)	Separate Trench Flow Response in CT Areas (GPAD)	Notes
Existing	Variable to over 500,000	20,000	Based on calibration flow monitoring
CT sewer rehabilitation or separation	35,000	20,000	Modeled catchment area weighted by trench type
Private property I/I remediation	10,000	10,000	Modeled catchment area weighted by trench type

4.4 PLANNING-LEVEL COST DEVELOPMENT

Construction and project costs have been developed at an approximate AACE[4] Class 5 planning level for sewer system improvement alternatives developed for the SWI-LSSES project. Class 5 costs were developed for concept screening and are indicated by AACE to range from 50% low to 100% high as compared to the actual cost. The cost opinions were developed to compare alternatives and provide preliminary costs for potential improvements, which may include the following:

- New sewers to control SSOs and/or provide adequate capacity for peak wet weather flow rates
- Sewer separation/replacement in common trench over/under (invert plate)
- Alternative stormwater separation within the public ROW and on private property
- Sewer system rehabilitation in common trench standard and dividing wall manhole areas using CIPP lining
- Illicit discharge remediation
- Correction of failing septic tanks

Class 5 construction and project costs were developed using previous District and local municipality construction project bid tabs and costing reports. Development of the estimated construction and project costs is summarized in the *HHI-LSSES Project Cost Opinion Technical Memorandum, Revision 2, September 2018*, included as **Appendix F**.

Construction costs were extracted from the project bid tabs and costing reports from 2010 to 2017, and an average unit price was calculated and escalated to 2018 costs. Escalation of the cost basis for the unit prices from the communities was updated to May 2018 using the *Engineering News-Record* (ENR) Construction Cost Index (CCI) of 12,325 for Cleveland. Future cost analysis may use the Cleveland CCI to escalate costs to current levels.

Total Project Costs

Project costs include construction, contingencies, design engineering, and construction engineering and administration costs. Engineering and administration costs for capital projects of similar complexity typically decrease as a percentage of construction cost with increasing project size and cost. **Table 4-2** summarizes standard assumptions for District design and construction engineering and administration updated during the 2013 Advanced Facilities Plan (AFP) project.

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[4] AACE – From AACE website: *The legal name since 1992 is AACE International. In 1956 the organization was established as the American Association of Cost Engineers. While you may have seen that "AACE" stands for the Association for the Advancement of Cost Engineering, this is only a statement that encompasses the work of the Association, not a legal name.*

Table 4-2. CSO AFP Professional Services Cost Estimates by Project Size		
Project Size (Construction Costs, $ Million)	Design, % of Construction Cost	CA/RE, % of Construction Cost
Up to 10	15	10
10 to 20	10	7
20 to 80	7	7
Greater than 80	6	4

Individual project construction costs for the LSSES project improvements are expected to average less than $10 million. Based on this assumption, and the planning-level information developed for the LSSES projects, project costs for the LSSES improvements were developed from construction costs using the following percentages:

- Construction contingency: 30% of construction cost
- Design engineering: 15% of construction cost including the contingency
- Construction engineering and administration: 10% of construction cost including the contingency

This results in a project cost multiplier of 1.625 times the construction cost, e.g.

*Project Cost = Construction Cost*1.3*(1.0+0.15+0.10) = 1.625*Construction Cost*

Project Definition Investigations

District LSSES projects were planning-level studies, and prioritized field investigations were completed in only 7% of the project area. In addition to standard construction, engineering and administrative activities/costs previously discussed, many potential improvements discussed in subsequent sections of this report may benefit significantly from additional investigations to refine the proposed work areas and preferred improvements. For example, even though dyed water testing in one portion of a subcatchment may identify pipe reaches with high infiltration in the public ROW, private property I/I may be a significant, if not greater source of wet weather flows, particularly in areas with pre-WWII vintage homes. **Figure 3-8** shows building construction year ranges in Berea.

As another example, even though elevated wet weather flows may be a partial cause of some BBU problem or SSO, a system bottleneck, a stormwater drainage problem, structural or recurrent debris or other O&M problems may also be a significant cause of the problem.

Improved definition of these types of potential unknown system characteristics will help to further optimize cost-effectiveness and resulting performance. **Section 7** of this report discusses implementation activities that may be beneficial in many potential improvement areas to better define the specific extents and causes of problems to be addressed.

These investigation activities will add up front cost to additional planning and project implementation costs but may also help reduce overall costs and improve cost-effectiveness by properly defining the work areas and specific system improvements to be implemented, particularly in common trench or SWMP project areas. Based on HHI and SWI-LSSES investigation costs, a planning-level allowance of $10,000 per acre was identified for project definition investigations in common trench remediation areas and was included as a separate line item for these work areas.

4.5 SYSTEM AND COMMUNITY SCREENING ALTERNATIVES

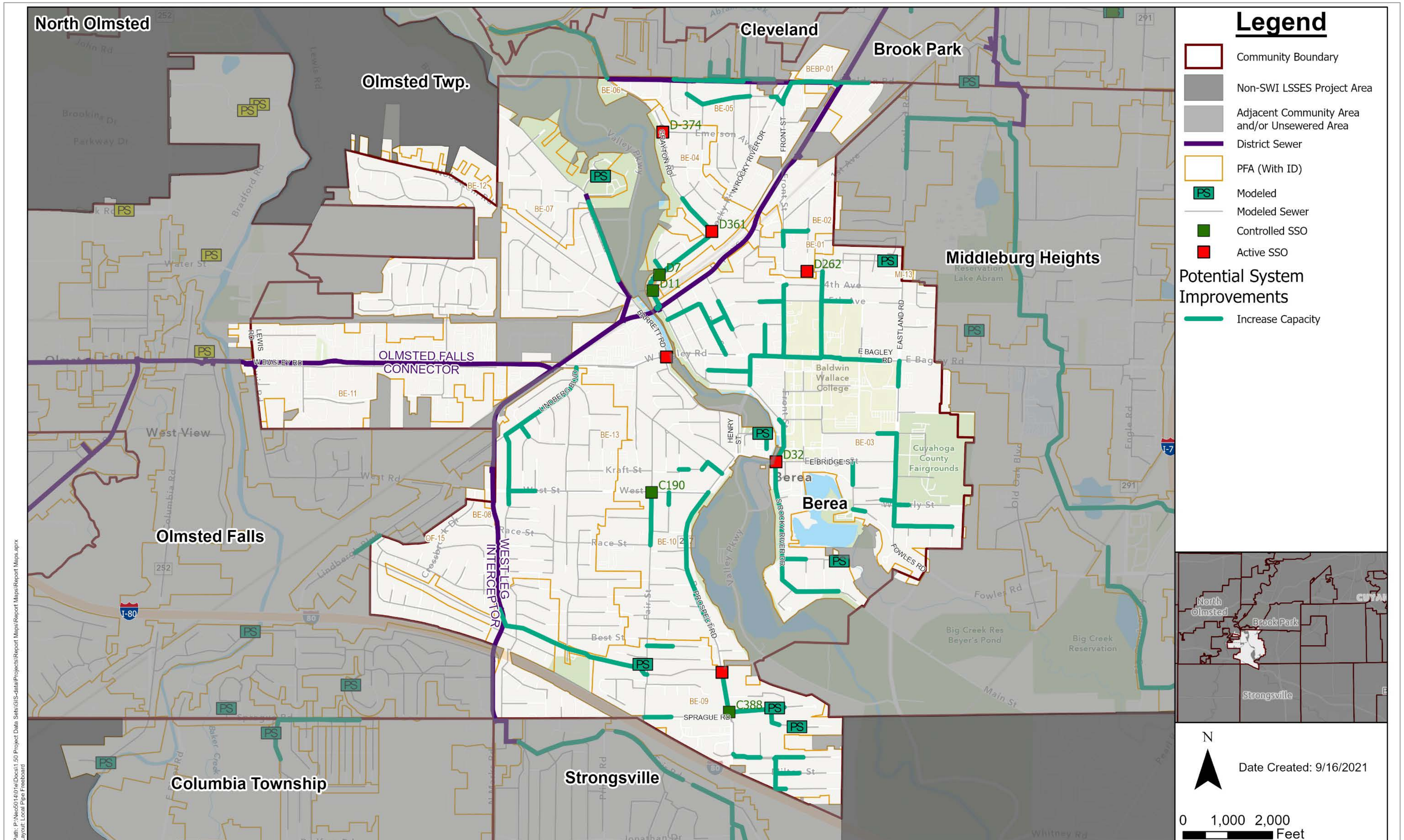
The initial screening of potential improvements developed three primary alternatives that were considered for the SWI system, for each community, and for the respective community PFAs to mitigate SSOs, BBUs, and flooded manholes based on set assumptions. These include 1) capacity improvements only, 2) sewer rehabilitation in high I/I areas with additional downstream capacity improvements if needed, and 3) sewer rehabilitation in high I/I areas and private property I/I reduction with additional downstream capacity improvements if needed. Potentially deficient pipes upstream of the modeled system and stormwater drainage deficiencies were not considered in the screening-level alternatives.

Capacity Improvements Only

This alternative was developed to understand the limitations of the District's infrastructure to mitigate all known and projected problems by adding capacity where needed to avoid surcharging that could result in BBUs and/or SSOs during the 5-year, 1-hour rainfall. One objective of this alternative was to determine the maximum peak flows that could be expected in the District system if local community systems were upgraded with adequate capacity, without pursuing I/I reduction in tributary areas. This found that most of the District sewer system would likely have adequate conveyance capacity, but that peak flows and treatment volumes at the Southerly WWTP would increase, making this an undesirable alternative. **Figure 4-9** shows the capacity-only improvements needed to mitigate the known and model-projected BBUs and SSOs.

This alternative allows stormwater pollution in common trench areas due to sanitary/storm sewer crossflows to remain. This means that the capacity-only screening alternative does not address the primary problems in the common trench systems and is therefore not a complete solution alternative. The capacity-only alternative would also allow many 50 to 100+ year-old sewers to remain in service. This implies higher future costs to replace aging infrastructure.

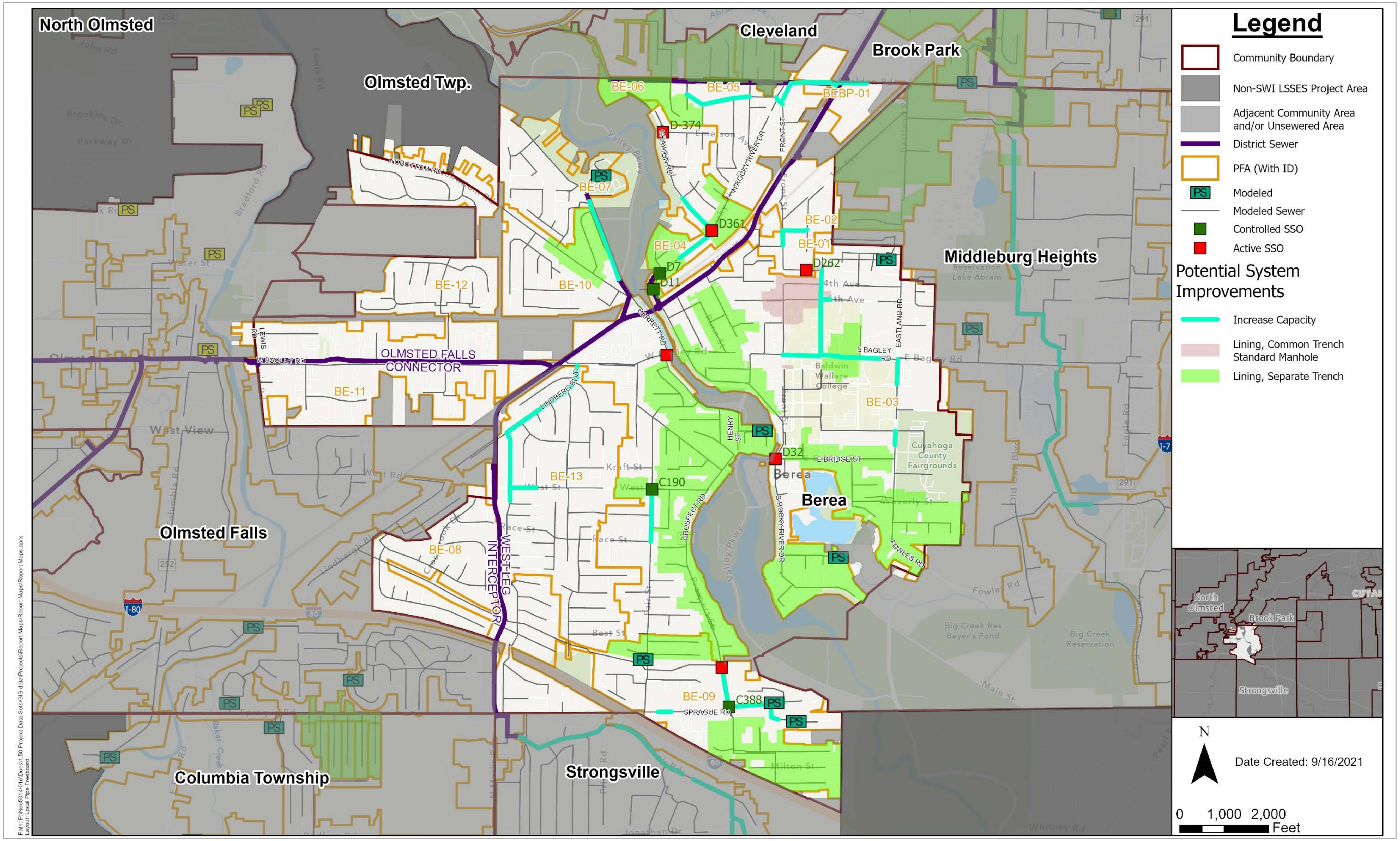
Figure 4-9. Screening Alternatives – Capacity Only Improvements for SSO and BBU Control



Sewer Rehabilitation and Capacity Improvements

This alternative was considered to determine if sewer system rehabilitation in high I/I areas alone would be sufficient to mitigate the known and projected problems. In areas where sewer rehabilitation alone is not expected to provide acceptable performance during the 5-year, 1-hour rainfall, capacity improvements were identified to provide the 5-year, 1-hour level of service. **Figure 4-10** shows the sewer system rehabilitation and capacity improvements needed to mitigate the known and model-projected BBUs and SSOs.

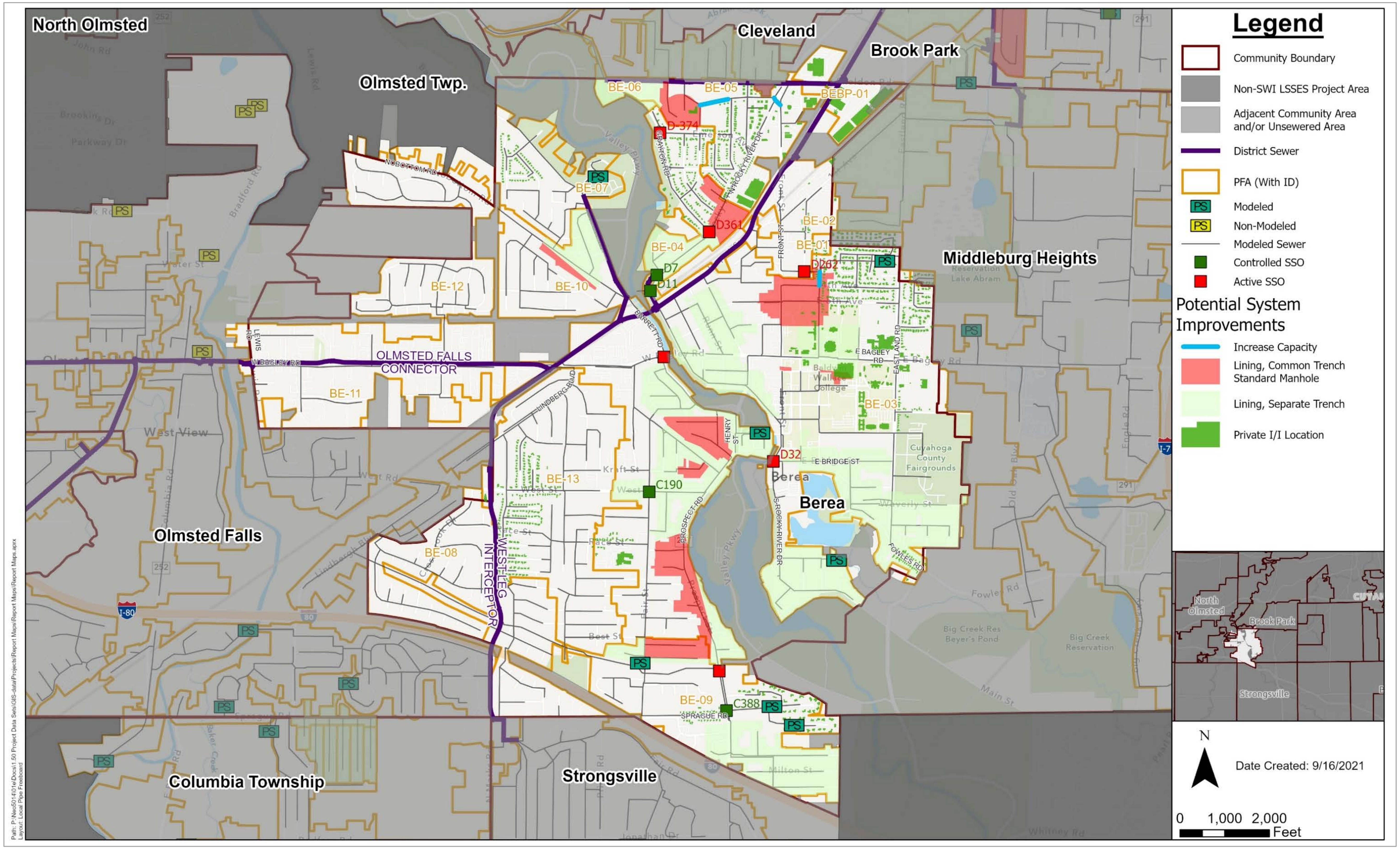
Figure 4-10. Screening Alternatives – Sewer Rehabilitation and Capacity Improvements for SSO and BBU Control



Sewer Rehabilitation, Private Property I/I Reduction, and Capacity Improvements

The final primary screening alternative was considered to determine if sewer system rehabilitation coupled with private I/I remediation alone would be sufficient to mitigate the known and projected problems. In areas where public rehabilitation and private property I/I remediation together are not expected to provide acceptable performance during the 5-year, 1-hour rainfall, capacity improvements were identified to provide the 5-year, 1-hour level of service. **Figure 4-11** shows the sewer system rehabilitation, private property I/I remediation, and capacity improvements needed to mitigate the known and model-projected BBUs and SSOs.

Figure 4-11. Screening Alternatives – Sewer Rehabilitation and Private Property I/I Remediation for SSO and BBU Control



5.0 POTENTIAL SOLUTIONS AND PRIORITIZATION

This section describes the potential solutions for Berea PFAs to help mitigate known and projected problems. Consideration of the trench types and problems reported and/or projected in SWI communities has resulted in suggested tiered improvements to focus limited infrastructure funding on the most significant issues first. This is included in the optimization analysis and summarized for proposed Tiers 1, 2, and 3 in **Figure 5-1**. **Figures 5-2** and **5-3** summarize locations of varying trench types and projected problems in Berea.

Figure 5-1. Improvements to Solve Sewer System Problems Prioritized into Three Tiers

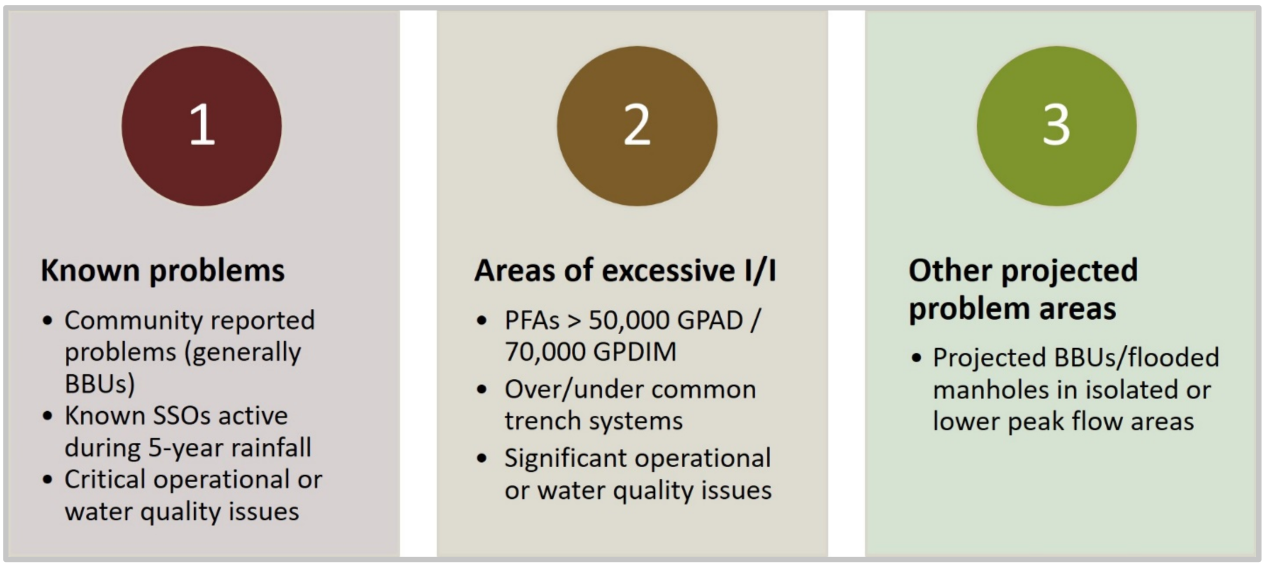


Figure 5-2. Sewer Trench Type Map

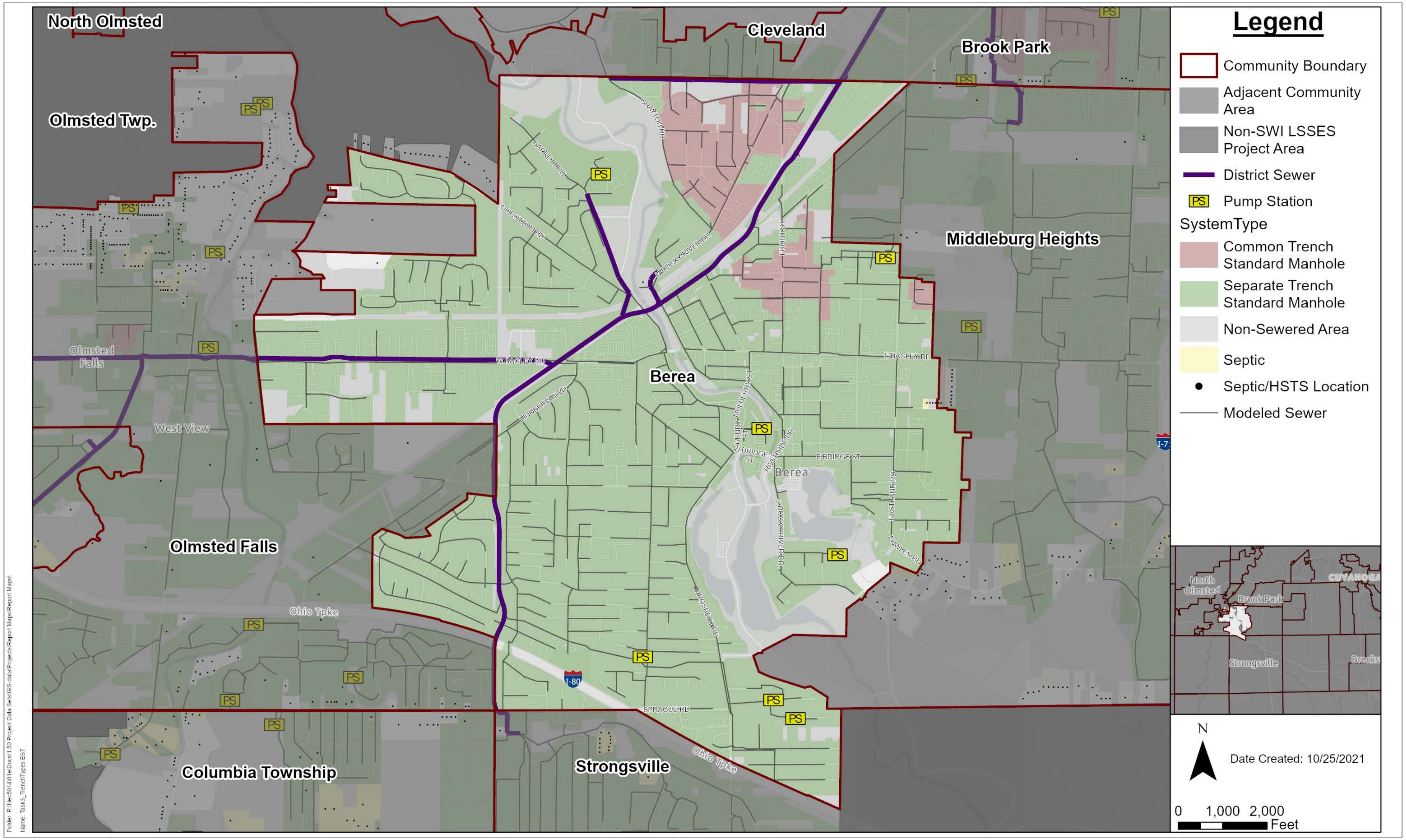
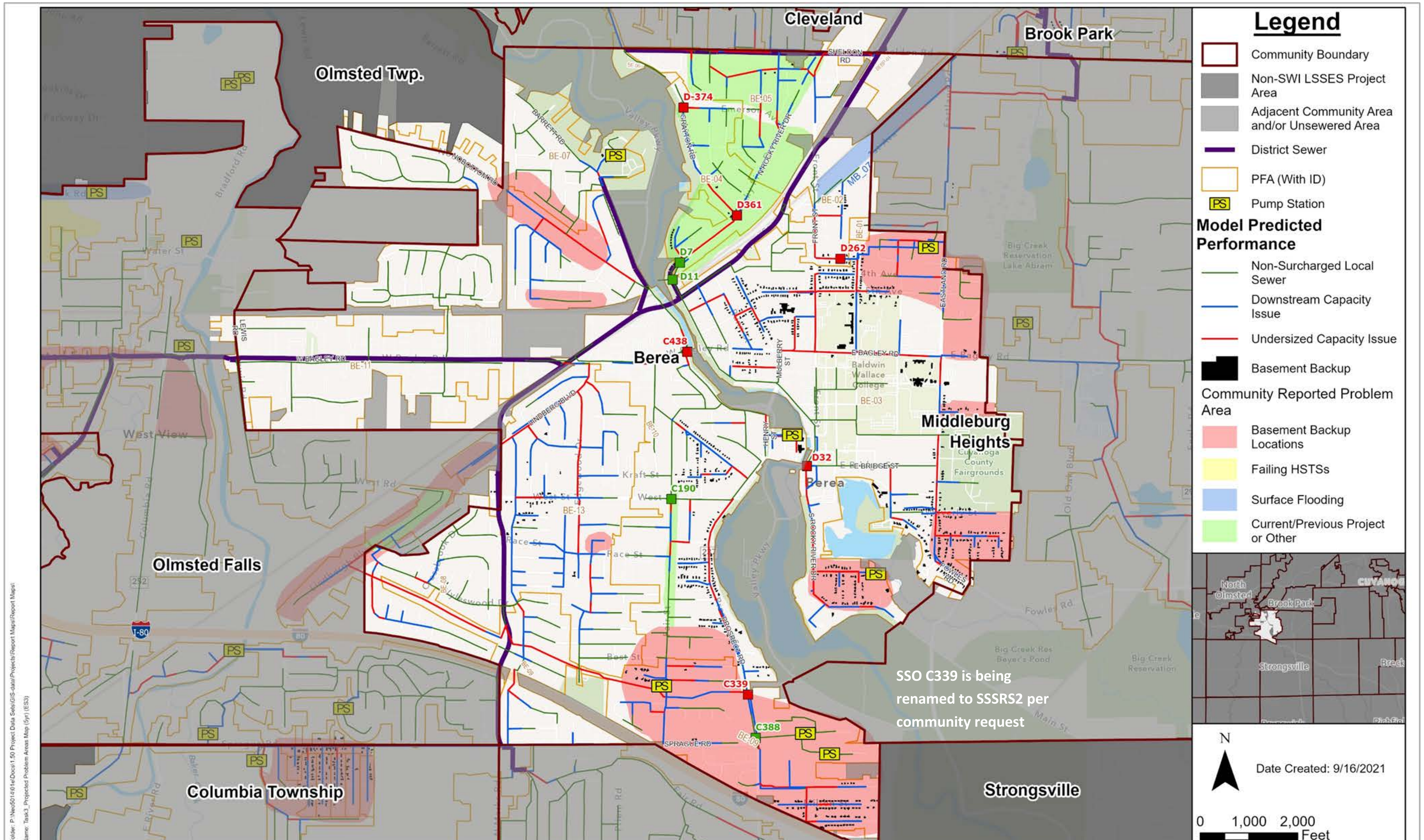


Figure 5-3. Reported and Projected Problem Area Map (5-Year, 1-Hour Rainfall)



Tier 1 Improvements – Address Community-Reported Problems and Active SSOs

Tier 1 improvements focus on solving known problems, including the following:

- Community-reported/recurrent BBUs
- Structural SSOs that are projected to activate for rainfalls less than the design rainfall event (5-year, 1-hour rainfall for SWI system)
- Illicit discharges of sewage to storm sewers
- Manholes that surcharge to grade
- Operations, maintenance, and repair (O,M&R) improvements needed to address critical system structural, obstruction, and capacity bottlenecks
- Failing septic systems that contaminate surface runoff or groundwater, or cause other local exposure to untreated waste

Berea reported ongoing BBU problem areas, as listed in **Table 2-1**, and active SSOs, listed in **Table ES-2** and **Table B3** in **Appendix B**, that were projected using the model for the 5-year, 1-hour rainfall. **Figure 5-4** shows the proposed Tier 1 improvements for Berea.

Tier 2 Improvements – Control Excessive I/I

The LSSES projects found that areas with predominately common trench sewer systems often produce excessive I/I, stormwater crossflow contamination, and BBUs. Common trench systems may also be more difficult for communities to maintain because of the proximity of the storm and sanitary sewers. Separate trench systems may also exhibit excessive I/I.

Improvements to control excessive I/I typically include sewer system and service lateral rehabilitation (lining, grouting, etc.) in the public ROW, and private property I/I rehabilitation where indicated by testing.

In some cases, sewer separation/replacement may be indicated if system condition is poor, or if additional capacity is needed. Potential alternatives for common trench system separation /replacement include complete replacement of all sewers and service laterals in the ROW, and a stormwater separation concept, both of which are described in **Section 4.2**. Communities and their engineers will determine the best improvement approaches for each area based on preliminary design investigations and cost and performance results of similar projects completed in District member communities. **Figure 5-5** shows locations of potential Tier 2 improvements.

Tier 3 Improvements – Address Other Projected Problems

Tier 3 improvements, including additional rehabilitation, private property I/I reduction and capacity enhancement, have been identified in portions of the system that are projected to experience surcharging and BBU problems in response to the 5-year, 1-hour rainfall, but where there have been no problems reported by the community. These potential problem areas and the proposed improvements are included in the study results to help communities identify where long-term improvements may be considered to reduce the risk of wet weather BBUs for 5-year, 1-hour, and larger rainfall events. Such improvements may be included in long-term master planning, private property redevelopment, time-of-sale improvements, and/or roadway reconstruction projects. **Figure 5-6** shows locations of potential Tier 3 improvements. **Figure 5-7** summarizes overall potential improvements in Berea.

Figure 5-4. Potential Tier 1 Improvements for Reported Problem Areas and Active SSOs

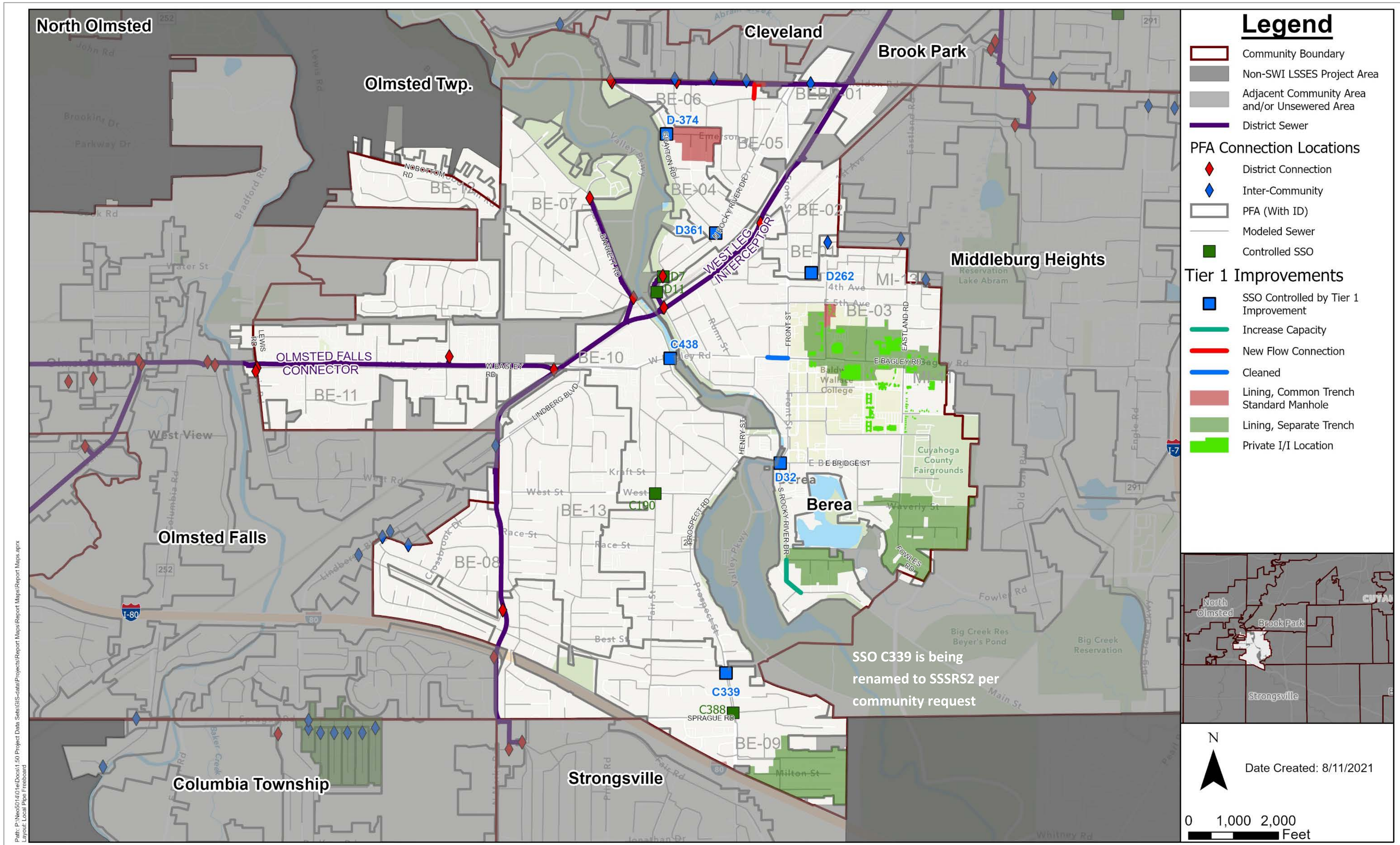


Figure 5-5. Potential Tier 2 Improvements for Areas of Excessive I/I

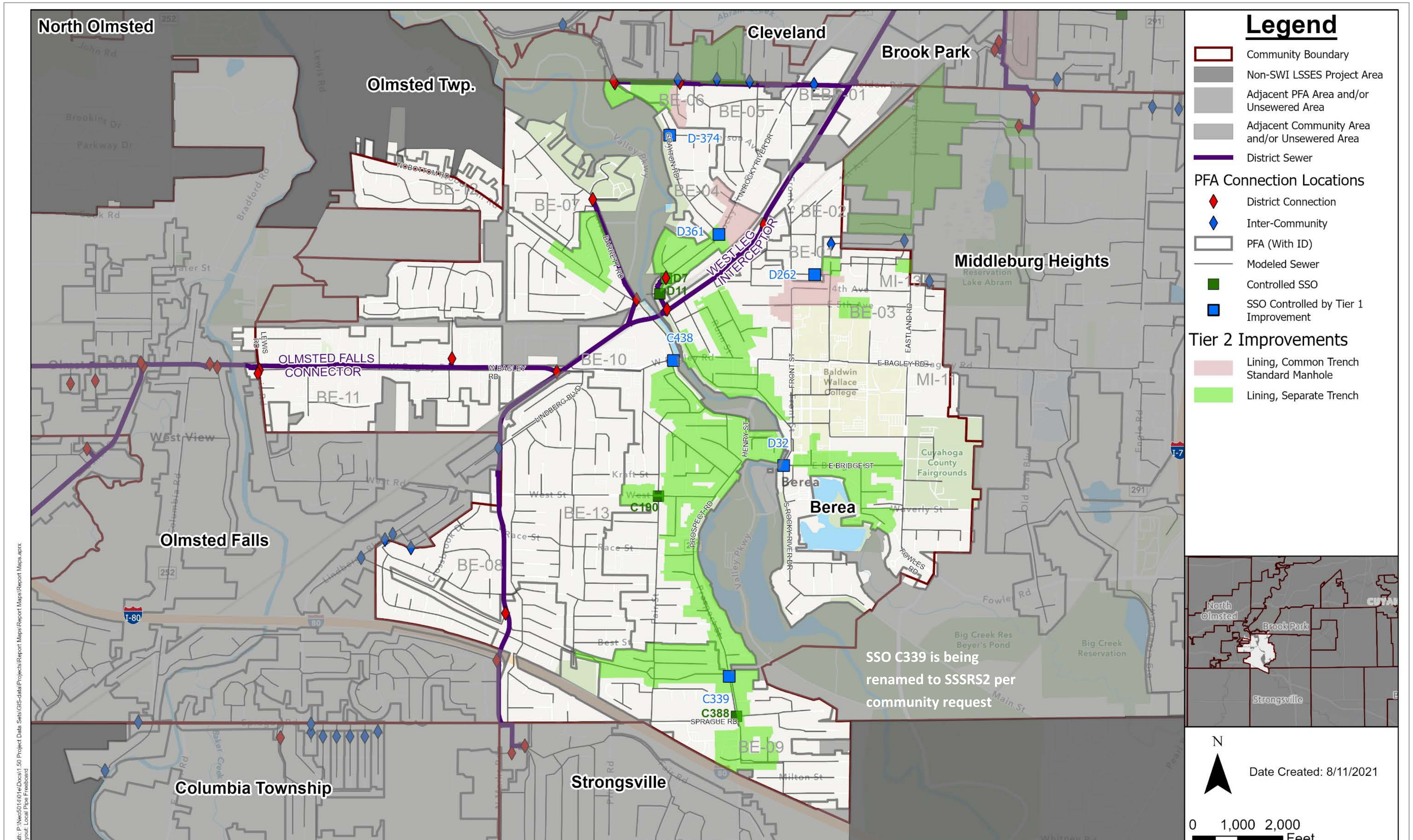


Figure 5-6. Potential Tier 3 Improvements for Other Projected Problem Areas

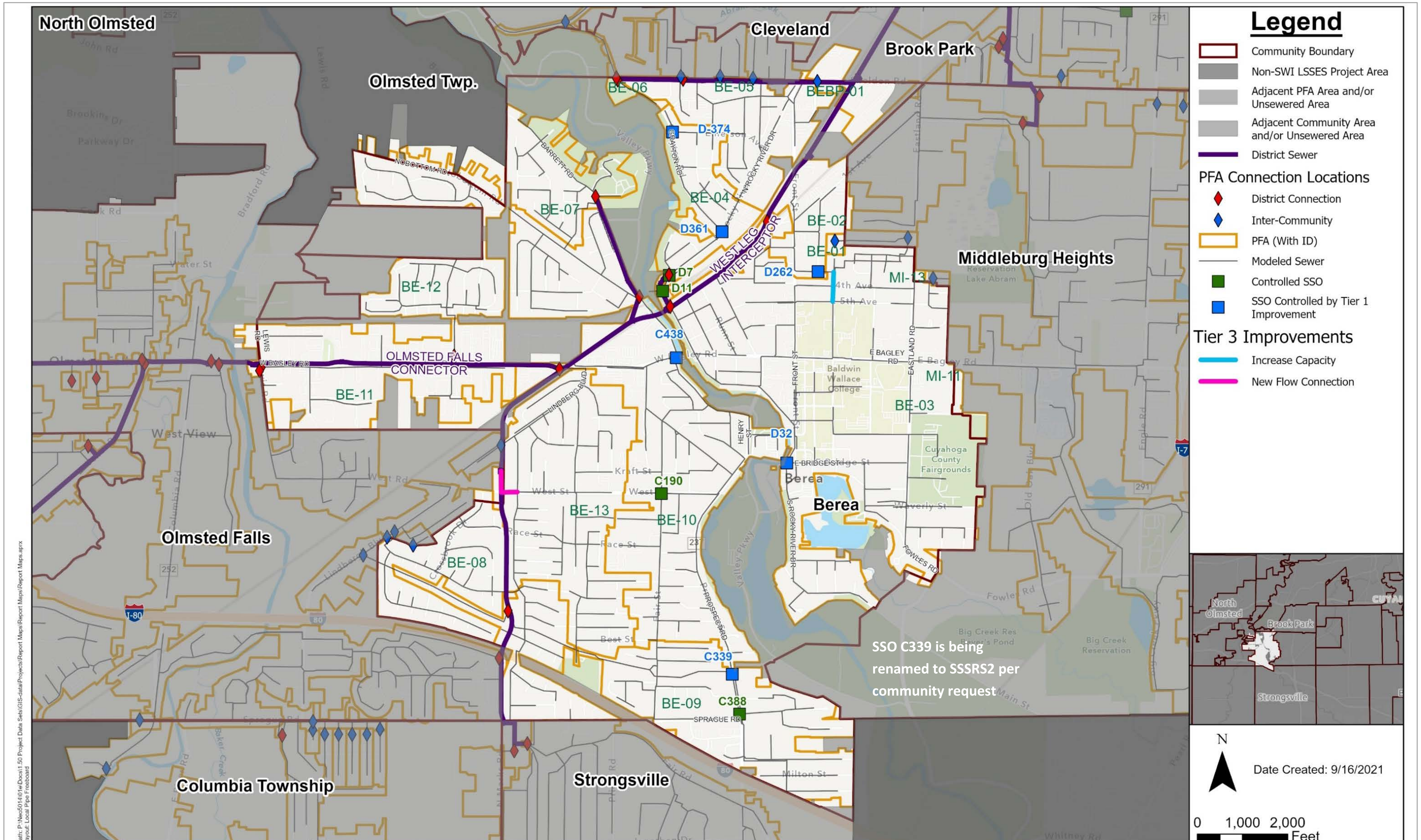
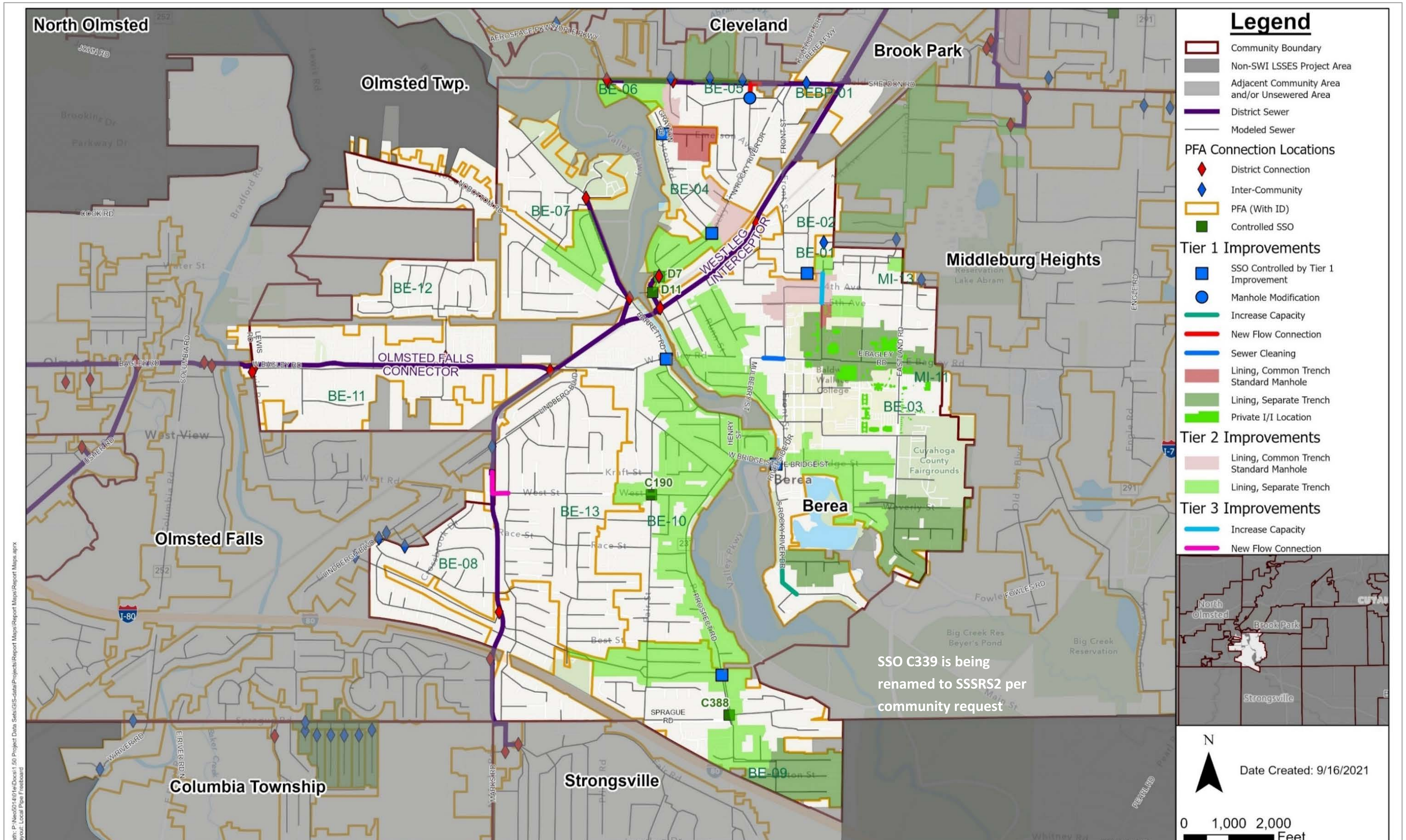


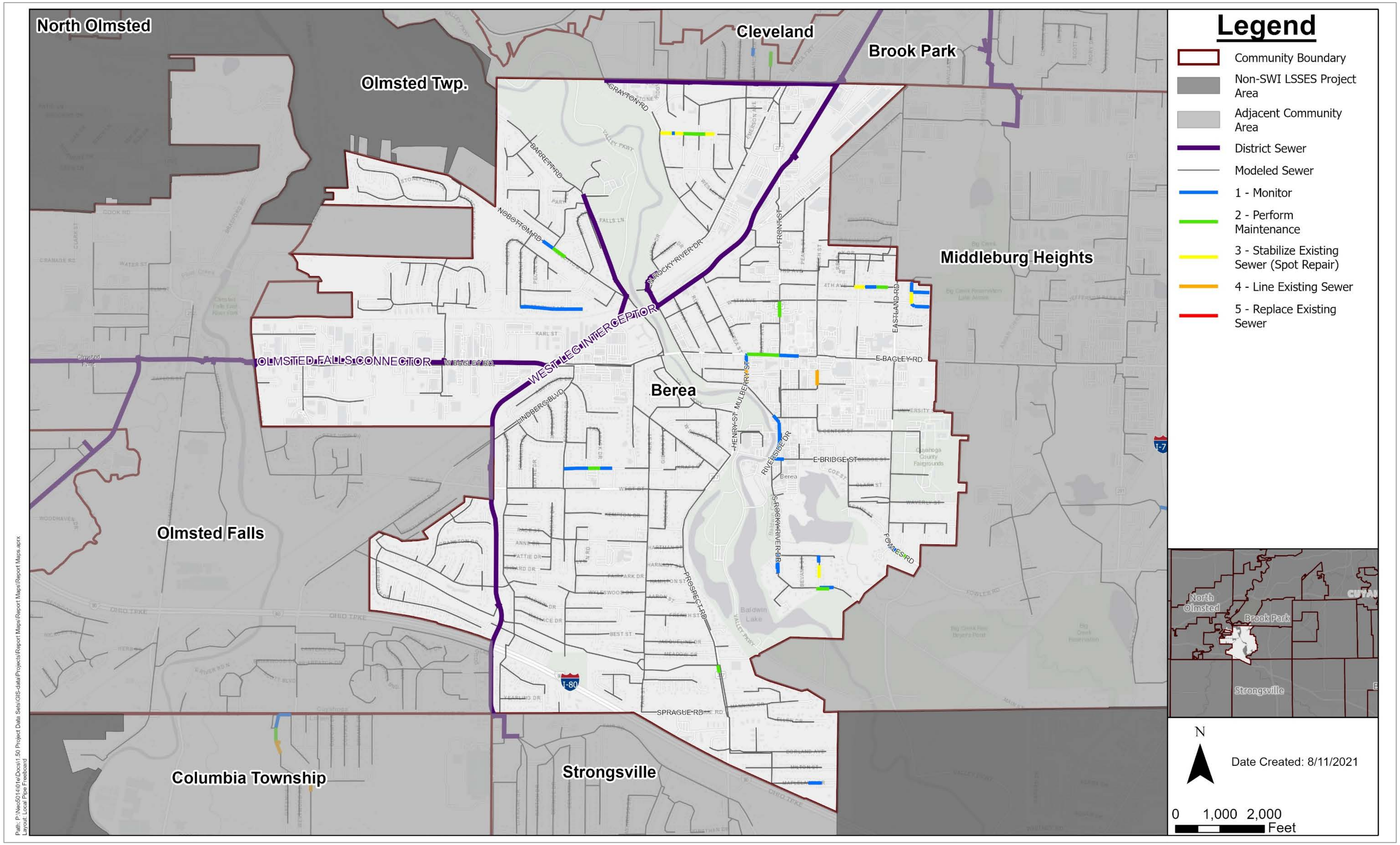
Figure 5-7. Overall Potential Solutions



Summary of Recommended Rehabilitation Levels

The project conducted field investigations, including closed-circuit television (CCTV) inspection of selected sewers, in prioritized field work order areas. The results and recommended sewer rehabilitation levels were detailed in a technical memorandum provided to the District and communities entitled, *Task 2 – Local System Inspection and Condition Assessment Report, July 2021*. This report included pipe condition assessments based on NASSCO guidelines and associated typical recommended rehabilitation levels based on the assessment. The suggested rehabilitation levels are summarized in **Figure 5-8** and are available on the District's AGOL website. The purpose of this figure is to remind communities that planning for system improvement and/or rehabilitation projects should consider both the condition assessment information and the overall performance improvements described subsequently in this community report. **Figure A3** in **Appendix A** summarizes the field investigations and findings that support the recommended rehabilitation levels.

Figure 5-8. Summary of Sewer Rehabilitation Recommendation Levels Based on Project CCTV Inspection



5.1 POTENTIAL COMMUNITY IMPROVEMENTS BY PFA

This section describes system characteristics and potential improvements to the Berea sewer system with respect to each PFA, for which the following information is included:

- PFA summary table—including problems, improvements, and costs
- PFA map showing potential Tier 1 improvements
- PFA map(s) showing potential Tiers 2 and 3 improvements
- Implementation considerations specific to each PFA

Supplementary information regarding each PFA has been compiled in the following appendices:

- **Appendix A** includes detailed system and performance information figures.
- **Appendix B** contains detailed information tables.
- **Appendix C** provides sewer system HGL profiles for select modeled sewer reaches.
- **Appendix E** provides modeling and alternatives analysis notes compiled as PDF slides to provide backup information supporting alternatives analysis.
- **Appendix F** provides the Project Cost Opinion Development for LSSES Improvement Alternatives Analysis Technical Memorandum, Revision 2, September 2018.
- **Appendix G** summarizes 5- and 10-year rainfall performance results.
- **Appendix H** provides figures summarizing the future conditions analysis.

PFA Excel Summary Tables

Attachment 1 provides an Excel spreadsheet that includes the PFA summary tables for each PFA. The PFA tables summarize significant information about each PFA, including:

- District asset to which the PFA is tributary.
- Summary of system trench type(s) within the PFA.
- Aggregated PFA peak flow rate, and corresponding GPAD and GPDIM, which accounts for the additional flow and area attributed to upstream PFAs as well as any flow diversions, if present. Aggregated GPAD and GPDIM comparisons are provided with respect to other Berea PFAs as well as with other SWI-LSSES PFAs, based on the percentile of gallons per acre per day. Percentiles indicate the percentage of PFAs below the specific PFA; for example, a PFA peak flow rate in the 75th percentile of the SWI-LSSES PFAs is larger than 75% of the other PFA peak flow rates in the whole of the SWI-LSSES.

- Summary of model-projected problems including SSO activations, projected BBUs, flooding manholes, and excessive degrees of conduit surcharge associated with the 5-year, 1-hour design rainfall.
- Summary of potential improvements, and associated costs by tier. Improvement quantities and associated costs may include storm sewer improvements in addition to the proposed sanitary improvements for modeled sewers. For example, if a sanitary sewer suggested for replacement is within a common trench configuration, or for unmodeled sanitary sewer public rehabilitation improvements, if an unmodeled sewer lies within a high inflow and infiltration area, additional costs are included to address these improvements. Note that while summary tables include these improvement quantities and costs, associated maps only show modeled sanitary assets that are being improved.

Grouped PFA Information

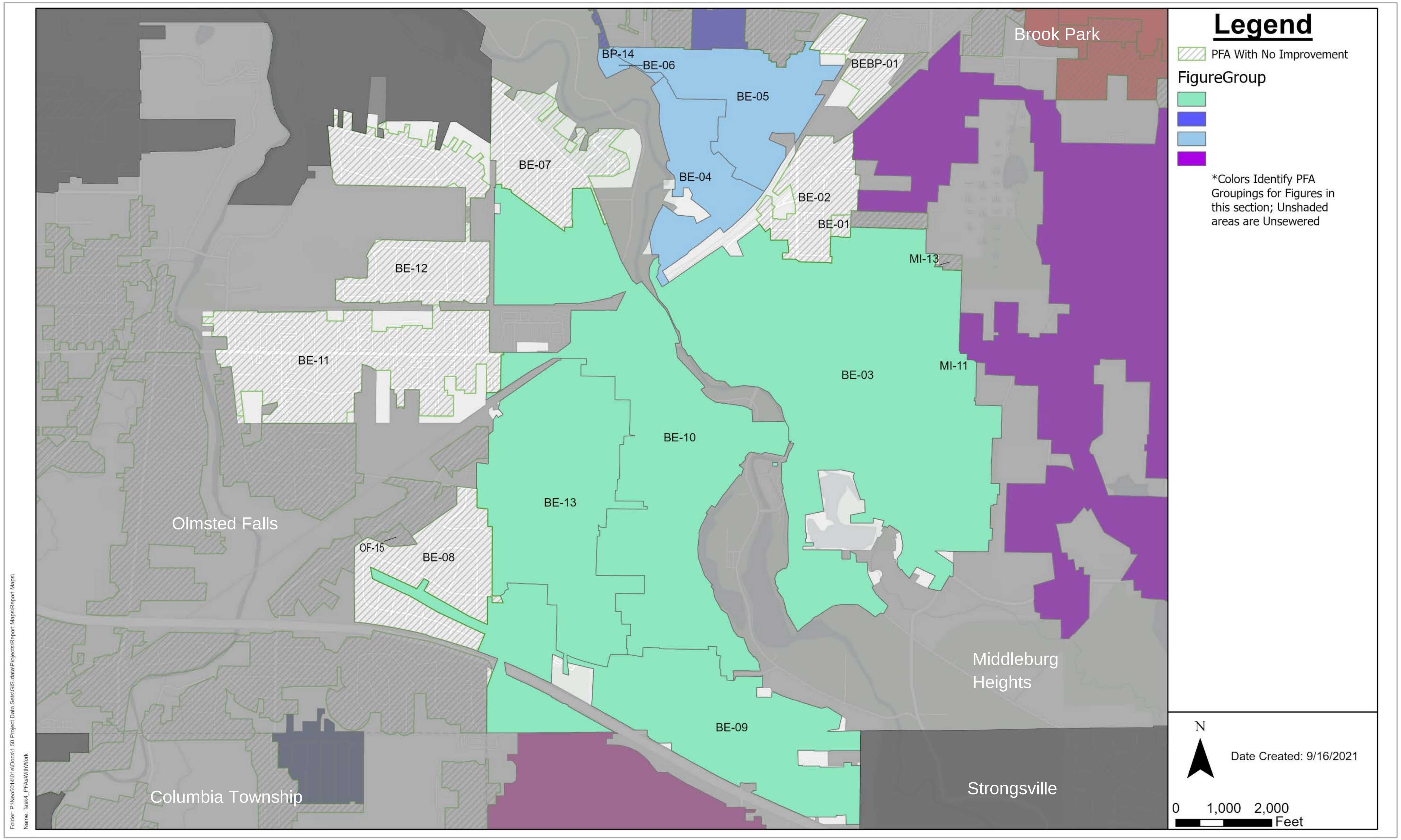
Several PFAs are grouped together in common figures and shown in **Figure 5-9**. The first group includes PFAs BE-03, BE-09, BE-10 and BE-13, which are shown in **Figures 5-10**, **5-11** and **5-12**. The remaining PFAs with suggested improvements including BE-04, BE-05 and BE-06 are also grouped together and are shown in Figures **5-14, 5-15** and **5-16**.

PFAs with No Improvements

No improvements are proposed for seven of Berea’s 14 PFAs since there were no identified problem areas, excessive I/I, projected BBUs, or active SSOs. These PFAs, listed below, are not addressed specifically in this section, but are included in the **Attachment 1** Excel summary tables.

- BE-01
- BE-02
- BE-07
- BE-08
- BE-11
- BE-12
- BEBP-01

Figure 5-9. Figure Groups for PFAs with Improvements



5.1.1 PFA BE-03 (Bagley and Eastland Roads)

PFA BE-03 is a 680-acre area located in eastern Berea that receives flow from PFAs MI-12 and MI-13 and discharges directly into the District's West Leg Interceptor. PFA BE-03 has outflowing cross connections with adjacent PFAs BE-04 and BE-02. Both cross connections are projected to be active during the 5-year, 1-hour rainfall. Sewer trench types in PFA BE-03 include 9% common trench and 91% separate trench configuration.

There is one SSO within this PFA (D32) that is projected to be active for both the 5-year, 1-hour rainfall and some of the District Typical Year rainfalls. This SSO is projected to produce 0.072 MG of overflow during the 5-year, 1-hour design event, and 0.01 MG of overflow during the District-defined Typical Year.

Over 37,000 LF of pipe is projected to surcharge within 8 feet of grade during the 5-year, 1-hour rainfall resulting in flooding to grade at 10 manholes and basement backups for 510 homes within PFA BE-03. Four community-identified problem areas (BR_04, BR_05, BR_06, and BR_10) and existing reports of basement backups are associated with this PFA.

Tier 1 improvements within PFA BE-03 are proposed for recurring problem areas as described below and shown in **Figure 5-10**. Additional Tier 2 sewer system rehabilitation improvements are suggested in other areas of BE-03 with excessive I/I as shown in **Figure 5-11**.

- **Eastland Road and Waverly Street Problem Area (BR_05):** Basement backups are primarily caused by high levels of I/I in the area. The area also includes a manhole (SA06FFFJ0) projected to overflow to grade during the 5-year, 1-hour rainfall. **Tier 1** Sanitary sewer rehabilitation is recommended. Capacity enhancement would not be cost effective since it would require a significant length of replacement downstream as well as additional work at SSO D32. Field investigations were sparse and inconclusive, and therefore unable to identify the primary source of the I/I. Additional field investigations are recommended to identify the primary source of I/I and guide the rehabilitation efforts.
- **S. Rocky River Drive and Monroe Street Problem Area (BR_04):** Basement backups are primarily caused by high levels of I/I in the area. For Monroe Street and upstream, **Tier 1** sanitary sewer rehabilitation is recommended. Field investigations were inconclusive and did not identify the primary source of the I/I. Additional field investigations are recommended to identify the primary I/I sources to guide the rehabilitation efforts. A **Tier 1** capacity enhancement is suggested for S. Rocky River Drive upstream of Monroe. I/I in the area, while elevated, is relatively low, and therefore capacity enhancement is more cost effective.

- **SSO D32 (Tier 1):** The SSO weir can be raised to prevent overflows. Monitor the area after raising the weir to verify the SSO is controlled, and that the modification does not cause issues upstream or downstream. The SSO may be considered for elimination if monitoring shows no significant surcharging.
- **Bagley Road and University Street Problem Areas (BR_06 and BR_10):** Both streets are projected to experience backwater surcharging from the East Bagley Road sewer downstream of Beech Street, due to excessive I/I. **Tier 1** sanitary sewer and private property rehabilitation is suggested in the area. Additional field investigations are recommended to identify the primary sources of I/I to guide the rehabilitation efforts. Tier 1 sewer cleaning is also suggested in Bagley west of Front Street.
- **Barberry Drive and Eastland Road Problem Area (BR_06):** The model projected no BBUs for the 5-year, 1-hour event. The issues in the area may be caused by the pump station capacity. During the monitoring period, inflows to the pump station appeared to have exceeded the capacity for one event. Flows were not high enough to cause basement flooding in the area, but a larger event may cause excessive surcharging. If issues persist, evaluate the issues in the area to determine if pump station rehabilitation is warranted. I/I in the area is relatively low and system rehabilitation may not be cost effective.

Tier 3 improvements within PFA BE-03 are proposed for areas with basement backups projected to remain after implementing Tier 1 and Tier 2 improvements and were applied to areas with remaining BBUs. In PFA BE-03, the suggested Tier 3 improvement is a capacity increase in Beech Street between 3rd and 5th avenues. The need for this improvement could be confirmed after Tier 1 and Tier 2 improvements.

Additional details relating to PFA BE-03, as well as improvements and associated costs, are outlined in **Table 5-1**. Improvements for Tier 1, as well as Tiers 2 and 3, are shown in **Figures 5-10** and **5-11**, respectively; overall improvements are shown in **Figure 5-12.** Note that improvements for PFAs BE-09, BE-10, and BE-13, have been grouped with PFA BE-03 for mapping purposes.

Figure 5-10. Tier 1 Improvements for PFAs BE-03, BE-09, BE-10, and BE-13

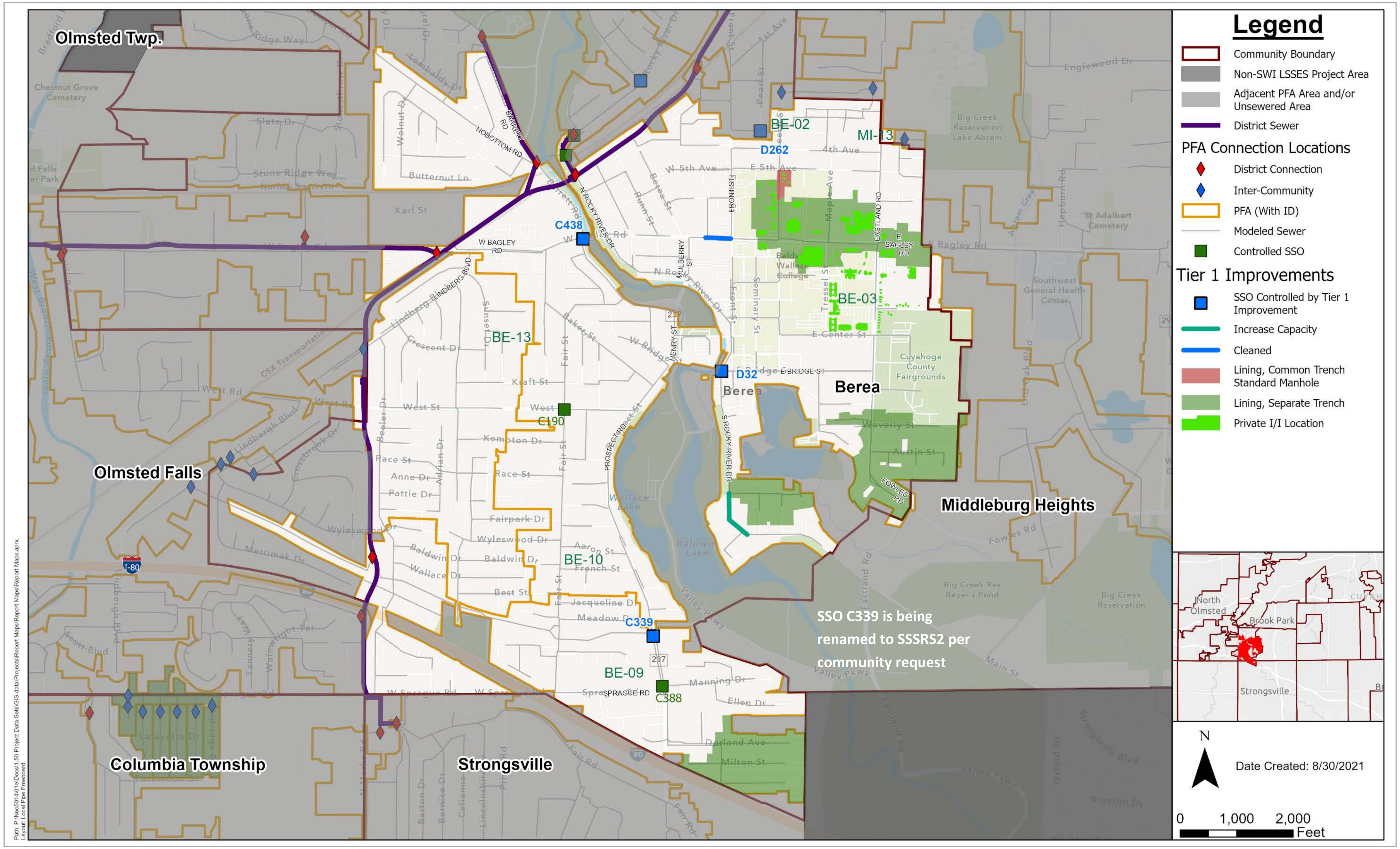


Figure 5-11. Tier 2 and Tier 3 Improvements for PFAs BE-03, BE-09, BE-10, and BE-13

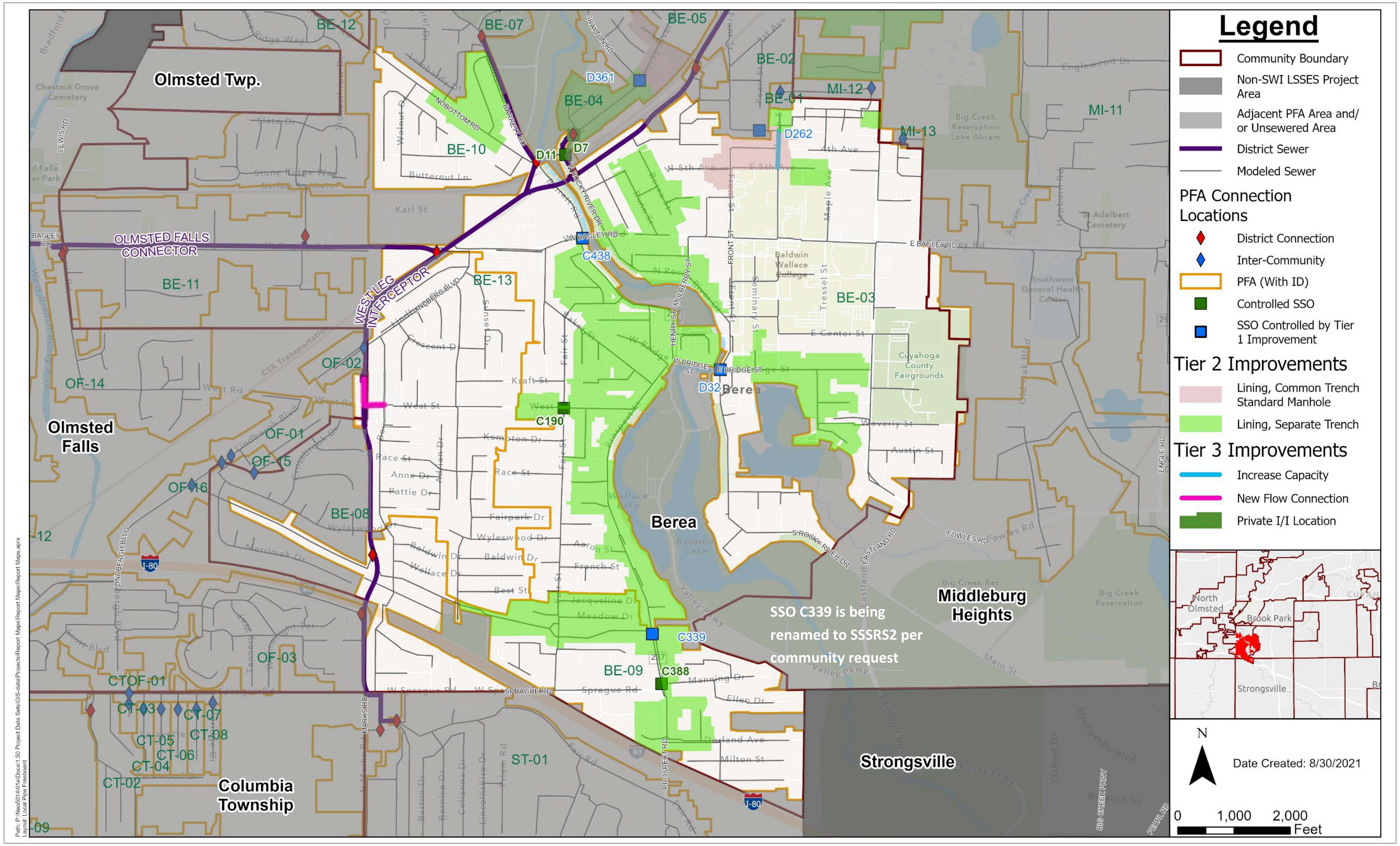


Figure 5-12. Overall Improvements for PFAs BE-03, BE-09, BE-10, and BE-13

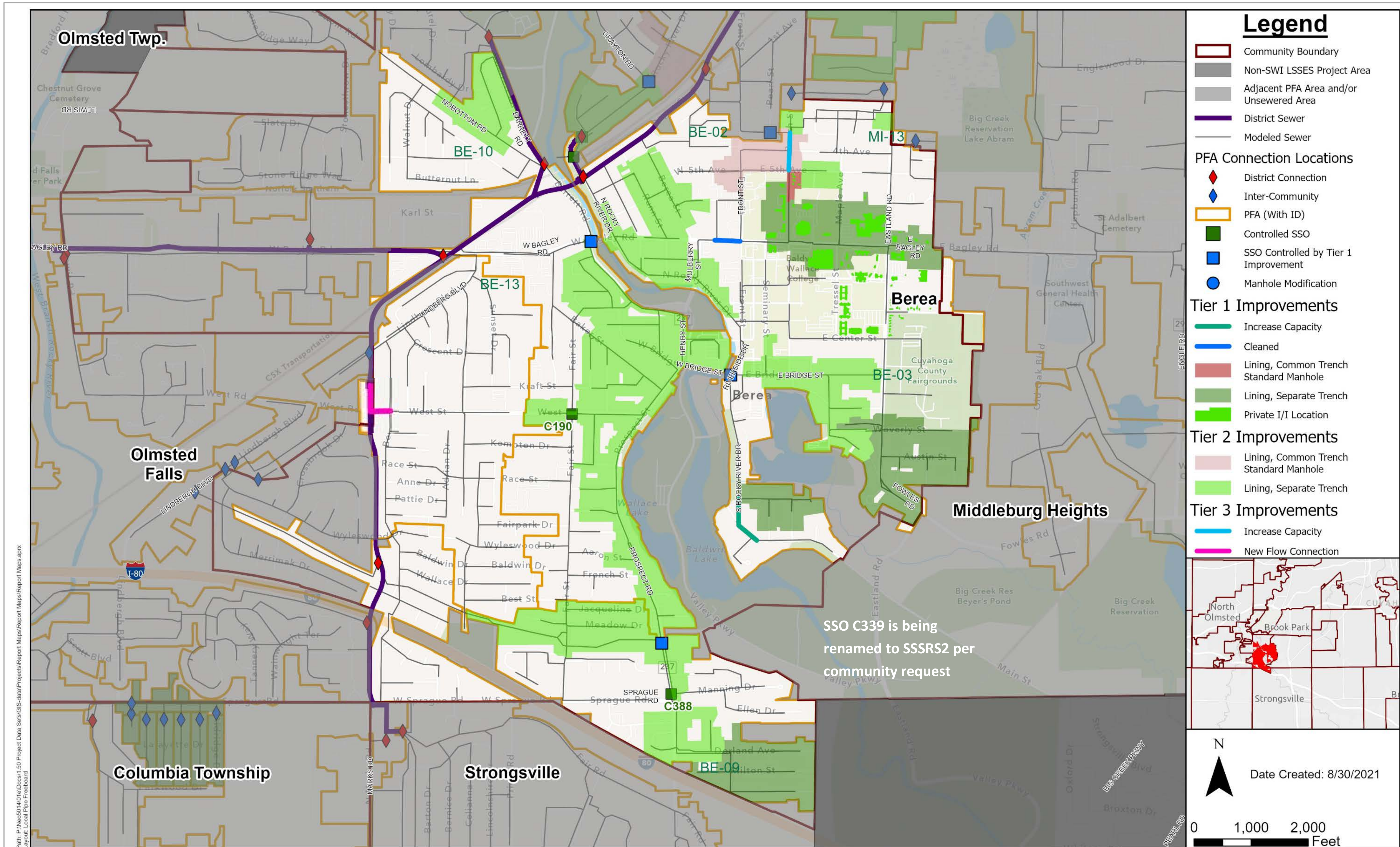


Table 5-1. Summary for PFA BE-03

PFA:	BE-03	Community:	Berea	District Branch:	West Leg Interceptor

Trench Type Summary	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	843	0.0	47.0	709
Sanitary Sewer Length (LF)	91,129	0	8,290	82,840
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**9.1%**	**90.9%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)		
Net Aggregated Sewered Area	706	Acres
Net Aggregated Peak Flow Rate	21.8	MGD
Net Aggregated Peak Flow Rate Per Acre	30,890	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	79%	Percentile
Comparison to SWI-LSSES PFAs	72%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems		
Active SSOs	1	Count
Controlled SSOs	0	Count
Projected BBUs	510	Count
Manholes Surcharged to Grade	8	Count
Modeled Pipe Surcharged Within 8' of Grade	37,076	LF

Potential Improvements

	Improvement Quantity (LF or Count)							2020 Class 5 Planning Costs ($)							
Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	0	537	16512	0	882	46	0	$7,049,000	$1,057,000	$705,000	$8,811,000	$2,643,000	$38,000	$11,492,000	39.9
2	0	4921	18769	0	0	0	0	$9,783,000	$1,467,000	$978,000	$12,228,000	$3,668,000	$344,000	$16,240,000	56.4
3	0	0	0	0	657	0	0	$685,000	$103,000	$69,000	$856,000	$257,000	$0	$1,113,000	3.9
Total PFA	**0**	**5458**	**35281**	**0**	**1539**	**46**	**0**	**$17,517,000**	**$2,627,000**	**$1,752,000**	**$21,895,000**	**$6,568,000**	**$382,000**	**$28,845,000**	**100.0**

Notes

1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.1.2 PFA BE-09 (Sprague Road and Prospect Street)

PFA BE-09 is a 387 acre PFA served by separate trench sewers located in southern Berea. This PFA receives flow from PFA OF-16 and discharges directly into the West Leg Interceptor south of Wyleswood Drive. PFA BE-09 has no other known cross connections with adjacent PFAs.

There is one known constructed SSO within this PFA (SSO C339 is being renamed by the District to SSSRS2 per community request). It is projected to activate during the 5-year, 1-hour rainfall with volume of 0.013 mg, but is not projected to overflow during District Typical Year rainfalls. Previously existing SSO C388 at Prospect Street and Manning Drive was found to be eliminated.

Nearly 14,000 LF of pipe is projected to surcharge within 8 feet of grade during the 5-year, 1-hour rainfall resulting in the projection of basement flooding for 82 homes within the area. Associated problem areas BR_01/BR_02 are located in this PFA.

Tier 1 improvements are proposed to address the BBUs and active SSO. Both are projected due to relatively high wet weather RDII that causes surcharging in the main trunk sewer in Prospect Street and then west to the West Leg Interceptor. Sewer system rehabilitation is suggested in the upstream area east of Prospect Street where BBUs are projected. Additional field investigations are recommended to identify the primary sources of I/I and guide the rehabilitation efforts.

Tier 2 sewer system rehabilitation improvements are proposed for additional areas with high inflow and infiltration. Tier 3 improvements are not expected to be required after implementing Tier 1 and Tier 2 improvements, as all projected BBUs are expected to be resolved for the 5-year rainfall.

Details relating to PFA BE-09, as well as improvements and associated costs, are outlined in **Table 5-2**. Improvements for Tier 1 and Tier 2 are shown in **Figures 5-10** and **5-11**, respectively; overall improvements are shown in **Figure 5-12.**

Table 5-2. Summary for PFA BE-09

PFA:	BE-09	Community:	Berea	District Branch:	West Leg Interceptor

Trench Type Summary	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	387	0.0	0.0	387
Sanitary Sewer Length (LF)	54,208	0	0	54,208
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**0.0%**	**100.0%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)		
Net Aggregated Sewered Area	563	Acres
Net Aggregated Peak Flow Rate	10.1	MGD
Net Aggregated Peak Flow Rate Per Acre	18,016	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	43%	Percentile
Comparison to SWI-LSSES PFAs	56%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems		
Active SSOs	1	Count
Controlled SSOs	0	Count
Projected BBUs	82	Count
Manholes Surcharged to Grade	0	Count
Modeled Pipe Surcharged Within 8' of Grade	13,954	LF

Potential Improvements

	Improvement Quantity (LF or Count)							2020 Class 5 Planning Costs ($)							
Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	0	0	5822	0	0	0	0	$1,854,000	$278,000	$185,000	$2,317,000	$695,000	$0	$3,012,000	25.9
2	0	0	14978	0	0	0	0	$5,316,000	$797,000	$532,000	$6,645,000	$1,994,000	$0	$8,639,000	74.2
3	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0	0
Total PFA	**0**	**0**	**20800**	**0**	**0**	**0**	**0**	**$7,170,000**	**$1,075,000**	**$717,000**	**$8,962,000**	**$2,689,000**	**$0**	**$11,651,000**	**100.0**

Notes

1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.1.3 PFA BE-10 (Prospect and West Streets)

PFA BE-10 is a 566 acre area served by separate trench sanitary sewers located in central Berea west of the Rocky River east branch. This PFA discharges directly into the West Leg Interceptor at Nobottom Road and has no cross connections with adjacent PFAs.

There is one constructed SSO in this PFA (C438) projected to overflow during both the design 5-year, 1-hour rainfall and some District Typical Year rainfalls. SSO C438 is projected to produce overflow volumes of 0.17 MG during the 5-year rainfall and 0.54 MG total during the Typical Year. Additionally, there is another SSO (C190) that is projected to be controlled for both the 5-year, 1-hour, and the Typical Year rainfalls.

A total of 16,600 LF of pipe is projected to surcharge within 8 feet of grade during the 5-year, 1-hour rainfall resulting in two manholes projected to flood to grade and BBUs at 180 homes within the area. Three community-identified BBU problem areas are associated with this PFA (BR_01/02, BR_03, BR_09 and BR_12).

Tier 1 improvements within PFA BE-10 are proposed only for elimination of SSO C438. The other reported problem areas are not projected to experience BBUs for the 5-year, 1-hour rainfall. Field investigations did not identify significant problems. The areas are summarized below.

- **SSO C438:** Potential Tier 1 elimination of SSO C438 is suggested. The modeled Tier 1 analysis projects no additional issues within the area after sealing the SSO. Additional monitoring is recommended before sealing the SSO, specifically monitoring depths in the inline storage upstream will monitor flows and depth at the SSO. The solution should also be evaluated against longer duration storm events.
- **Fair Street problem area (BR_03):** The sanitary sewer in Fair Street was recently replaced and the model does not project issues in this area for the 5-year, 1-hour rainfall. Three complaints were received on 5/15/2020 after a rainfall that may have exceeded a 10-year event occurred. This may indicate that the system has adequate capacity for a 5-year rainfall but not for greater than a 10-year event. Additional evaluations and field work, potentially including private property service lateral inspections may help define the remaining problems.
- **Butternut Lane problem area (BR_12):** The model does not project BBU problems in this area for the 5-year, 1-hour rainfall. Five complaints were received on 5/15/2020 after the rainfall that may have exceeded a 10-year event. This may indicate that the system has a 5-year LOS (but not a 10-year). Field investigations found no major issues on Butternut Lane. Additional evaluations and field work are suggested to better understand the problem.

- **Nobottom Road problem area (BR_09_:** The model does not project BBU problems in this area for the 5-year, 1-hour storm event. Five complaints were received on 5/15/2020 after a 10-year rainfall. The monitoring in the area observed surcharging, but not high enough to predict basement backups.

Tier 2 sewer system rehabilitation improvements are proposed for large portions of PFA BE-10 to reduce high RDII flows where noted. These improvements are expected to improve wet weather performance for larger rainfalls. Project definition investigations in both the public ROW and on private property may be helpful prior to design of rehabilitation improvements to better define the sources of excessive I/I flows.

Further Tier 3 improvements within PFA BE-10 are not indicated as all model identified BBUs are projected to be eliminated after implementation of the sewer system rehabilitation improvements in Tier 2.

Additional details relating to the PFA, as well as improvements and associated costs, are outlined in **Table 5-3**. Improvements for Tier 1, as well as Tier 2, are shown in **Figures 5-10** and **5-11**, respectively; overall improvements are shown in **Figure 5-12.**

Table 5-3. Summary for PFA BE-10

PFA:	BE-10	Community:	Berea	District Branch:	West Leg Interceptor

Trench Type Summary

	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	566	0.0	0.0	530
Sanitary Sewer Length (LF)	74,734	0	0	74,734
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**0.0%**	**100.0%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)

Net Aggregated Sewered Area	512	Acres
Net Aggregated Peak Flow Rate	11.9	MGD
Net Aggregated Peak Flow Rate Per Acre	23,191	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	57%	Percentile
Comparison to SWI-LSSES PFAs	63%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems

Active SSOs	1	Count
Controlled SSOs	1	Count
Projected BBUs	180	Count
Manholes Surcharged to Grade	1	Count
Modeled Pipe Surcharged Within 8' of Grade	16,602	LF

Potential Improvements

Improvement Quantity (LF or Count)

Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers
1	0	0	0	0	0	0	0
2	0	0	32937	0	0	0	0
3	0	0	0	0	0	0	0
Total PFA	**0**	**0**	**32937**	**0**	**0**	**0**	**0**

2020 Class 5 Planning Costs ($)

Tier	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	$10,000	$2,000	$1,000	$13,000	$4,000	$0	$17,000	0.1
2	$13,654,000	$2,048,000	$1,365,000	$17,067,000	$5,120,000	$0	$22,187,000	100
3	$0	$0	$0	$0	$0	$0	$0	0
Total PFA	**$13,664,000**	**$2,050,000**	**$1,366,000**	**$17,080,000**	**$5,124,000**	**$0**	**$22,204,000**	**100.0**

Notes

1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.1.4 PFA BE-13 (West Street and Edgewood Drive)

PFA BE-13 is a 313 acre separate trench area located in west central Berea along the District's West Leg Interceptor. This PFA receives flow from PFA OF-02 and discharges directly into the Olmsted Falls Connector, immediately upstream of the West Leg Interceptor. PFA BE-13 has no other cross connections with adjacent PFAs. There are no known constructed SSOs located within this PFA.

A total of 26,000 LF of pipe is projected to surcharge within 8 feet of grade during the 5-year, 1-hour rainfall resulting in BBUs at 33 homes within the area. Community identified problem area BR_11 (Fairwood Circle) is located in this PFA as well as recent complaints of basement backups.

There are no Tier 1 improvements suggested within PFA BE-13 because there are no model projected BBUs in the reported problem area for the 5-year rainfall. BBUs are projected for the 10-year rainfall. Most of the homes in PFA BE-13 are constructed as slab on grade without basements. The homes in the problem area are some of the only homes in that portion of the PFA with basements. Initial site visits found an obstruction just downstream of the problem area that was removed before flow meter installation. The obstruction may have been at least a partial cause of the problems. The model and monitoring data show significant surcharge in the downstream sewer, but it is not projected to reach a level to impact basements.

Several alternatives were evaluated to reduce surcharging in the area. Since I/I in the area is not excessive and the surcharge extends a long distance, many solutions considered were expensive. A new flow connection improvement suggested under Tier 3 is projected to provide surcharging relief. If issues persist, additional alternatives such as the high pipe concept to disconnect affected basements from gravity sanitary sewer service can be evaluated.

Tier 2 improvements to reduce peak wet weather RDII flows are not suggested within PFA BE-13 because the peak wet weather flows, while relatively high in some areas, were not found to be excessive based on project criteria as discussed in Section 3.2.

Tier 3 improvements are proposed to control BBUs projected to remain after any Tier 1 and/or Tier 2 improvements. In PFA BE-13, a new flow connection is suggested to redirect sanitary sewer flows at West Street to the existing West Leg Interceptor manhole located approximately 500 feet north of West Street. This new connection is expected to significantly reduce the risk of projected BBUs throughout PFA BE-13.

Details relating to PFA BE-13, as well as improvements and associated costs, are outlined in **Table 5-4**. Improvements for Tier 3 are shown in **Figure 5-11**; overall improvements are shown in **Figure 5-12.**

Table 5-4. Summary for PFA BE-13

PFA:	BE-13	Community:	Berea	District Branch:	Olmsted Falls Connector

Trench Type Summary	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	313	0.0	0.0	310
Sanitary Sewer Length (LF)	45,436	0	0	45,436
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**0.0%**	**100.0%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)		
Net Aggregated Sewered Area	320	Acres
Net Aggregated Peak Flow Rate	5.1	MGD
Net Aggregated Peak Flow Rate Per Acre	16,034	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	36%	Percentile
Comparison to SWI-LSSES PFAs	51%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems		
Active SSOs	0	Count
Controlled SSOs	0	Count
Projected BBUs	33	Count
Manholes Surcharged to Grade	0	Count
Modeled Pipe Surcharged Within 8' of Grade	25,956	LF

Potential Improvements

	Improvement Quantity (LF or Count)							2020 Class 5 Planning Costs ($)							
Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0	0
2	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0	0
3	0	0	0	0	0	0	828	$843,000	$126,000	$84,000	$1,054,000	$316,000	$0	$1,370,000	100
Total PFA	**0**	**0**	**0**	**0**	**0**	**0**	**828**	**$843,000**	**$126,000**	**$84,000**	**$1,054,000**	**$316,000**	**$0**	**$1,370,000**	**100.0**

Notes
1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.1.5 PFA BE-04 (N Rocky River Drive and Grayton Road)

PFAs BE-04, 05 and 06 are located in north-central Berea between the east branch of the Rocky River, North Rocky River Drive and Sheldon Road. These areas are discussed together and are shown in common figures. These areas have also been the focus of the recent North End Phase 1 (2017) and Phase 2 (2020) MCIP sewer system rehabilitation projects implemented by the Cuyahoga County Department of Public Works, as shown in **Figure 5-13**.

This report developed potential solutions for the areas based on spring/summer 2019 flow monitoring and modeling conducted for this project. This implies that the Phase 1 system rehabilitation preceded the SWI-LSSES flow monitoring and that the Phase 2 system rehabilitation followed the SWI-LSSES monitoring. The parallel SSES studies and MCIP projects implemented in these areas by the County are provided as supplemental information.

PFA BE-04 discharges directly into the West Leg Interceptor and has an inflowing cross connection from PFA BE-03 that is active during the 5-year, 1-hour rainfall. PFA BE-04 is served by 52% common trench and 48% separate trench sewers.

There are two known SSOs within this PFA (D361 and D-374) that are projected to activate during the 5-year, 1-hour rainfall, but not during District Typical Year rainfalls. SSO activation is projected to produce 0.013 MG of overflow during the 5-year, 1-hour design event. There are two additional SSOs within this PFA (D11 and D7) that are not projected to activate during the 5-year, 1-hour rainfall or the District Typical Year rainfalls.

Over 2,700 LF of pipe is projected to surcharge within 8 feet of grade during the 5-year, 1-hour rainfall resulting in basement backups for 11 homes within PFA BE-04. One community-identified problem area (BR_08) is associated with this PFA and it is being resolved by a current/previous project.

Tier 1 improvements within PFA BE-04 are proposed to control the active SSOs. Sanitary sewer rehabilitation is recommended upstream of SSO D-374 and is projected to control both D-374 and D-361.

Tier 2 improvements within PFA BE-04 are proposed for the areas with high observed RDII. This proposed improvement is also proposed to eliminate the projected BBUs, so no further Tier 3 improvement is suggested.

Details relating to PFA BE-04, as well as improvements and associated costs, are outlined in **Table 5-5**. Improvements for Tier 1 and Tier 2 are shown in **Figures 5-14** and **5-15**, respectively; overall improvements are shown in **Figure 5-16.**

Figure 5-13. North End Phase 1 and Phase 2 MCIP Project Areas

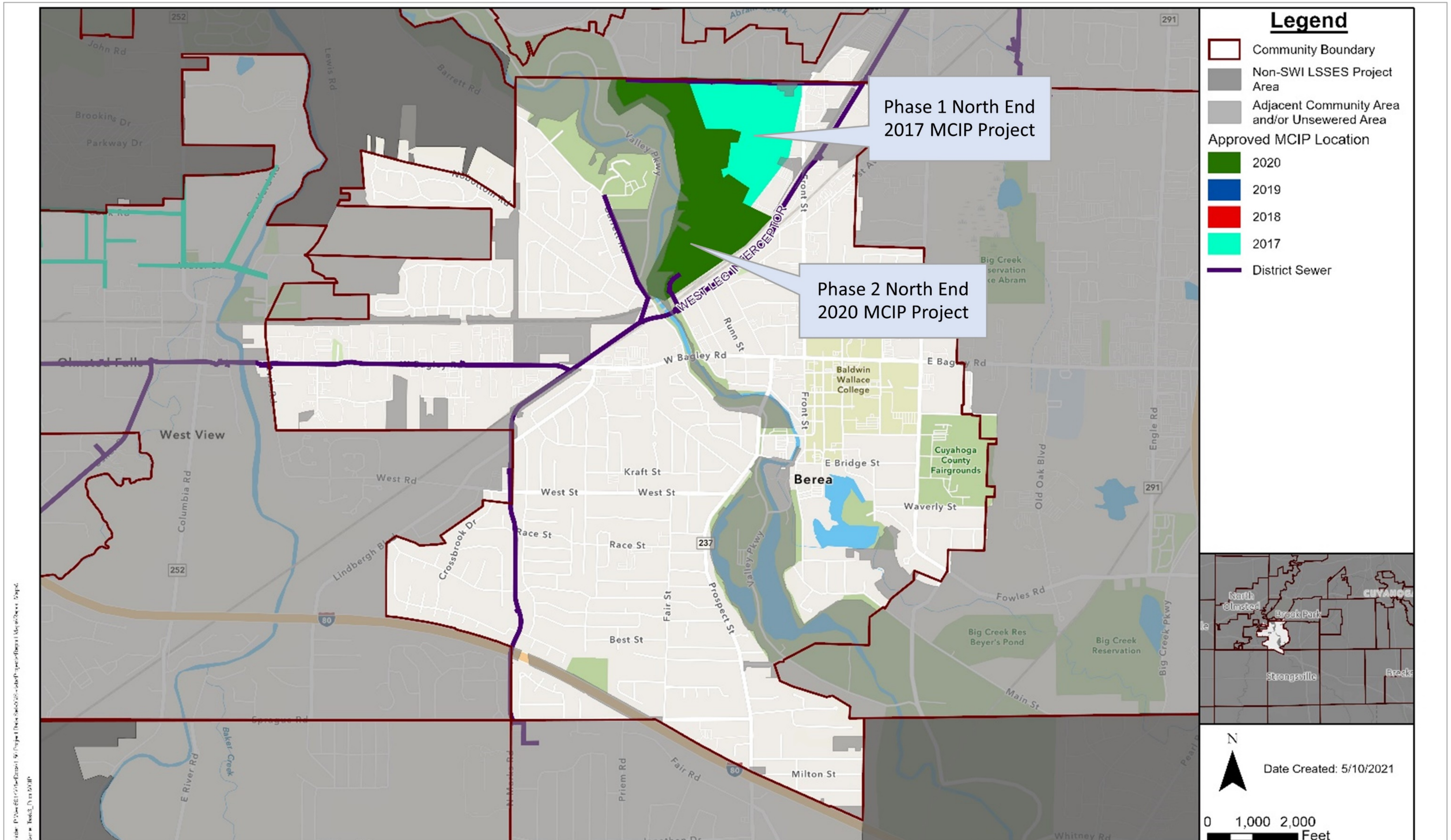


Figure 5-14. Tier 1 Improvements in PFAs BE-04 and BE-05

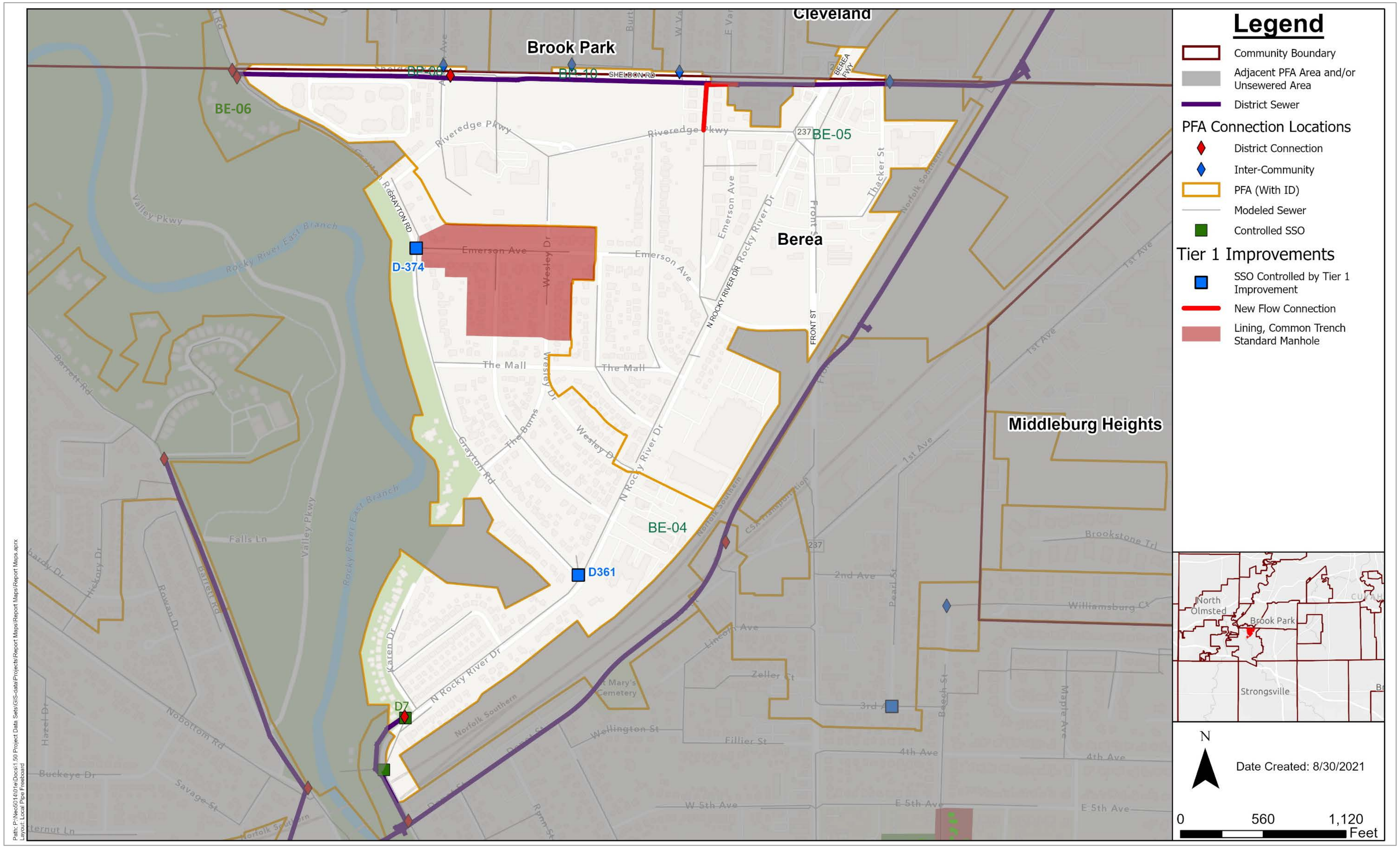


Figure 5-15. Tier 2 and Tier 3 Improvements in PFAs BE-04, BE-05 and BE-06

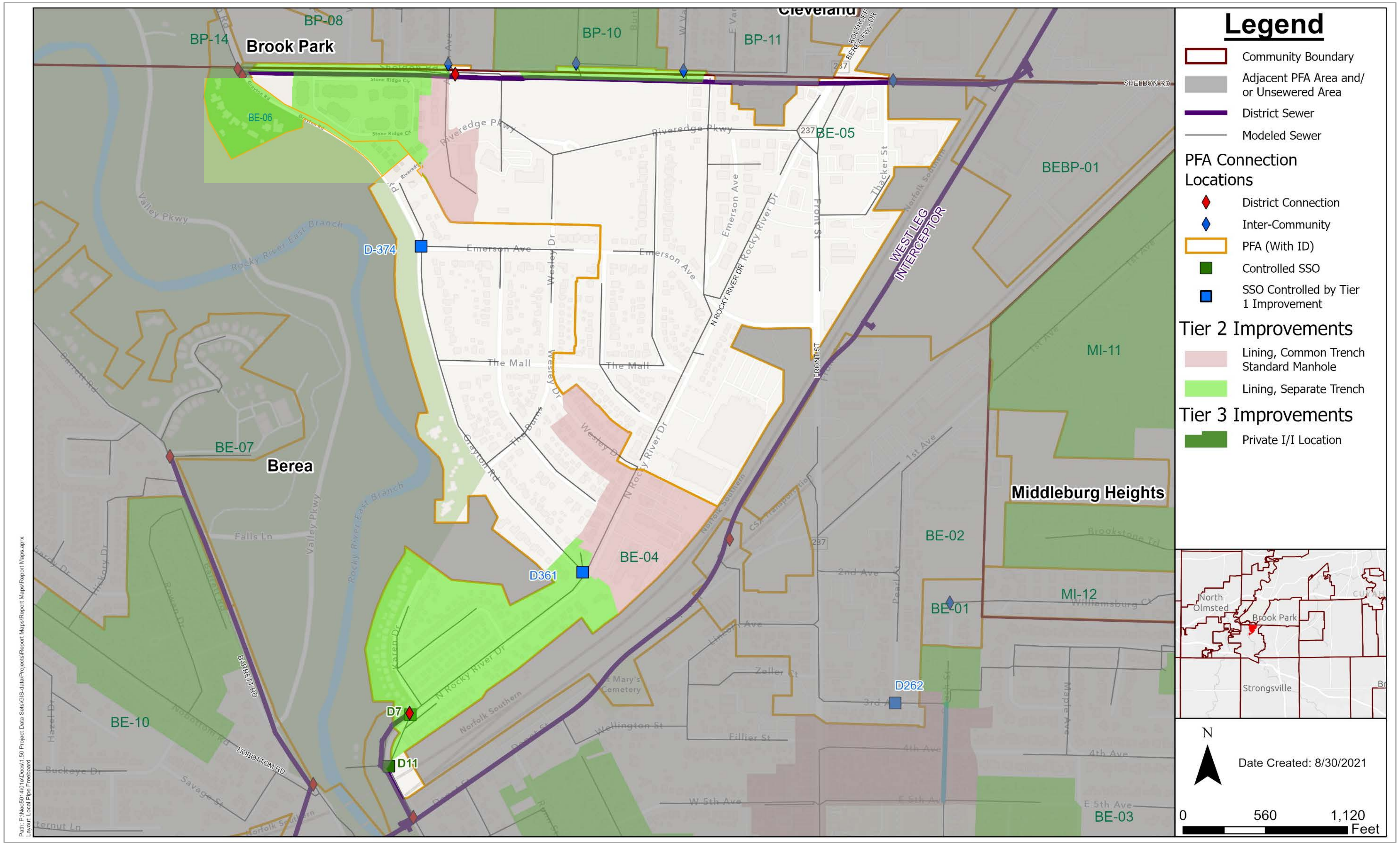


Figure 5-16. Overall Improvements for PFAs BE-04, BE-05 and BE-06

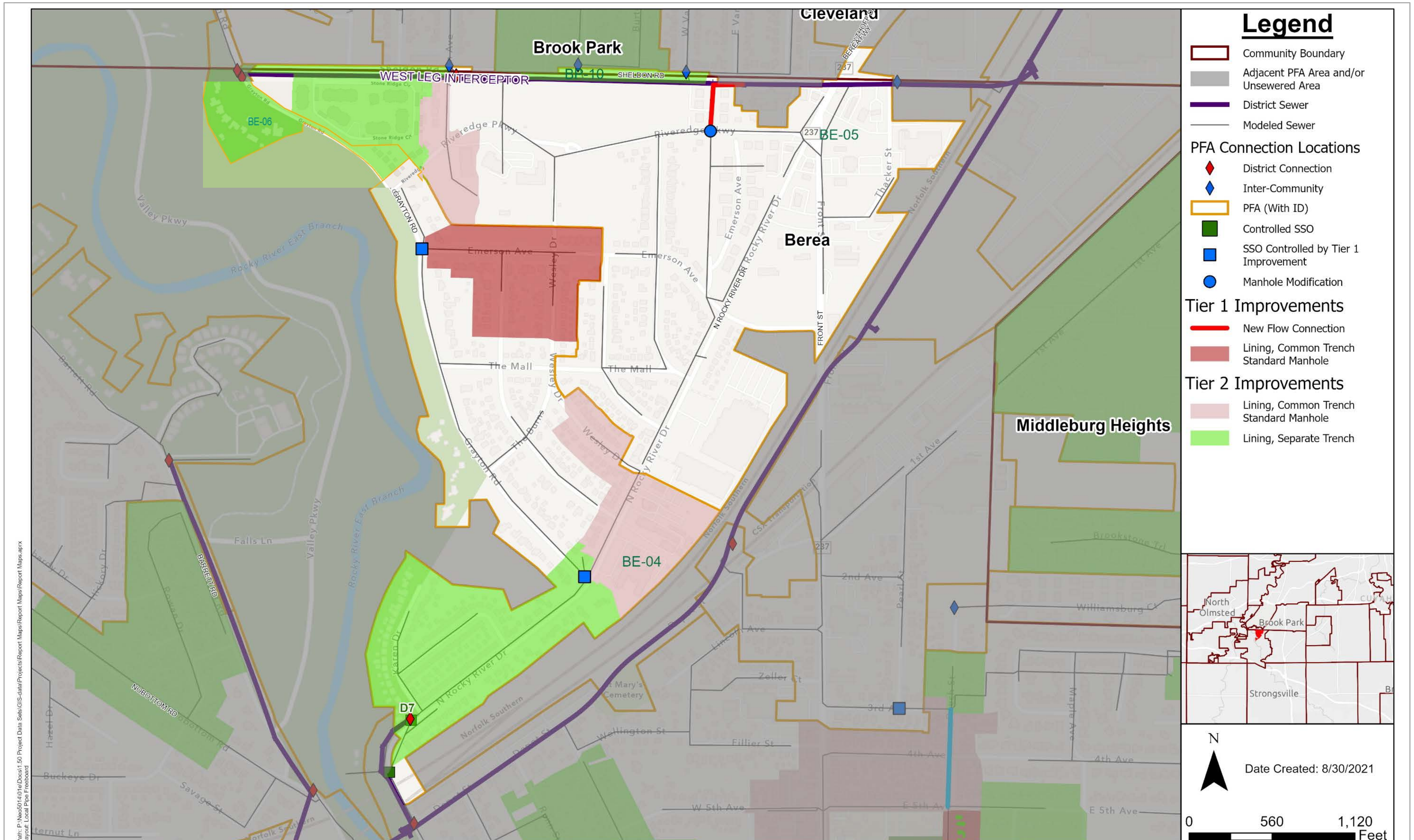


Table 5-5. Summary for PFA BE-04

PFA:	BE-04	Community:	Berea	District Branch:	West Leg Interceptor

Trench Type Summary	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	114	0.0	54.8	53
Sanitary Sewer Length (LF)	14,645	0	7,565	7,080
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**51.7%**	**48.3%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)		
Net Aggregated Sewered Area	103	Acres
Net Aggregated Peak Flow Rate	4.2	MGD
Net Aggregated Peak Flow Rate Per Acre	40,523	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	93%	Percentile
Comparison to SWI-LSSES PFAs	79%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems		
Active SSOs	2	Count
Controlled SSOs	2	Count
Projected BBUs	11	Count
Manholes Surcharged to Grade	0	Count
Modeled Pipe Surcharged Within 8' of Grade	2,733	LF

Potential Improvements

Improvement Quantity (LF or Count)

Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers
1	0	2464	0	0	0	0	0
2	0	1429	4274	0	0	0	0
3	0	0	0	0	0	0	0
Total PFA	**0**	**3893**	**4274**	**0**	**0**	**0**	**0**

2020 Class 5 Planning Costs ($)

Tier	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	$785,000	$118,000	$78,000	$981,000	$294,000	$172,000	$1,447,000	31.1
2	$1,918,000	$288,000	$192,000	$2,397,000	$719,000	$100,000	$3,216,000	69
3	$0	$0	$0	$0	$0	$0	$0	0
Total PFA	**$2,703,000**	**$406,000**	**$270,000**	**$3,378,000**	**$1,013,000**	**$272,000**	**$4,663,000**	**100.0**

Notes

1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.1.6 BE-05 (N Rocky River Drive and Emerson Avenue)

PFA BE-05 receives flows from PFAs BEBP-01, BP-08, BP-10, and BP-11, and discharges directly into the West Leg Interceptor immediately east of Arden Avenue. PFA BE-05 has no other cross connections with adjacent PFAs. The sewers serving PFA BE-05 are 78% common trench and 22% separate trench configuration. There are no known constructed SSOs in this PFA.

A total of 5,637 linear feet of pipe exhibits an excessive (within 8 feet of grade) degree of surcharge within this PFA when subjected to the 5-year, 1-hour rainfall. Surcharge within the system results in the projection of basement flooding for three homes within PFA BE-05 during the 5-year, 1-hour rainfall. Two community-identified problem areas (BR_07 and BR_08) associated with this PFA were addressed with system rehabilitation in 2016.

Tier 1 improvements within PFA BE-05 are proposed for potential recurring problem areas. The meter data shows surcharge in the Riveredge Parkway sewer and the calibrated model projects BBUs. The Riveredge sewer runs near and parallel to the District interceptor. A new sewer near the upstream end of Riveredge Parkway to offload flows to the District sewer will help control the local surcharge and reduce risk of BBUs.

Tier 2 improvements are suggested in the northwest corner of the PFA for areas with high RDII. After Tier 1 and Tier 2 improvements, Tier 3 improvements are not needed as all projected BBUs have been resolved.

Details relating to PFA BE-05, as well as improvements and associated costs, are outlined in **Table 5-6**. Improvements for Tier 1, as well as Tier 2, are shown in **Figures 5-14** and **5-15**, respectively; overall improvements are shown in **Figure 5-16.**

Table 5-6. Summary for PFA BE-05

PFA:	BE-05	Community:	Berea	District Branch:	West Leg Interceptor

Trench Type Summary

	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	152	0.0	88.5	41
Sanitary Sewer Length (LF)	20,204	0	15,669	4,536
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**77.6%**	**22.5%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)

Net Aggregated Sewered Area	245	Acres
Net Aggregated Peak Flow Rate	5.8	MGD
Net Aggregated Peak Flow Rate Per Acre	23,843	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	64%	Percentile
Comparison to SWI-LSSES PFAs	63%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems

Active SSOs	0	Count
Controlled SSOs	0	Count
Projected BBUs	3	Count
Manholes Surcharged to Grade	0	Count
Modeled Pipe Surcharged Within 8' of Grade	5,637	LF

Potential Improvements

	Improvement Quantity (LF or Count)							2020 Class 5 Planning Costs ($)							
Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	0	0	0	0	0	0	508	$602,000	$90,000	$60,000	$752,000	$226,000	$0	$978,000	34
2	0	1403	1920	0	0	0	0	$1,113,000	$167,000	$111,000	$1,391,000	$417,000	$98,000	$1,906,000	66.1
3	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0	0
Total PFA	**0**	**1403**	**1920**	**0**	**0**	**0**	**508**	**$1,715,000**	**$257,000**	**$171,000**	**$2,143,000**	**$643,000**	**$98,000**	**$2,884,000**	**100.0**

Notes

1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.1.7 BE-06 (Grayton Road at Sheldon Road)

PFA BE-06 is a small area located within northwestern Berea adjacent to PFAs BE-04 and BE-05. This PFA discharges directly into the West Leg Interceptor and has no cross connections with adjacent PFAs. PFA BE-06 is served by separate trench sewers and there are no known constructed SSOs in this PFA.

There is no surcharging or BBUs projected in this PFA, and no community reported problem areas, but peak wet weather flows are projected to be excessive, so Tier 2 sewer system rehabilitation improvements are proposed, but no Tier 1 or Tier 3 improvements are identified.

Additional details relating to PFA BE-06, as well as improvements and associated costs, are outlined in **Table 5-7**. Tier 2 sewer rehabilitation Improvements are shown in **Figure 5-15.**

Table 5-7. Summary for PFA BE-06

PFA:	BE-06	Community:	Berea	District Branch:	West Leg Interceptor

Trench Type Summary

	Total	Over/Under	Common Standard	Separate
PFA Area (Acres)	7.5	0.0	0.0	7.4
Sanitary Sewer Length (LF)	1,326	0	0	1,326
Percentage of Total Sewer Length (%)	**100.0%**	**0.0%**	**0.0%**	**100.0%**
Notes	1. Total PFA Area may include non-sewered areas.			

PFA Net Aggregated Area Using Peak Modeled Flow Rate (5-Year, 1-Hour Rainfall, 15-Minute Rainfall Increments)

Net Aggregated Sewered Area	7.4	Acres
Net Aggregated Peak Flow Rate	0.9	MGD
Net Aggregated Peak Flow Rate Per Acre	116,892	GPAD
Weighted Average Community PFA GPAD	27,505	GPAD
Weighted Average SWI-LSSES PFA GPAD	34,249	GPAD
Comparison to Community PFAs	100%	Percentile
Comparison to SWI-LSSES PFAs	94%	Percentile

Net Aggregated Peak Flow Rate is pipe routed flow calculated through the addition of all flows diverted out from the PFA to, and the subtraction of all flows diverted into the PFA from the PFA's intrinsic flow; the Aggregated GPAD is this flow over the Net Aggregated Sewered Area. Note that the model routed pipe flows shown above may be significantly lower than the model catchment RDII runoff flows. See report for further discussion.

Model Projected Problems

Active SSOs	0	Count
Controlled SSOs	0	Count
Projected BBUs	0	Count
Manholes Surcharged to Grade	0	Count
Modeled Pipe Surcharged Within 8' of Grade	0	LF

Potential Improvements

	Improvement Quantity (LF or Count)							2020 Class 5 Planning Costs ($)							
Tier	Over/Under Separation	Common Standard Rehab	Separate Trench Rehab	Cleaning	Capacity Enhancement	Private Property Rehab	New/Relief Sewers	Construction	Design (15%)	CA/RE (10%)	Total Capital	Contingency (30%)	Project Definition Investigation	Total	% of PFA Total
1	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0	0
2	0	0	1294	0	0	0	0	$420,000	$63,000	$42,000	$525,000	$157,000	$0	$682,000	100
3	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0	0
Total PFA	**0**	**0**	**1294**	**0**	**0**	**0**	**0**	**$420,000**	**$63,000**	**$42,000**	**$525,000**	**$157,000**	**$0**	**$682,000**	**100.0**

Notes

1. Tier 1 represents improvements to address reported system problems and active SSOs.
2. Tier 2 represents improvements to control excessive I/I and eliminate the over/under system.
3. Tier 3 represents improvements to address other projected problems.

1. Total Capital Costs = Construction + Design + CA/RE
2. Contingency = 30% of Total Capital Costs
3. Project Definition Investigation = $10,000 per acre (for common trench work areas).
4. Total Cost = Total Capital Costs + Contingency + Project Definition Investigation

5.2 SUMMARY OF IMPROVEMENT QUANTITIES, COSTS, AND BENEFITS

Figure 5-17 shows the overall potential solutions in Berea. **Table 5-8** summarizes the improvement quantities and class 5 cost opinions for Berea PFAs. The quantities are provided for the overall potential system improvements and the estimated total improvement costs are provided for the three tiers of the overall potential system improvements. Total improvement costs include engineering, construction administration, contingencies, and a project definition allowance for common trench work areas. **Section 4.4** provides additional detail regarding cost development. The estimated quantities for the three tiers are provided in **Table 5-9**.

Figure 5-17. Overall Potential Solutions in Berea

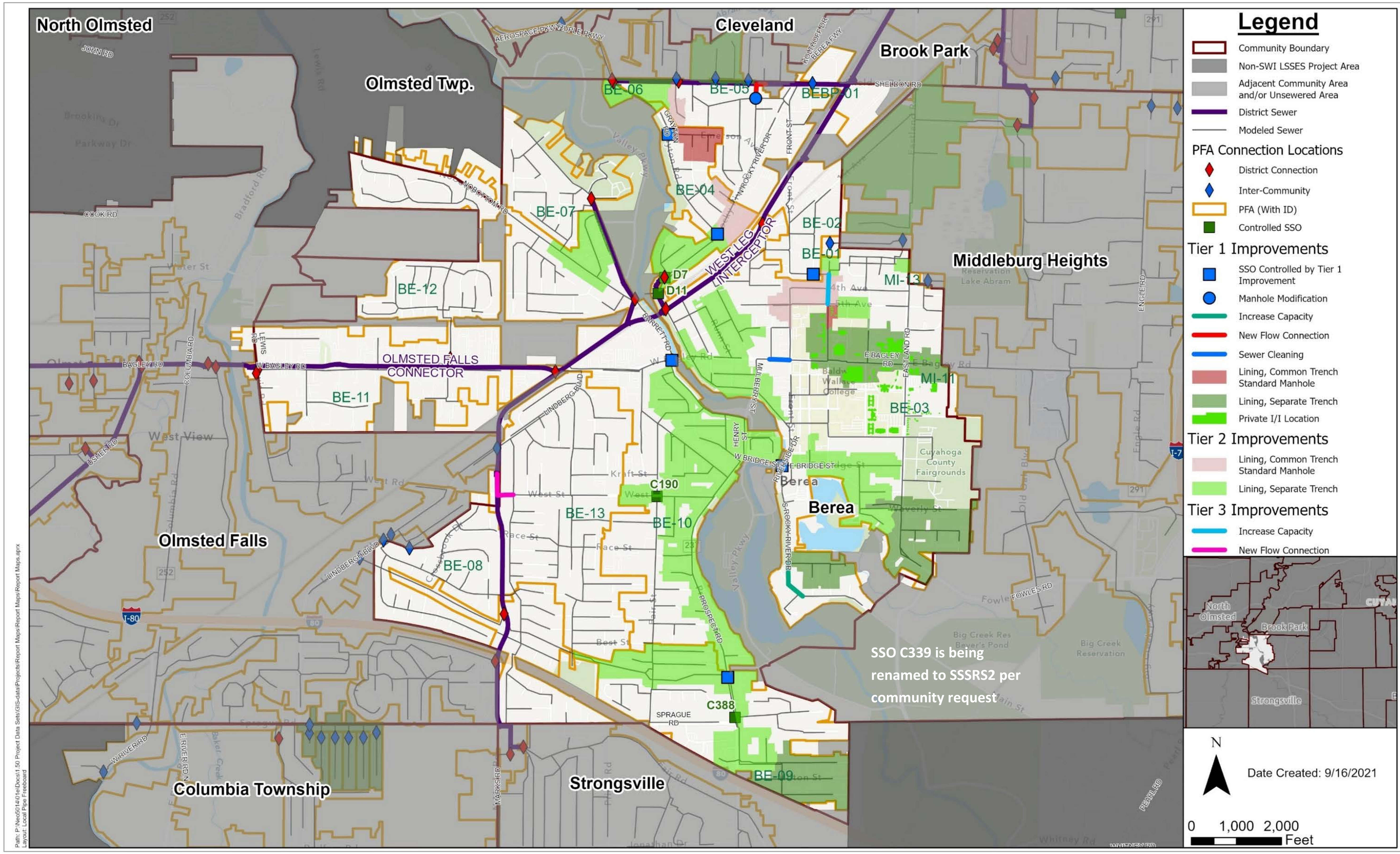


Table 5-8. Improvements and Costs By PFA and Tier

PFA ID	Total Area, acres	Quantities - Overall Potential System Improvements					Current Year Planning Level (Class 5) Costs					
								Total Cost (including engineering and contingencies)				
		Common Standard Rehabilitation, LF	Separate Trench Rehabilitation, LF	New Flow Connection, LF	Increased Capacity, LF	Private Property, no. of Parcels	Construction Overall Cost, $	Tier 1, $	Tier 2, $	Tier 3, $	Common Standard Rehabilitation Project Definition, $	Total, $
BE-01	2	0	0	0	0	0	$0	$0	$0	$0	$0	$0
BE-02	93	0	0	0	0	0	$0	$0	$0	$0	$0	$0
BE-03	843	5,458	35,281	0	1,539	46	$17,517,000	$11,493,000	$16,241,000	$1,113,000	$382,000	$28,847,000
BE-04	114	3,893	4,274	0	0	0	$2,703,000	$1,447,000	$3,216,000	$0	$272,000	$4,663,000
BE-05	151	1,403	1,920	508	0	0	$1,715,000	$978,000	$1,907,000	$0	$98,000	$2,885,000
BE-06	7	0	1,294	0	0	0	$420,000	$0	$682,000	$0	$0	$682,000
BE-07	132	0	0	0	0	0	$0	$0	$0	$0	$0	$0
BE-08	130	0	0	0	0	0	$0	$0	$0	$0	$0	$0
BE-09	387	0	20,800	0	0	0	$7,170,000	$3,012,000	$8,639,000	$0	$0	$11,651,000
BE-10	566	0	32,937	0	0	0	$13,664,000	$16,000	$22,187,000	$0	$0	$22,203,000
BE-11	283	0	0	0	0	0	$0	$0	$0	$0	$0	$0
BE-12	197	0	0	0	0	0	$0	$0	$0	$0	$0	$0
BE-13	313	0	0	828	0	0	$843,000	$0	$0	$1,370,000	$0	$1,370,000
BEBP-01	36	0	0	0	0	0	$0	$0	$0	$0	$0	$0
TOTAL	3,255	10,754	96,506	1,336	1,539	46	$44,032,000	$16,946,000	$52,872,000	$2,483,000	$752,000	$72,301,000

Table 5-9. Improvement Quantities Summary by PFA and Tier															
PFA ID	Improvement Quantities - Tier 1					Improvement Quantities - Tier 2					Improvement Quantities - Tier 3				
	Common Standard Rehab, LF	Separate Trench Rehab, LF	New Flow Connection, LF	Increased Capacity, LF	Private Property Rehab, no. of Parcels	Common Standard Rehab, LF	Separate Trench Rehab, LF	New Flow Connection, LF	Increased Capacity, LF	Private Property Rehab, no. of Parcels	Common Standard Rehab, LF	Separate Trench Rehab, LF	New Flow Connection, LF	Increased Capacity, LF	Private Property Rehab, no. of Parcels
BE-01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BE-02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BE-03	537	16,512	0	882	46	4,921	18,769	0	0	0	0	0	0	657	0
BE-04	2,464	0	0	0	0	1,429	4,274	0	0	0	0	0	0	0	0
BE-05	0	0	508	0	0	1,403	1,920	0	0	0	0	0	0	0	0
BE-06	0	0	0	0	0	0	1,294	0	0	0	0	0	0	0	0
BE-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BE-08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BE-09	0	5,822	0	0	0	0	14,978	0	0	0	0	0	0	0	0
BE-10	0	0	0	0	0	0	32,937	0	0	0	0	0	0	0	0
BE-11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BE-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BE-13	0	0	0	0	0	0	0	0	0	0	0	0	828	0	0
BEBP-01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**3,001**	**22,334**	**508**	**882**	**46**	**7,753**	**74,172**	**0**	**0**	**0**	**0**	**0**	**828**	**657**	**0**

5.2.1 Benefits

The proposed improvements will provide several system performance and water quality benefits. Estimated benefits associated with the proposed overall potential system improvements in Berea are summarized by PFA in **Table 5-10**. The projected benefits are summarized below.

Improved System Performance and Human Health

The number of parcels at risk of BBUs and the number of SSOs controlled at the 5-year, 1-hour design rainfall level and the resulting reduction in Typical Year overflow volume are provided.

Water Quality Improvements

Control of SSOs and separation or rehabilitation of common trench sewers will improve stormwater quality by eliminating crossflows of sewage into storm sewers.

System Serviceability and Reliability

Non-costed benefits include improved serviceability, O&M, reliability during dry and wet weather conditions, and capacity for new sewage flows.

Peak Wet Weather Flow Reductions

Common trench and private I/I remediation reduce peak flows in the system and reduce the risk of surcharge, SSOs, and BBUs. Flow reductions also help reduce downstream treatment costs and potential CSO volumes. As SWI proposed improvements are completed, pre- and post-construction flow monitoring will help the District and communities assess the actual peak flow reductions provided by the varying system improvements. This information can be used to adapt successive improvement projects to maximize wet weather flow reduction and performance improvement per dollar spent. **Table 5-10** summarizes projected existing and post-improvement peak flow rates and resulting reductions for PFAs.

Table 5-10. Estimated Benefits of System Improvements

PFA ID	BBUs Controlled, no.	SSOs Controlled				Rehabilitation Improvement Areas, acres				PFA Projected Peak Flow Rate Comparisons (5-year, 1-hour Rainfall)		
		Active 5-year, no.	5-year Volume, MG	TY Activation(s), no.	TY Volume, MG	Over/Under	Common Standard	Separate Trench	Total	SWI-LSSES Existing Conditions, MGD	SWI-LSSES Improved System, MGD	Reduction (-) Increase (+), MGD
BE-01	0	0	0.00	0	0.00	0.0	0.0	0.0	0.0	0.1	0.1	0.0
BE-02	18	1	0.03	0	0.00	0.0	0.0	0.0	0.0	2.0	2.3	0.3
BE-03	510	1	0.07	2	0.01	0.0	29.9	430	460	21.8	9.5	-12.3
BE-04	11	2	0.01	0	0.00	0.0	33.3	33.3	66.6	4.2	2.3	-1.8
BE-05	3	0	0.00	0	0.00	0.0	14.2	12.5	26.8	5.8	2.3	-3.5
BE-06	0	0	0.00	0	0.00	0.0	0.0	7.2	7.2	0.9	0.0	-0.8
BE-07	3	0	0.00	0	0.00	0.0	0.0	0.0	0.0	2.1	2.1	0.0
BE-08	0	0	0.00	0	0.00	0.0	0.0	0.0	0.0	1.8	1.8	0.0
BE-09	82	1	0.01	0	0.00	0.0	0.0	150	150	10.1	8.2	-1.9
BE-10	180	1	0.17	15	0.54	0.0	0.0	209	209	11.9	7.4	-4.5
BE-11	0	0	0.00	0	0.00	0.0	0.0	0.0	0.0	1.3	1.3	0.0
BE-12	0	0	0.00	0	0.00	0.0	0.0	0.0	0.0	0.8	0.8	0.0
BE-13	33	0	0.00	0	0.00	0.0	0.0	6.1	6.1	5.1	4.8	-0.3
BEBP-01	0	0	0.00	0	0.00	0.0	0.0	0.0	0.0	0.6	0.6	0.0
TOTAL	**840**	**6**	**0.30**	**17**	**0.55**	**0.0**	**77.5**	**848**	**925**	**68.6**	**43.7**	**-24.8**

5.3 ANALYSIS OF 10-YEAR RAINFALL

The project included analysis of additional BBUs and SSO activations projected to accompany the 10-year, 1-hour rainfall (1.63 inches). This resulted in an increase in the number of projected BBUs from 840 to 1,036, an increase of approximately 23%. **Appendix G** provides a figure summarizing the 5- and 10-year rainfall analysis results. The **Attachment 1** spreadsheet also includes a tab summarizing the 5- and 10-year rainfall results. For Berea, it appears the additional BBUs projected are all located near BBUs projected in response to the 5-year rainfall. Previous LSSES analyses have found that in many instances where improvements are proposed, a relatively small amount of additional work/cost may provide a significant improvement in performance for larger rainfall events, so communities may wish to consider this opportunity during design of improvements.

5.4 FUTURE CONDITIONS MODELING

A future conditions model was developed to evaluate system capacity for potential future development flow increases. Planning-level estimates of future flows were developed assuming full build-out on undeveloped land and connection of all septic areas in the SWI service area to local sewers. Undeveloped areas were initially identified using the Cuyahoga County building and parcel data available on the District's AGOL platform. Parcels without buildings were deemed undeveloped, and parcel boundaries were followed to define undeveloped areas. Parcels with existing structures were assumed to be developed regardless of parcel size. The August 2020 NearMap AGOL basemap aerial was used to visually screen out any additional parcels with buildings that were not indicated in the buildings layer.

Once the undeveloped areas were identified, further screening removed the following areas:

- Public right-of-way including public parks and protected lands
- Utility Right-of-Way (ROW)
- School and government property
- Stream, lake, and pond areas, surrounded by a 100-foot buffer

The future land uses of undeveloped parcels were assumed to match the current zoning code except for agricultural areas, which were assumed to be developed into 1-acre residential lots. **Figure 5-18** depicts the identified areas for future development, as well as the septic areas assumed to be connected to the local system under future conditions. There are no current member community infrastructure program (MCIP) septic abatement projects. **Table 5-11** provides an area summary by land use.

Figure 5-18. Potential Future Development and Existing Septic Areas Considered for Discharge to the Local System

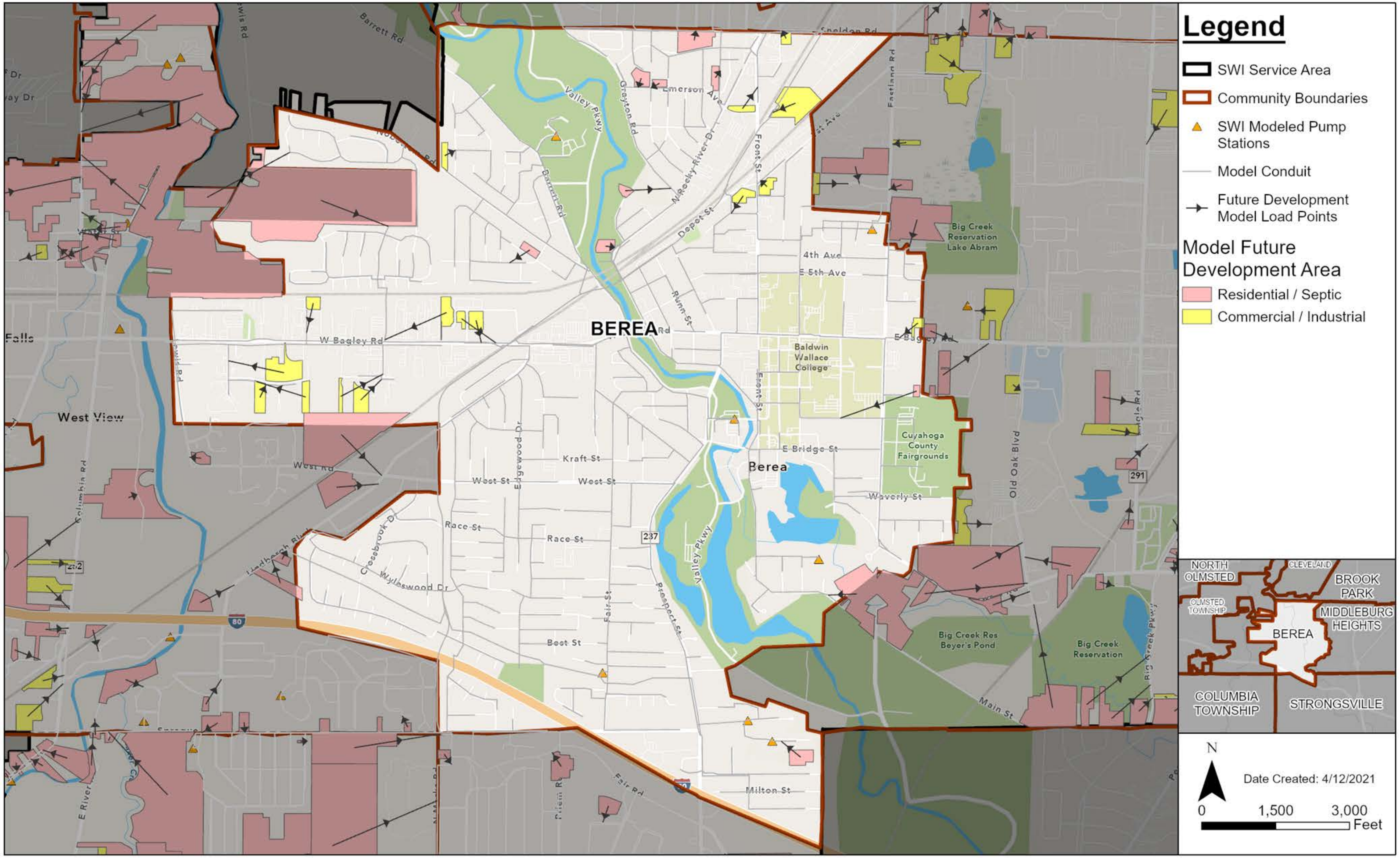


Table 5-11. Future Development Areas by Land Use		
Land Use	Area (Acres)	Percent of Total (%)
Commercial/Industrial	45	45
Residential	19	19
Septic to be Connected	37	37
Total	101	100

Future residential and commercial/industrial dry and wet weather flows were estimated based on similar, recently-developed areas within the SWI service area. Multiple areas with similar land uses and lot sizes developed since 1990 were selected to determine representative flows. Area-weighted dry and wet weather flow parameters were then developed for each land use, as summarized in **Table 5-12**.

Table 5-12. Future Flow Parameters				
Land Use	Population per acre	Groundwater Baseflow (gpm/acre)	Per Capita Sewage Flow (gal/day)	RDII1 (GPAD)
Residential/Septic	6.7	0.2429	58	12,364
Commercial/Industrial	5.5	0.2915	90	8,443

[1] *Rainfall dependent infiltration/inflow*

Areas shown in **Figure 5-18** were added to the base (existing) system model, assigned the estimated dry and wet weather flow parameters, and connected to the nearest modeled node. Existing and future development conditions were then run for the 5-year, 1-hour design event for three models: base system condition with no improvements, base system model with Tier 1 improvements, and base system model with Tier 1, Tier 2, and Tier 3 improvements. **Figure 5-19** shows the existing conditions versus the future conditions base system model results, and **Table 5-13** summarizes the results for all three models. Results for the Tier 1 improvements model and the Tiers 1-3 improvements model are provided in **Appendix H**. A summary report was also developed for the SWI-LSSES future conditions analysis and is available from the District upon request.

Figure 5-19. Existing Versus Future Conditions Base Model Results

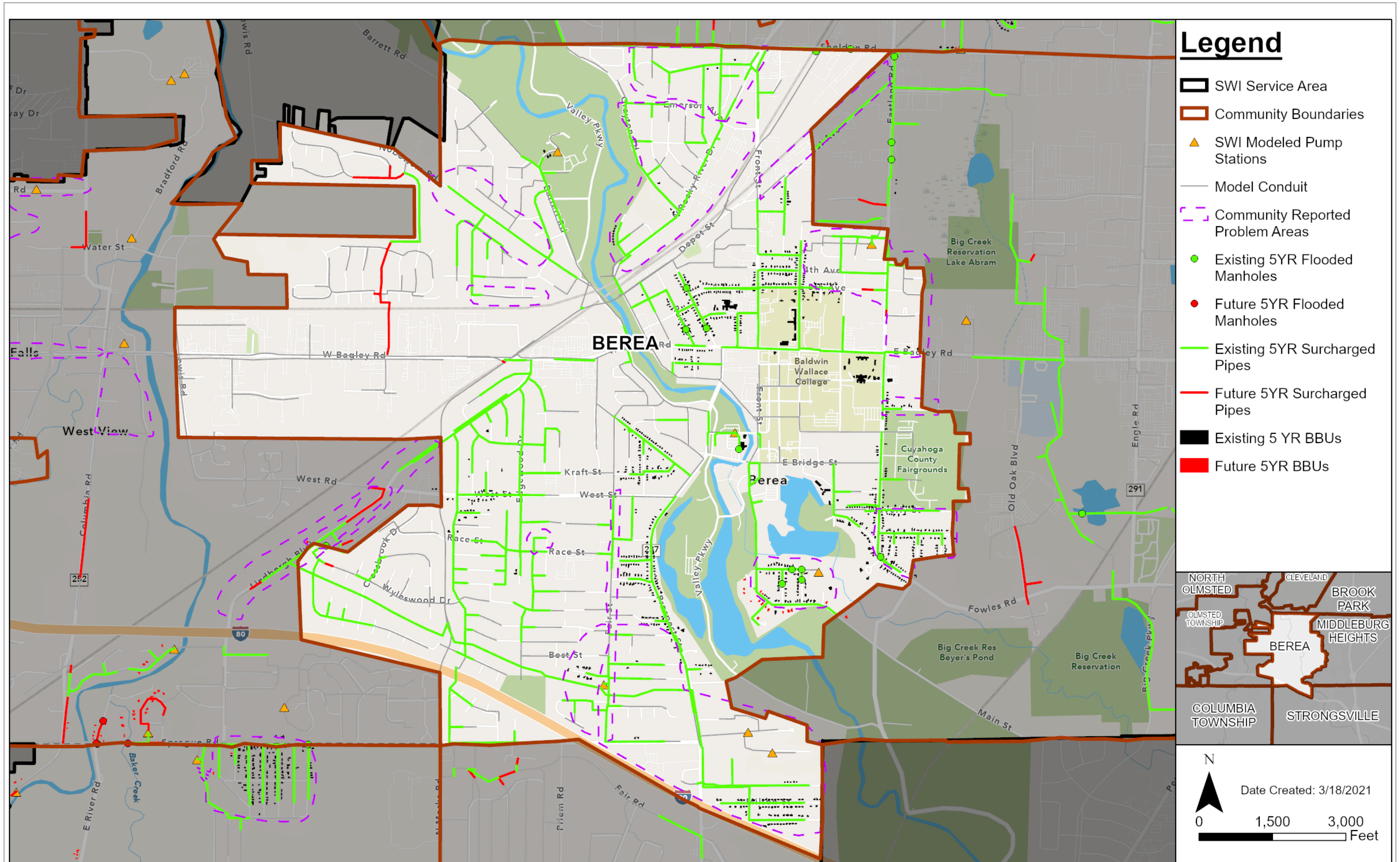


Table 5-13. Existing vs. Future Conditions Results Summary				
Sewer System Improvements Completed (Sewer System Model Version)	Development Scenario	Model-Projected Sewer System Performance		
		Surcharged Pipes	Flooded Manholes	BBUs
Base model (no improvements)	Existing[1]	738	12	836
	Future	760	12	851
Tier 1 Improvements Completed	Existing	638	7	491
	Future	666	7	503
Tiers 1-3 Improvements Completed	Existing	431	2	22
	Future	462	3	32

[1] *Development of study area existing during 2018/2019 model calibration flow monitoring periods*

Table 5-13 indicates that the model-projected BBUs increase by less than 3% under the future development scenario for both the base system model and the system with Tier 1 improvements completed as compared to the existing development scenario. The table also shows that implementation of Tier 1 through 3 sewer system improvements reduces the number of projected BBUs by 96% under the future development scenario compared to the base model.

The developed Tier 1, 2, and 3 improvements were not adjusted based on the future conditions modeling results. This should be considered during design of improvements to address hydraulic issues in problem areas.

6.0 PRIORITIZATION OF IMPROVEMENTS WITHIN TIERS 1, 2, AND 3

Prioritization of potential improvements in Berea may be based on the proposed SWI-LSSES project phasing and the following priorities:

- Prevent property damage and human contact with untreated sewage
- Identify and repair sewer system structural and/or O&M problems that may cause SSOs and/or BBUs
- Prevent discharge of untreated sewage to the environment

During implementation, which is described in **Section 7**, the District encourages additional project definition investigations to update the findings of this study and determine appropriate, cost-effective solutions to problems.

6.1 TIER 1 PRIORITIZATION – REPORTED SYSTEM PROBLEMS AND ACTIVE SSOS

Reported/Recurrent BBUs

Berea reported areas of known/recurrent BBU problems. The City may investigate and update the findings of this study to consider appropriate solutions. Peak flows and projected HGLs in several Berea modeled sewers indicate that BBUs are expected during the 5-year, 1-hour rainfall. Relevant HGL profiles for Berea are provided in **Appendix C**. BBU frequency and severity may be used to prioritize flooding problem locations.

Active SSOs

In Berea, six known SSOs are projected to activate during the 5-year, 1-hour rainfall. **Table B3** in **Appendix B** shows 5-year, 1-hour, and Typical Year activation volumes for all Berea SSOs. Tier 1 alternatives include common trench separation, common trench remediation, private property remediation and capacity enhancement. Other alternatives, such as the diversion of upstream flow or SSO diversion structure elimination/adjustment, may be considered.

Known/Suspected Illicit Discharges

Two potential illicit discharges have been identified for Berea as summarized in **Table B5** in **Appendix B**. One of the investigations currently has its source investigation completed, and the other one is on the District’s list for investigation. Confirmed illicit discharges should be corrected as soon as practical in Tier 1 to eliminate continuous discharge of untreated sewage to local waters.

Known Manholes Surcharging to Grade

Several locations in Berea have relatively high peak flows where the 5-year, 1-hour HGL is projected to reach the ground surface as shown in **Figure A1** in **Appendix A**. These may or may not occur, based on actual conditions in these systems. If evidence of manhole overflows at grade is observed, the City may conduct detailed investigations to isolate and correct the excessive I/I sources and/or capacity deficiencies to control the wet weather peak flows and surcharging.

Operations, Maintenance, and Repair

SWI-LSSES field work order findings, including O,M&R issues requiring attention, were provided to Berea during the SWI-LSSES. Regular manhole inspections, sewer cleaning, and CCTV inspection may be completed to optimize existing system performance and identify and resolve any critical structural defects, obstructions, or other issues found. Routine cleaning and televising of all sanitary sewers on a 5-year or shorter average period is suggested. Higher-frequency cleaning is suggested as needed for FROG (fats, roots, oils, grease) problem areas. Televising and cleaning may indicate that some portions of the system can be cleaned and inspected less frequently without causing problems. This information can be used in a simple asset management process to optimize cost and benefits of these activities.

Failing Septic Systems

Two septic systems within Berea are failing according to the Cuyahoga County Board of Health database, and 5 other septic tanks are more than 20 years old and should be inspected to assess condition.

6.2 TIER 2 PRIORITIZATION – CONTROL EXCESSIVE I/I

Control of excessive I/I may be prioritized based on several factors including sanitary and/or storm sewer system hydraulic performance/risk, peak wet weather flow response, stormwater contamination, O&M issues, structural condition, and other planned projects. Overlaying or combining the relevant factors for each potential common trench project area may provide a reasonable prioritization. **Table 6-1** provides an example of a potential prioritization concept for similar size/cost, over/under projects in a community. Actual quantification values of each factor may need to be adjusted for each community. Sewers with significant structural problems and reaches in areas with recurrent BBUs should be given highest priority.

Table 6-1. Example Prioritization for Tier 2 Over/Under System Elimination Projects			
Prioritization Factor	Positive (+1)	Neutral (-)	Negative (-1)
5-year peak HGL level	No surcharge or spare capacity	Minor surcharge	Risk of backups
5-year peak wet weather flow response	<10,000 GPAD	10,000 – 25,000 GPAD	>25,000 GPAD
Rainfall event average E. coli loading	<1,000 C/100ml	1,000 – 10,000 C/100ml	>10,000 C/100ml
O&M issues – sanitary sewer	Self-cleaning, no recurrent issues	Routine cleaning	High frequency or difficult O&M required
Structural condition – sanitary sewer (PACP defects score)	Up to 2	Up to 3	Greater than 3
Other planned projects in area	No other projects needed	Average roadway and utilities condition	Major infrastructure improvements needed in the ROW

Sum scores for each factor. Total Score: higher = better (lower priority)

Best score = 6, worst score = -6

6.3 PRIORITIZATION OF TIER 3 IMPROVEMENTS

Longer-term Tier 3 improvements may also be prioritized using a combination of factors including the following:

- Sewer system structural conditions (e.g., using NASSCO P/M/LACP[5] rating system) and risks associated with failure – for example, potential failure of a trunk sewer serving hundreds of properties poses a greater risk than the upstream reach of a local sewer system that may affect a few properties
- New reports of BBUs
- Stormwater quality downstream of common trench areas based on wet weather sampling
- Ongoing O&M problems
- Peak wet weather I/I flow rates per sewer length or tributary area and/or stormwater capture rates (% of total rainfall)
- Integration with other proposed District, community, or private development and/or infrastructure renewal projects

[5] Pipeline/Manhole/Lateral Assessment Certification Program

7.0 IMPLEMENTATION

This section outlines steps that communities may consider to cost-effectively implement improvements and improve system performance based on information gathered from completed projects.

7.1 PROGRAM PLANNING

The improvements identified in many communities may require several years, or in some cases decades, to complete due to the projected costs and the need to integrate with other long-term community master planning objectives. Developing a comprehensive plan to prioritize and fund sewer system and associated infrastructure improvements may include the following steps:

- Confirm extent and severity of sewer system problems by conducting a survey. This may identify new problem areas that need to be considered for work prioritization. Consider online, door-to-door, and mail-in surveys.
- Develop and maintain a sewer system complaint system to track reported problems.
- Update the SWI-LSSES proposed work phasing and prioritization, if needed. The community should revisit the most current version of Title III and their Community Discharge Permit for additional considerations.
- Develop a feasible financial plan and rate structure that may also consider District and other funding sources as detailed in **Appendix J**, and summarized below:
  - The District's MCIP provides up to 75% grant funding of eligible projects. If MCIP funding is desired, consider RFP scoring criteria to confirm project components to maximize the score. For example, capacity improvement projects in conjunction with I/I remediation would score more favorably than capacity improvement alone. https://www.neorsd.org/community/member-community-infrastructure-program-mcip/
  - The District Community Cost share program may feasibly be combined with MCIP if stormwater control is integrated into the project. https://www.neorsd.org/community/community-cost-share-program/
  - The Ohio Public Works Commission (OPWC) provides funding for capital improvement (wastewater and stormwater infrastructure) projects through the State Capital Improvement Program (SCIP). In Cuyahoga County, this program is overseen by the District One Public Works Integrating Committee (DOPWIC). http://www.countyplanning.us/services/grant-programs/infrastructure-programs/

  - Ohio EPA's Clean Water State Revolving Fund (SRF) is known as the Water Pollution Control Loan Fund (WPCLF) and provides financial and technical assistance to public or private applicants for planning, design, and construction of a wide variety of projects to protect or improve the quality of Ohio's water resources. https://epa.ohio.gov/defa/ofa
  - USEPA's Water Infrastructure Finance and Innovation Act (WIFIA) program that works separate from, but in coordination with State Revolving Fund (SRF) programs to subsidize financing for large projects. See EPA's website for more information: https://www.epa.gov/wifia
  - USEPA's Sewer Overflow and Stormwater Reuse Municipal Grants are prioritized for distressed communities implementing a long-term plan for control of CSOs or SSOs. Funding can apply to planning, design, and construction. Ohio share in FFYs2020/21 is $4.7 million. https://www.epa.gov/cwsrf/sewer-overflow-and-stormwater-reuse-municipal-grants-program
- Integrate with other planned improvements and provide a mechanism to include improvements in conjunction with private developments that may occur.
- Consider potential for doing sanitary sewer system and stormwater drainage I/I rehabilitation work on private property, as this may be part of a cost-effective approach in many areas. Develop policy and appropriate ordinance(s) to support private property work.
- Develop public education information to show need, costs, and benefits.
- Prioritize and develop a detailed plan for 5 to 10 years' worth of work to get started on Tier 1 and 2 improvements. Update the plan as appropriate at a regular interval.
- Develop program for pre- and post-construction flow monitoring, performance verification, and stormwater quality checking.

7.2 PROJECT DEFINITION, DESIGN, AND CONSTRUCTION

Communities may need to conduct new or supplementary preliminary design (project definition) investigations to refine prioritization and proposed work.

- Use micromonitoring, dyed water testing and/or smoke testing, and CCTV to isolate high I/I areas and identify failing infrastructure in the public ROW and on private property. Check for plugged stormwater lateral traps and other obstructions. Stormwater laterals must be maintained in a clean condition to avoid crossflows and surcharging problems on private property.
- Use stormwater sampling to identify illicit discharges and rank common trench areas based on stormwater pollutant loading.

- Define specific project areas and work locations in the public ROW and the private parcels requiring work.
- Conduct pre- and post-construction flow monitoring for performance verification and confirmation of design flow rates.
- This may include monitoring and modeling of both the storm and sanitary systems to determine hydraulic interaction.
- Determine best method(s) for improvements in each project area.
  - CIPP and other system rehabilitation for common standard systems in good structural condition
  - Sewer separation – new piping
  - Stormwater separation – allow CT system to remain for sewage conveyance
  - Private property I/I reduction – remove stormwater lateral traps if feasible to provide adequate drainage. Reroute directly-connected downspouts and other significant inflow sources away from the sanitary service lateral. Rehabilitate or replace leaky/failing service laterals.
  - Capacity improvements and flow rerouting
- Document conditions and lessons learned during design and construction.
  - Varying conditions
  - High groundwater areas, poor soils, etc.
  - Unusual piping configurations
  - Preferred construction methods
- Prepare accurate construction record drawings, and update AGOL. Consider developing record drawings in GIS-compatible format to streamline updating of GIS information.

7.3 FURTHER SSO CONTROL

Two SSOs in Berea are projected to overflow less than 0.01 MG during the 5-year rainfall. This projected SSO volume is small and likely beyond the accuracy of the calibrated model. The project has identified improvements to address these small volume SSOs because they are projected to occur during a 5-year, 1-hour rainfall for at least some antecedent conditions. Communities should consider this during review and planning of improvements and may wish to consider additional, longer-term flow monitoring or SSO activation monitoring using tethered blocks or level sensors to confirm SSO activations vs. rainfall prior to design and construction of improvements.

Known SSOs that are/will be controlled for at least the 5-year, 1-hour rainfall should also be considered for further control and ultimate elimination to reduce the risk of stormwater backflow into the sanitary sewer system. As the sanitary sewer system is improved to provide adequate capacity for the 5-year, 1-hour or larger rainfalls, the risk of stormwater backflow at controlled SSOs increases during these larger rainfalls, particularly in areas of limited stormwater capacity. In this condition, the SSO may degrade sanitary sewer system performance as opposed to providing an emergency overflow relief. Such structures may ultimately be considered for complete abandonment to prevent stormwater inflows to the sanitary sewer system during larger rainfalls.

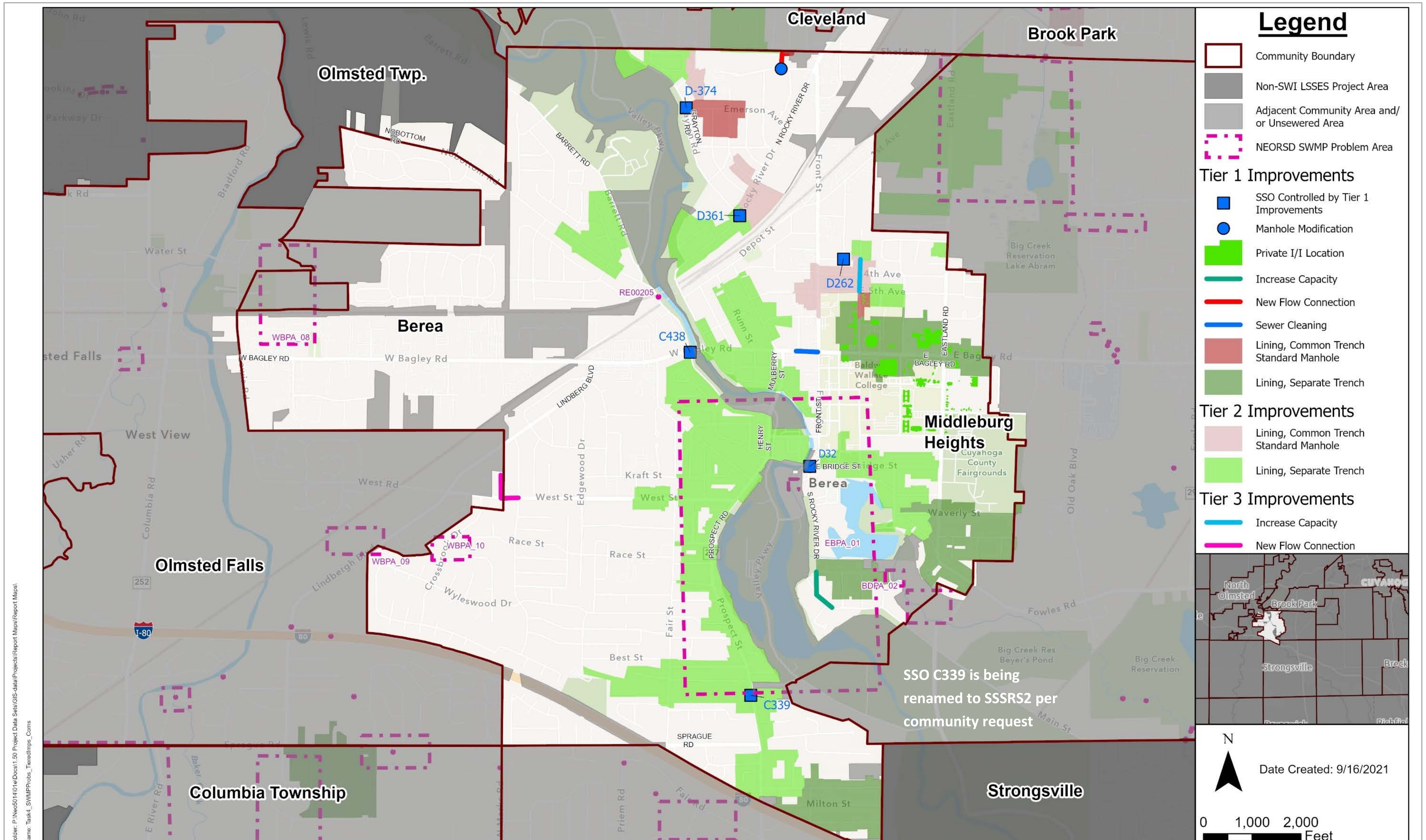
Confirmation of this condition, and the decision to physically abandon SSO connections to local storm sewers may be based on temporary flow monitoring in the storm and sanitary sewers with local rainfall monitoring to confirm that the sanitary sewer system provides more capacity for larger rainfalls than the storm sewer system.

7.4 STORMWATER MASTER PLANNING

The District completed SWMP studies that cover the regional stormwater assets for the City of Brook Park area. The primary stormwater planning objectives were to inventory the condition of those regional stormwater assets, develop improvements to address structural issues, and provide conceptual plans for flooding relief where identified in the SWMP area. The program did not specifically address stormwater-related issues in the local community system but did evaluate the capacity of nearby regional stormwater assets to handle local stormwater flows.

The SWI-LSSES project identified SWMP problem areas with respect to where potential opportunities may exist for coordinated sanitary and storm projects that could be considered by the community. These overlapping locations indicate areas where additional investigation of storm sewer related problems may be impacting the sanitary system if the storm sewer and/or sanitary systems are not relatively watertight. **Figure 7-1** provides an overview of the SWMP identified problem areas with the recommended LSSES tiered improvements. More detailed information on specific collected data, identified problems and the potential recommended projects from the SWMP is available from the District Watershed Team Leader.

Figure 7-1. LSSES Recommended Improvements Near District SWMP Problem Areas



7.5 POST-CONSTRUCTION PERFORMANCE VERIFICATION AND DOCUMENTATION

Post-construction performance verification and documentation could include the following.

- Post-construction flow monitoring data may be used to compare to pre-construction data using rainfall capture percentage and peak flow rate projected to 5-year, 1-hour rainfall.
- Projected peak 5-year flow should also be compared to the project design capacity as appropriate.
- Pre and post-construction flow monitoring may be affected by seasonal precipitation variations and antecedent moisture effects. These may be considered for the improvement projects by using control basin monitoring in conjunction with the pre- and post-construction monitoring in a nearby area of similar system type that does not undergo improvements. This information allows more accurate estimation of the pre/post-construction flow changes and the benefits attributable to the infrastructure improvements.
- Develop a summary report and suggestions for future project improvement and/or continued remediation in the project area, if needed.

7.6 SEWER SYSTEM BEST MANAGEMENT PRACTICES (BMPS)

Communities may consider developing long-term BMP guidance to share successful management practices, and design and benchmarking information, particularly for maintenance and remediation of common trench sewer systems.

Many varying asset management approaches and software programs are available to support sewer system management. Two relevant documents from USEPA provide additional information:

https://www3.epa.gov/region1/sso/pdfs/condition-assessment-underground-pipes.pdf

https://www3.epa.gov/npdes/pubs/cmom_guide_for_collection_systems.pdf

APPENDIX A. DETAILED SYSTEM AND PERFORMANCE INFORMATION FIGURES

Figure A1 – Peak Flow Areas Location Map

Figure A2 – Sewer System Trench Types

Figure A3 - Field Investigation Summary Map

Figure A4 – Existing Conditions Performance Map

APPENDIX B. DETAILED INFORMATION TABLES

APPENDIX C. LOCAL SEWER SYSTEM HGL PROFILES

APPENDIX D. DISTRICT AGOL ACCESS GUIDELINES

APPENDIX E. MODELING AND ALTERNATIVES ANALYSIS NOTES BY PFA

APPENDIX F. PROJECT COST OPINION DEVELOPMENT FOR LSSES IMPROVEMENT ALTERNATIVES ANALYSIS TECHNICAL MEMORANDUM, REVISION 2, SEPTEMBER 2018

APPENDIX G. SUMMARY OF 5- AND 10-YEAR RAINFALL ANALYSES

APPENDIX H. TIERED IMPROVEMENT MODELS RESULTS WITH FUTURE CONDITIONS DEVELOPMENT

APPENDIX I. COMMUNITY MEETING PRESENTATION SLIDES

APPENDIX J. OHIO FUNDING SOURCES FOR PUBLIC WATER AND WASTEWATER PROJECTS