City of Waltham, MA
Phosphorus Control Plan
Phase I

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Phosphorus Control Plan Phase I

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Brown AND Caldwell

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Limitations

This report was prepared solely for the City of Waltham in accordance with the standards of the environmental consulting industry at the time the services were performed and in accordance with the contract between the City of Waltham and Brown and Caldwell dated August 9, 2022. This report is governed by the specific Scope of Work authorized by the City of Waltham and is not intended to be relied upon by any other party except regulatory agencies as contemplated by the Scope of Work. We have relied on information or instruction provided by the City of Waltham and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Section 1. Executive Summary

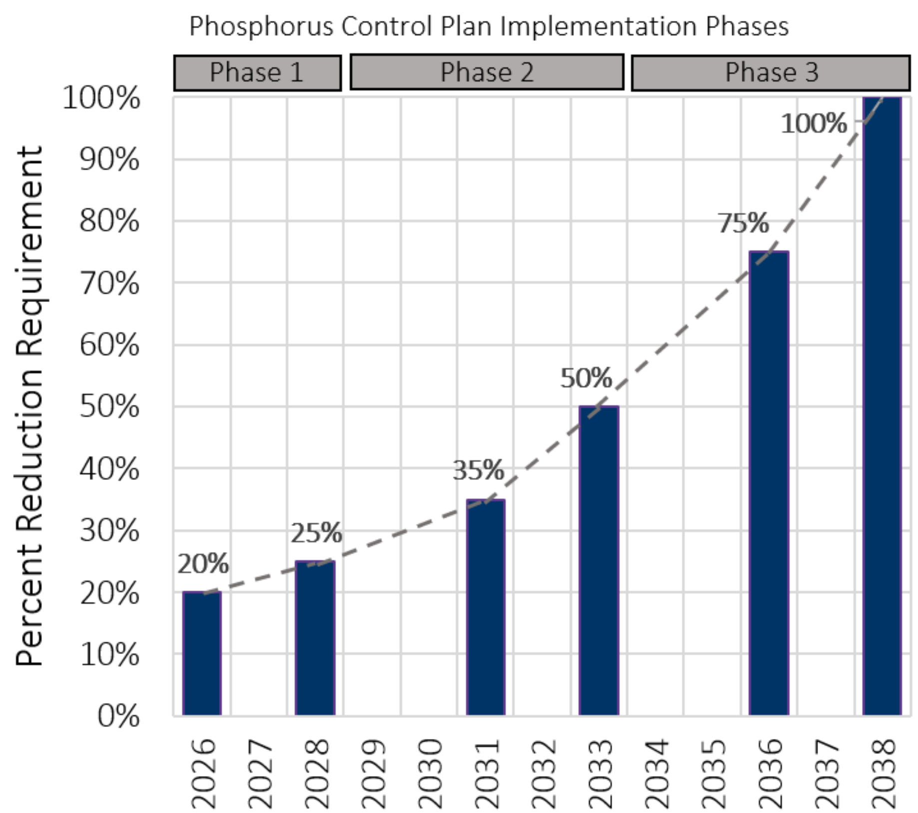
The 2016 Municipal Separate Storm Sewer System (MS4) Permit requires that the City of Waltham significantly reduce the phosphorus in its stormwater reaching the Charles River. The City must develop a Phosphorus Control Plan to accomplish this goal. This report documents the City's Phase 1 plan which will be implemented from July 2023 through June 2028.

Phosphorus Reduction Requirements

The MS4 Permit estimated the phosphorus load in the City's stormwater and established a reduction requirement based on conditions in the year 2005.

2005 Average Annual Phosphorus Export Rate	6,382 lb/yr
Reduction Requirement (lb/yr)	3,861 lb/yr

The reductions must be achieved in accordance with the schedule below.



Adjustments due to Development/Redevelopment

In addition, the City must also remove all of the additional phosphorus load due to development/redevelopment that occurred from 2005 to present day. These reductions must be achieved by 2026.

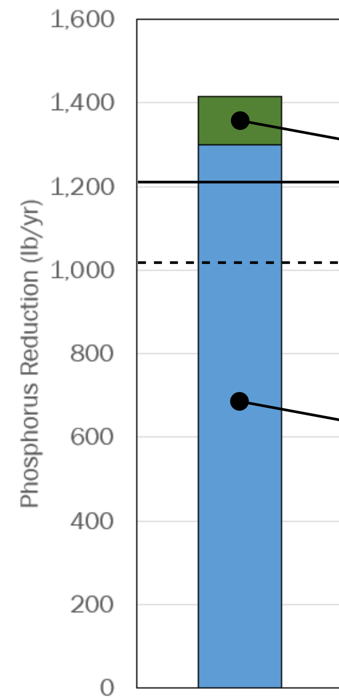
Estimated increase in phosphorus load due to development/redevelopment from 2005 - present day	265 lb/yr

Adjusted Phase 1 Reduction Requirements

Year 2026: 1,037 lb/yr (3,861 b/yr x 0.2 + 265 lb/yr)	Year 2028: 1,230 lb/yr (3,861 lb/yr x 0.25 + 265) lb/yr

Meeting the Phase 1 Reduction Requirements

The City will meet the phosphorus reduction requirements through the implementation of stormwater best management practices (BMPs)



	Phosphorus Reduction (lb/yr)	Notes
Planned BMPs		
Summit Ave BMPs	2	1
High School BMPs	18	1
Embassy Parking Lot BMPs	2	1
Bobby Connors Playground BMP	13	2
Monsignor McCabe Playground BMP	20	2
Beaver Brook Reservation BMP	63	2
Subtotal	118	
Implemented BMPs		
Street sweeping	24	
Catch basin cleaning	43	
Existing private property structural BMPs	140	3
Existing City-owned structural BMPs	71	4
Cambridge Reservoir	1,020	5
Subtotal	1,298	
Total	1,416	

----- 2026 Phosphorus Reduction Requirement (adjusted to include changes since 2005)

—— 2028 Phosphorus Reduction Requirement (adjusted to include changes since 2005)

Notes

1. These BMPs have already been designed and are either under construction or will be constructed soon (see Section 7.2.1).
2. These BMPs are in the planning phase. Conceptual designs have been developed. The City plans to implement these during Phase 1. (see Section 7.2.2)
3. The City requires that development/redevelopment provide stormwater treatment, resulting in 836 structural BMPs on private properties since 2005 (see Section 6.2.1).
4. The City has implemented 68 structural BMPs on City-owned properties since 2005 (see Section 6.2.2).
5. About 30% of the City drains to the Cambridge Reservoir. It is estimated that the Reservoir removes about 1,020 pounds of phosphorus per year from the City's stormwater runoff (see Appendix G). The City will undertake a yearlong study to collect more data and refine this estimate (see Section 6.2.3).

Phase 1 Projects

The City plans to invest almost $8 million in stormwater BMPs over the next 5 years. These investments are expected to reduce the City's phosphorus load to the Charles River by an additional 118 lb/yr.

Planned Structural BMP	Implementation Schedule						Cost	Phosphorus Reduction Credit (lb/yr)	Cost Per Pound of Annual Phosphorus Reduction ($/lb/yr)
	2023	2024	2025	2026	2027	2028			
Summit Avenue	■						$300,000	1.7	$177,515
High School		■					$1,780,000	17.8	$100,000
Embassy Parking Lot		■					$350,000	2.0	$175,000
Bobby Connors Playground BMP			■	■			$1,555,500	12.9	$120,600
Monsignor McCabe Playground BMP					■	■	$2,010,700	20.1	$100,184
Beaver Brook Reservation BMP		■	■				$1,995,400	63.4	$31,483
							$7,991,600	117.9	

2 Introduction and Purpose

The 2016 Massachusetts Small Municipal Separate Storm Sewer System (MS4) General Permit, referred to hereafter as the MS4 Permit or the Permit, was signed on April 4, 2016 and become effective on July 1, 2018. Discharges from the City of Waltham's stormwater system are regulated under this permit which is administered by the United States Environmental Protection Agency (EPA) through its National Pollutant Discharge Elimination System.

Appendix F of the MS4 Permit requires that the communities that discharge stormwater to the Charles River comply with the requirements of the Charles River Total Maximum Daily Load (TMDL). The TMDL was established in response to summertime algae outbreaks in the Charles River. These outbreaks are attributed to excess levels of phosphorus in the river. The goal of the TMDL is to reduce the phosphorus concentrations in the river to an acceptable concentration.

Appendix F of the Permit requires the development of a Phosphorus Control Plan (PCP) to meet the phosphorus reduction requirements in the Permit. The PCP is to be developed and implemented through three phases. This report constitutes the City's Phase 1 PCP.

2.1 Phosphorus Control Plan Schedule

The MS4 Permit established a phosphorus reduction requirement for stormwater discharged by the City to the Charles River. The Permit requires that the stormwater phosphorus reduction be achieved within 20 years of the permit's effective date. Since the effective date of the MS4 Permit was July 1, 2018, the reductions must be achieved by July 1, 2038.

The MS4 Permit defines a three-phase schedule as shown in Figure 2-1 with each phase having a 5-year planning and 5-year implementation phase. An updated PCP must be submitted to EPA at the end of each planning phase. The elements of the PCP are shown in the bottom left-hand corner of Figure 2-1; but it should be noted that during the first phase, there are additional elements shown in the Phase 1 planning phase that must also be included in the PCP.

The MS4 Permit specifies reduction milestones that must be achieved during each of the three implementation phases. The milestones are shown in the top panel of Figure 2-1. During the Phase 1 implementation, 20 percent of the phosphorus reduction must be achieved by the end of year 8, and 25 percent must be achieved by the end of year 10. The Phase 2 reductions must reach 35 percent by year 13 and 50 percent by year 15. In the final phase, an 80 percent reduction must be achieved by year 18 with 100 percent reduction achieved by year 20.

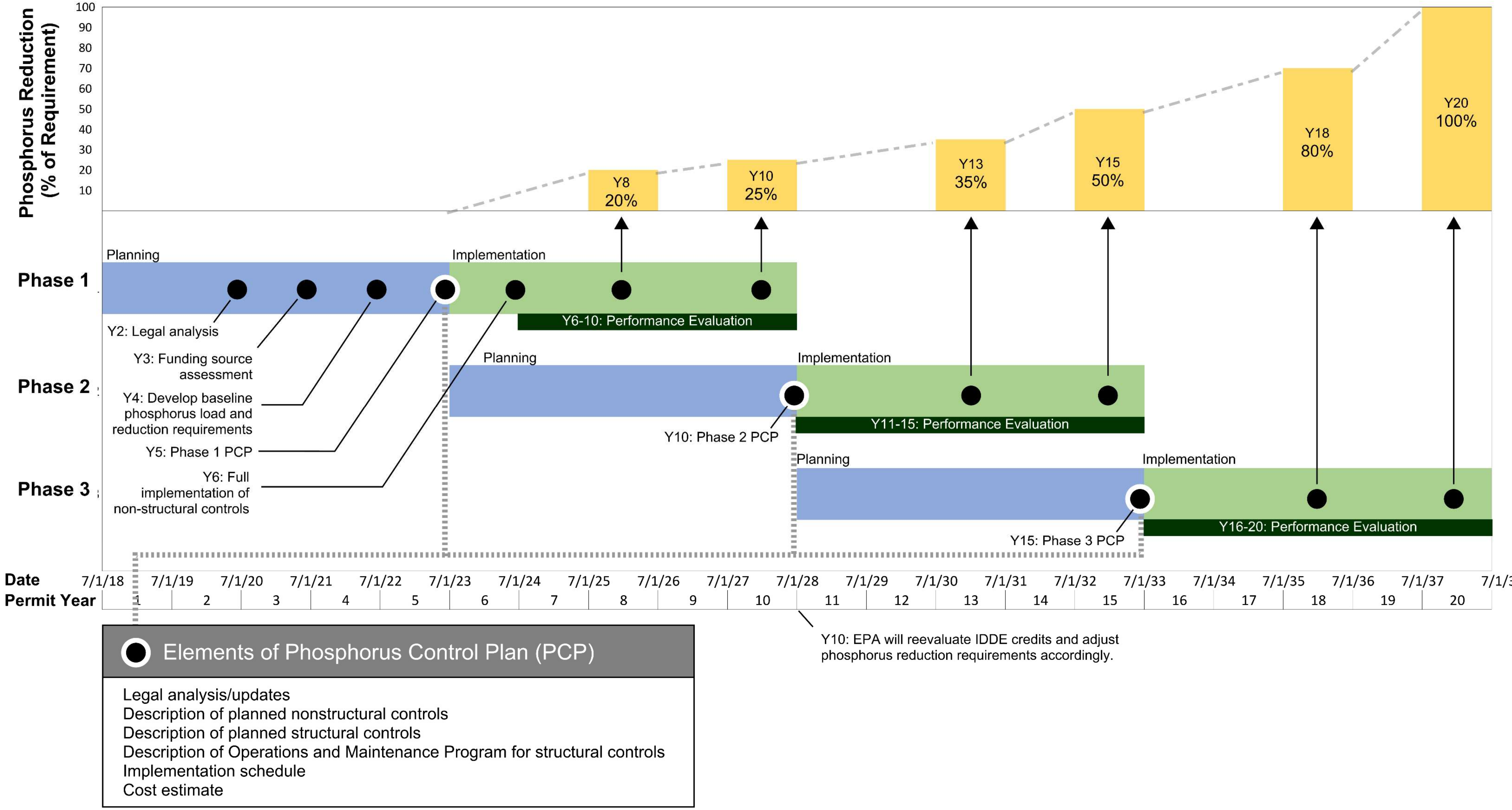


Figure 2-1. PCP Schedule

2.2 Overview of all PCP Phase 1 milestones

The detailed components of the PCP due during Phase 1 are outlined in Table 2-1.

Table 2-1. Phase 1 Component Deadlines

Permit Year #	Year	PCP Components Due
Year 1	2019	N/A
Year 2	2020	Legal Analysis
Year 3	2021	Funding Source Assessment
Year 4	2022	PCP Scope
Year 5	2023	Descriptions of the following Phase 1 items: - Nonstructural controls - Structural controls - O&M program for structural controls - Implementation schedule - Phase 1 cost estimate - Written Phase 1 PCP - Full implementation of nonstructural controls
Year 6	2024	Performance Evaluation
Year 7	2025	Performance Evaluation
Year 8	2026	Performance Evaluation & Implementation of structural controls to achieve 20% of target phosphorus reduction
Year 9	2027	Performance Evaluation
Year 10	2028	Performance Evaluation & Implementation of structural controls to achieve 25% of target phosphorus reduction

The City of Waltham acknowledges that to meet the phosphorus reduction deadlines set forth in the MS4 Permit, significant preparation is required. To plan, allocate funds to, design, and construct structural controls to meet the Year 8 and Year 10 reduction deadlines, there is significant work to be completed during the initial years of PCP implementation. Some controls that rely on local bylaw or regulatory updates, or engaging landowners directly through incentives, may take even longer to implement.

3 Phosphorus Reduction Requirement

This Section provides an overview of the baseline (2005) and current (2020) phosphorus loads in the City of Waltham and the load reduction requirements that must be achieved through this Plan.

3.1 Selection of Phosphorus Control Plan Area

Permittees are required to indicate the area in which they plan to implement the PCP. Permittees have the choice of (1) implementing their PCP in the entirety of their jurisdictional area within the Charles River Watershed, or (2) implementing their PCP only in the urbanized portion of their jurisdiction within the Charles River Watershed. All of the City is urbanized and within the Charles River Watershed. Accordingly, the Town selects option 1 and will implement the PCP within the entirety of its jurisdictional border.

3.2 Baseline Phosphorus Loads

The City's baseline phosphorus load, allowable load and reduction requirement are reported in Appendix F of the MS4 Permit and are summarized below in Table 3-1.

Table 3-1. City of Waltham Stormwater Phosphorus Reduction Requirements to Charles River (Source: 2016 MS4 Permit Appendix F, Table F-2)

Description	Value
Baseline phosphorus load	6,382 lbs/year
Stormwater phosphorus load reduction requirement	3,861 lbs/year
Allowable phosphorus load	2,521 lbs/year
Stormwater percent reduction in phosphorus load	60%
Phase 1 reduction target: 20% by 2026	772 lbs/year
Phase 1 reduction target: 25% by 2028	965 lbs/year

The MS4 Permit provides a process by which the City's baseline phosphorus loads can be revised based on data that better reflects actual conditions in 2005. This process is discussed in Appendix F.A.I.1.a.3 of the MS4 Permit:

> The Permittee may submit more accurate land use data from 2005, which is the year chosen as the baseline land use for the purposes of permit compliance, for EPA to recalculate baseline phosphorus stormwater loads for use in future permit reissuances. Updated land use maps, land areas, characteristics, and MS4 area and catchment delineations shall be submitted to EPA along with the year 4 annual report in electronic GIS data layer form for consideration for future permit requirements. Until such a time as future permit requirements reflect information submitted in the year 4 annual report, the permittee shall use the Baseline Phosphorus Load, Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load Table F-2 (if its PCP Area is the permittee's entire jurisdiction) or Table F-3 (if its PCP Area is the regulated area only) to calculate compliance with milestones for Phase 1, 2, and 3 of the PCP.

The baseline load presented in Table 3-1 was derived by EPA using the methodology documented in the draft memorandum dated 1/14/2014 by Mark Voorhees to the Permit File for Draft Small

Massachusetts MS4 Permit. The methodology uses the following GIS data to estimate phosphorus loads: land use, impervious cover and hydrologic soil groups.

The City reviewed the 2005 land use and impervious cover GIS data used by EPA to develop the baseline phosphorus loads. The review was performed with the help of 2005 orthoimagery and land use data from the Town. The review found some locations where the GIS data did not adequately reflect conditions in 2005. As a result, the City manually revised the 2005 impervious cover and land use layers to better reflect 2005 conditions. In addition, the hydrologic soil group data used for the 2005 calculations had large areas with unknown soil types. Since that time, the National Resources Conservation Service (NRCS) has released an updated soils layer that has better coverage within the City.

The City calculated the baseline phosphorus loads using the EPA methodology and revised GIS data. The details of this analysis are documented in Appendix A, which was submitted to EPA with the Year 4 Annual Report in compliance with the Permit.

In summary, using the revised GIS data, the baseline load was calculated to be 5,909 pounds/year compared to the Permit value of 6,382 pounds/year, as shown in Table 3-2. This represents a reduction of 473 pounds/year. The City has requested that EPA revise the City's baseline phosphorus load accordingly. However, the revision request will not impact the reduction targets planned for Phase 1, and all the information presented in this Plan will adhere to the reduction targets derived from EPA's baseline. If EPA approves the City's baseline load revision request, the revised loads will be taken into account during Phase 2 of the PCP.

Table 3-2. City of Waltham's 2005 Baseline Phosphorus Load Revision Request

Description	Value
Baseline phosphorus load, by EPA	6,382 lbs/year
Baseline phosphorus load, revised	5,909 lbs/year

3.3 Adjustment to Phosphorus Loads due to Development from 2005 to 2020

While all the load reduction requirements are calculated in the Permit based on 2005 conditions, the Permit requires that all municipalities update their loads to reflect the impacts of development since that time. The updates are to be performed during the performance evaluations which take place during each of the three implementation phases. The first performance evaluation will take place during years 6 through 10 of the MS4 Permit (i.e., July 2023 – July 2028).

The Permit details a process for updating phosphorus loads due to development/redevelopment in Attachment 1 of Appendix F. The process requires detailed information about the projects. Since 2005, a large number of development/redevelopment projects have taken place in the City, but unfortunately much of the data needed to perform the calculations is not available.

Instead of using the detailed accounting approach, a "catch up" approach[1] was used instead: the GIS data layers from 2005 were updated to 2020 conditions through orthoimagery review, and the phosphorus loads were recalculated using 2020 data layers. Since this analysis was performed in

[1] EPA's Newton Tedder confirmed that the "catch up" approach would be acceptable for updating loads to 2020 conditions in an email exchange with Matt Davis (Brown and Caldwell) on March 4, 2022.

2020, “present day” conditions at the time of this PCP is 2020.

The City will continue to update its phosphorus loads during the Performance Evaluations in Years 6 through 10; however, it is expected that future updates will use the detailed accounting method in Attachment 1 of Appendix F

Revised land use and impervious surface GIS layers were developed to reflect conditions in 2020. These layers were created initially from the 2005 layers (i.e., Waltham Land Use 2005 and Waltham Impervious Surface Area 2005) and were then updated using 2020 orthoimagery to reflect changes that have taken place from 2005 through 2020. It is important to note that the 2005 layers are the *revised* layers that were developed for the baseline phosphorus load revision request discussed in Section 2.1. These layers provide a more accurate representation of conditions in the year 2005, so these layers were used as a starting point for the 2020 layers.

The analysis found that the impervious area in the City increased from 3,055 acres in 2005 to 3,188 acres in 2020. This is a net increase of 133 acres.

The annual phosphorus loads for the year 2020 were calculated using the methodology described in the previous section, but instead of the using the GIS layers from 2005, the layers from 2020 were used instead. **The analysis found that the annual phosphorus export load for the City has increased by an estimated 265 lbs/yr from 2005 to 2020 due** to redevelopment. It should be noted, however, that the City requires that development/redevelopment projects retain and infiltrate the stormwater runoff from new impervious surfaces on-site. So, while this value reflects an increase in phosphorus loads due to redevelopment, it does not consider the offsetting phosphorus reductions achieved by the stormwater control practices that were put into place when the development occurred. The phosphorus reduction credits for the stormwater controls that have been implemented between 2005 and 2020 will be discussed in Section 6.2.

3.4 Adjusted Phosphorus Reduction Requirement

The Town must meet the baseline Phase 1 phosphorus reduction targets shown in Table 3-1 and remove all of the phosphorus increases due to new development/redevelopment since 2005 (see previous section). The combination of these reductions is referred to as the adjusted phosphorus reduction requirement. The adjusted phosphorus reduction requirements are shown in Table 3-3.

Table 3-3. Adjusted Phosphorus Reduction Requirements

Phosphorus Load/Reduction Requirement	Average Annual Phosphorus Load (lbs/yr)
EPA Baseline Phosphorus Reduction Requirement[1]	3,861
Increase in Phosphorus Due to Redevelopment (2005 – 2020)	265
Phosphorus Reduction Required by 2026[2]	1,037
Phosphorus Reduction Required by 2028[3]	1,230

Notes:

1. *This is the total amount of phosphorus that must be reduced by 2038. Any additional phosphorus generated by redevelopment after 2005 will also need to be offset.*
2. *The MS4 Permit requires a 20 percent reduction in the baseline load by 2026. In addition, any increases in phosphorus due to redevelopment must also be offset. The value was calculated as follows: 3,861 x 0.2 + 265 = 1,037.*
3. *The MS4 Permit requires a 25 percent reduction in the baseline load by 2026. In addition, any increases in phosphorus due to redevelopment must also be offset. The value was calculated as follows: 3,861 x 0.25 + 265 = 1,230.*

4 Legal Analysis

Appendix F of the MS4 Permit requires that the City perform a review of existing regulatory mechanisms available to the MS4 (e.g., bylaws and ordinances) and identify any changes to regulatory mechanisms that may be necessary to effectively implement the PCP. This may include the creation or amendment of financial and regulatory authorities. The City's Legal Analysis is attached as Appendix B.

5 Funding Source Assessment

Appendix F of the MS4 Permit requires that the City describe known and anticipated funding mechanisms (e.g., general funding, enterprise funding, stormwater utilities) that will be used to fund PCP implementation. The City must describe the steps it will take to implement its funding plan. This may include but is not limited to conceptual development, outreach to affected parties and development of legal authorities. The City's Funding Source Assessment is attached as Appendix C.

6 Implemented Phosphorus Control Practices

The City of Waltham has already begun implementing phosphorus control practices that reduce the City's stormwater phosphorus load to the Charles River. This Section discusses these practices and estimates the average annual amount of phosphorus that they remove from the City's stormwater. These reductions go a long ways towards meeting the total phosphorus reduction targets shown in Table 3-3. The remaining reductions will be achieved by additional BMPs that will be implemented during the Phase 1 Implementation period as described in Section 6.

6.1 Non-structural BMPs

Non-structural BMPs are practices that reduce stormwater flows and/or pollutants through stormwater management practices that do not rely on constructed infrastructure. The EPA has provided a methodology for calculating phosphorus reduction credits for the following three types of non-structural BMPs:

- Street sweeping
- Catch basin cleaning
- Organic waste/leaf litter collection

The methodology for calculating the credits is detailed in Attachment 2 of Appendix F of the MS4 Permit. The City has implemented all of these non-structural BMPs and is eligible for phosphorus reduction credits.

The phosphorus reduction credits for the City's non-structural BMP practices, calculated using the Permit's methodology, are shown in Table 6-1. The City's non-structural BMPs are discussed in detail in the following sections.

Table 6-1. Non-Structural BMP Phosphorus Reductions for Waltham	
Non-Structural BMP	**Annual Phosphorus Reduction (lbs/yr)**
Street sweeping	24
Catch basin cleaning	43
Total	67

Notes:

1. *Credit calculated according to methodology in Attachment 2 of Appendix F of the MS4 Permit.*

6.1.1 Street Sweeping Credit

Appendix F, Attachment 2 of the MS4 Permit provides the methodology for calculating phosphorus credits for street sweeping. The City deploys its street sweeping program generally from April through December, and it has a fleet of three mechanical broom sweepers which are used citywide. The Main Street and the Moody Street neighborhoods are swept the most frequently, typically about three times a week. Additionally, municipal parking lots within the City are swept weekly. These areas are illustrated in Figure 6-1. The rest of the City is swept on a monthly basis over a six-month period.

To calculate the street sweeping credit, the following equation is used:

$$Phosphorus\ Credit = IA_{swept} * \ PLER_{IC-la\quad use} * PRF_{sweeping} * AF \qquad (6\text{-}1)$$

where;

IA_{swept} = Area of impervious surface that is swept under the enhanced sweeping program, in acres

$PLER_{IC\text{-}land\ use}$ = Phosphorus load export rate for impervious cover and specified land use, in lbs/acre/yr

$PRF_{sweeping}$ = Phosphorus reduction factor for sweeping based on sweeper type and frequency

AF = Annual frequency of sweeping

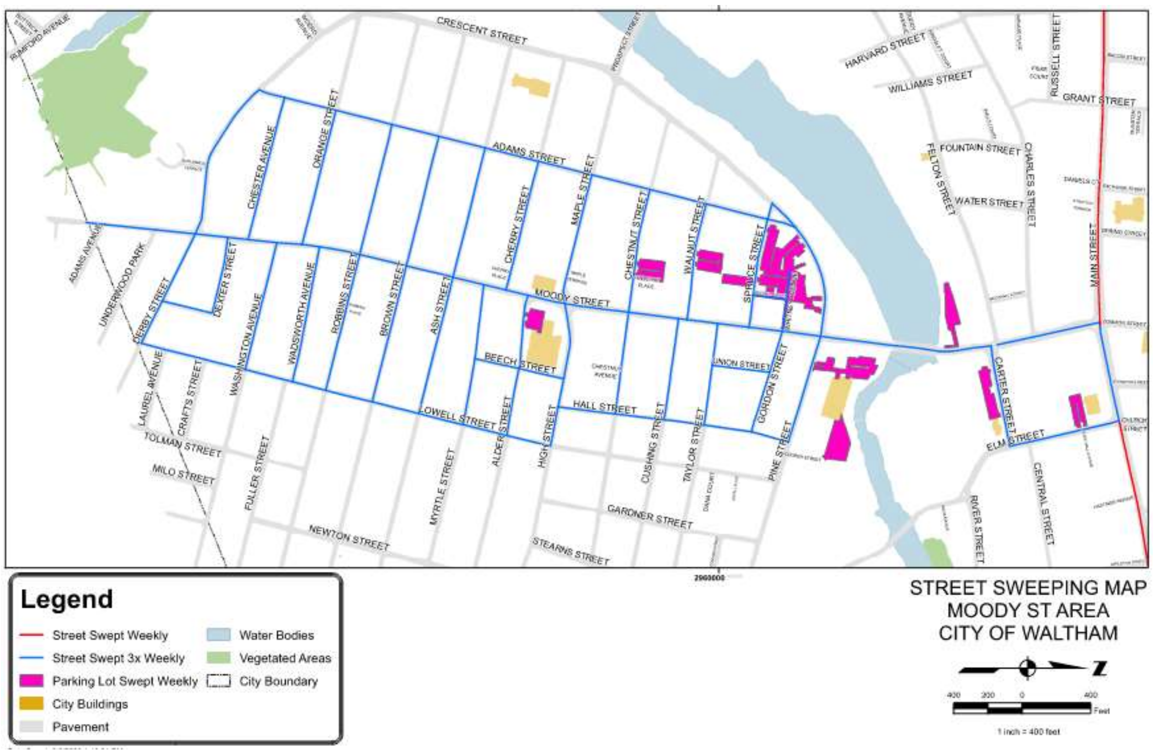


Figure 6-1. Moody Street Sweeping Map

Since the land uses for the roadways across the City vary, and the associated PLERs for these areas vary as well, the equation above is used in two iterative steps. First, the phosphorus load over the swept area is calculated; and second, the ratios are applied to calculate the credit associated with street sweeping. Based on an analysis of the City's current sweeping practices, the street areas swept span multiple land use types and subsequently, many PLERs. The Town therefore used the impervious areas swept and MS4 Permit Appendix F PLERs to calculate a composite phosphorus load and then applied the street sweeping factors to that phosphorus load. The values in Table 6-2 are used to calculate the credit of 24.25 lbs/yr shown in Table 6-1.

Table 6-2. Street Sweeping Credit Calculation

Area Swept Description	Contributing Road Impervious Area (ac)	Available P Load (lbs/year)	PRF	Annual Factor	P Credit (lbs/year)
Moody Street Area Roads, Swept Weekly	69.3	126.6	0.05	6/12	4.75
Rest of City Roads, Swept Monthly	765.5	1,275.3	0.03	6/12	19.13
Parking Lots, Swept Weekly	5.8	9.8	0.05	6/12	0.37
Total	840.6	1,411.7			24.25

6.1.2 Catch Basin Cleaning Credit

The City's catch basin cleaning credit is shown in Table 6-1, which is calculated based on the following equation as presented in Attachment 2 to Appendix F of the Permit:

$$Phosphorus\ Credit = IA_{CB} * \ PLER_{IC \quad use} * PRF_{CB} \qquad (6\text{-}2)$$

where;

IA_{CB} = Area of impervious surface draining to catch basins, in acres

$PLER_{IC\text{-}land\ use}$ = Phosphorus load export rate for impervious cover and specified land use, in lbs/acre/yr

PRF_{CB} = Phosphorus reduction factor for catch basin cleaning

As long as catch basins are being cleaned such that a minimum sump storage capacity of 50% is maintained throughout the year, a PRF_{CB} value of 0.02 may be used and a credit may be claimed for catch basin cleaning. Waltham routinely cleans its network of approximately 8,000 catch basins, and so the values used to calculate the credit of 43 pounds/year are summarized in Table 6-3.

Table 6-3. Catch Basin Cleaning Credit Calculation

Area Cleaned	Contributing Road Impervious Area (ac)	Available P Load (lbs/year)	PRF	P Credit (lbs/year)
Catch Basins in Roadway	4.75	4.75	0.02	26
Catch Basins in Parking Lots	19.13	19.13	0.02	17
Total	0.37	0.37	N/A	43

6.2 Structural BMPs

Structural BMPs are practices that reduce stormwater flows and/or pollutants through stormwater management practices that rely on constructed infrastructure. Rain gardens, porous pavement and underground infiltration chambers are all examples of structural BMPs. The City is eligible for a phosphorus reduction credit for all structural BMPs that are being operated and maintained, whether installed on public or private property.

The City has installed structural BMPs on City-owned properties and required that new development/redevelopment install structural BMPs to manage stormwater. The phosphorus credits for structural BMPs installed from 2005 through 2022 are shown in Table 6-4. The development of these credits is discussed in the following sections.

Table 6-4. Phosphorus Reduction Credits for Structural BMPs Implemented in Waltham from 2005-2020

Location of Structural BMPs	Average Annual Phosphorus Reduction (lbs/yr)
Private properties	140.4
City-owned properties	70.7
Total	211.1

6.2.1 Private Property Structural BMPs

Structural BMPs have been implemented on private properties throughout the City. This has been largely driven by the City's requirement that where feasible new development and redevelopment incorporate infiltration BMPs capable of infiltrating the 100-year, 24-hour storm event (8.09 inches of rain) on-site. This requirement has been implemented through the City's Permit Application Package. This reduction of stormwater leads to a reduction of the City's annual load of total phosphorus to the Charles River, largely offsetting increases in phosphorus export loads due to development/redevelopment.

A review was performed of the development/redevelopment projects approved by the City from 2005 through 2022. In total, approximately 836 projects were reviewed along with their as-built plans, review comments and stormwater reports.

Each project was reviewed for the incorporation of a stormwater mitigation BMP. For the projects that installed a BMP, the following information was recorded:

- Site address
- Impervious area draining to the BMP. This was either delineated from the as-built plans or taken from the StormCAD calculations provided by the developer's engineer.
- The 2005 land use category for each parcel from the MassGIS database.
- The soil class for each parcel from the NRCS Soils GIS layer.
- BMP type (e.g., infiltration chambers, wet ponds, permeable pavers).

The total phosphorus reduction was calculated using the following formula:

$$TP_{reduction} = A_{treated} \times TP_{export\ rate} \times E \qquad (5\text{-}3)$$

where $TP_{reduction}$ is the annual total phosphorus reduction (lbs-TP/yr), $A_{treated}$ (acres) is the land area treated by the BMP, $TP_{export\ rate}$ (lbs-TP/acre-yr) is the total phosphorus loading export rate, and E is the average annual treatment efficiency of the BMP.

The total phosphorus loading export rates and the BMP treatment efficiencies were estimated using values provided in Appendix F of the 2016 Massachusetts General MS4 Permit. The MassGIS land use GIS layer was used to determine the land use category for the City's parcels that were developed/redeveloped.

Attachment 3 of Appendix F of the MS4 Permit provides treatment efficiencies for structural BMPs. The treatment efficiencies are provided for storms with up to 2-inches of rainfall; however, the Town requires infiltration requirement of 8.09 inches (i.e., 100-year, 24-hour storm) exceeds this value. As a result, based on the same reasoning as presented in the previous section, a treatment efficiency of 98 percent was used for all the BMPs. Please refer to Appendix D for the load calculations.

6.2.2 City-Owned Property Structural BMPs

The City has implemented structural BMPs on City-owned properties as well. The City has inventoried the BMPs and developed estimates of the phosphorus reductions at these sites (see Appendix E).

The City BMPs utilize surface and subsurface infiltration practices and, where feasible, are designed to infiltrate the 100-year, 24-hr storm. The approach described for private property structural BMPs is used for the structural BMPs on City-owned properties. Where impervious area draining to a BMP wasn't available, the City assumed that all impervious area from a site drains to the BMP.

As shown in Table 6-4, it is estimated that the existing City-owned structural BMPs reduce the annual phosphorus load to the stormwater system by 71 pounds/year. Please refer to Appendix E for the load calculations.

6.2.3 Cambridge Reservoir

Approximately 30% of the City's area (2,491 acres) falls within the Cambridge Reservoir (*Reservoir*) watershed. The Cambridge Reservoir serves as a water supply for the City of Cambridge, MA. Excess water in the Reservoir is released through a dam into a waterway that ultimately discharges to the Charles River. It is suspected that the Cambridge Reservoir significantly reduces phosphorus loads to the Charles River due primarily to (1) the transfer of water to Cambridge for water usage and to (2) natural treatment processes in the Reservoir (e.g., sedimentation, biological uptake) that remove phosphorus.

In order to better understand the Reservoir's phosphorus treatment capabilities, the City performed a three-month water quality study in the Fall of 2022. The program collected weekly water quality grab samples downstream of the Stony Brook Basin dam. The City used this data to estimate the average annual phosphorus load discharged from the Reservoir. The City then estimated the phosphorus loads in stormwater entering the Reservoir (using the data and methods used by EPA for developing the baseline phosphorus loads in the MS4 Permit). By comparing the phosphorus loads into and out of the Reservoir, the City was able to estimate the level of phosphorus reduction provided by the Reservoir. A summary of the water quality study is provided below. Please refer to the study's Technical Memorandum in Appendix G for more information.

From September 2022 – November 2022, weekly water quality samples were collected downstream of the Stony Brook Basin dam and analyzed for total phosphorus concentrations. Samples were collected without regard to weather conditions. Some were collected during dry weather and some were collected during wet weather. It would have been ideal to collect just wet weather samples since the PCP targets phosphorus loads in stormwater, but due to the time of travel, hydraulic residence time and mixing in the Reservoir it was not possible to collect water samples composed primarily of stormwater runoff. Due to the large storage volume of the Reservoir, it is expected that the discharge from the Reservoir is typically a well-mixed blend of waters that were supplied during both dry and wet weather conditions. As a result, it is expected that phosphorus concentrations are not very sensitive to current weather conditions, except for extreme events.

The USGS operates a monitoring station at the location where water quality samples were collected. The monitoring station measures the rate of flow discharged from the Reservoir. This flow data was used in conjunction with the measured phosphorus concentrations to estimate the phosphorus loads discharged from the Reservoir during the monitoring period.

In general, the study found that the phosphorus concentration in waters discharged from the dam were very low. Many of the samples were below the detection level. The average concentration was 0.021 mg/L. Over the 84 days of the study, it is estimated that the 66 lbs of phosphorus were discharged from the dam. Of this amount, it is estimated that approximately 20 pounds are attributable to Waltham. Linearly extrapolating these loads to a full year leads to an estimate of 287 lbs/yr, with 87 lbs/yr attributable to Waltham.

The Cambridge Reservoir watershed experienced a drought during the summer months before the study. Rainfall returned during the study, but it is possible that the preceding drought may have influenced the study's findings. As a result, an additional analysis was performed to estimate the phosphorus loads under conditions that are more representative of historical averages.

The average annual phosphorus loads were estimated for the Reservoir using 5-years of flow data (June 2018 – June 2023) from the Reservoir and an assumed average phosphorus concentration of 0.03 mg/L, a conservative value given the sampling results. As with previous analysis, rainfall and flow data were taken from USGS monitoring station at the outlet of the Cambridge Reservoir. The study estimated that the average annual phosphorus load over the 5 year period was 1,427 lbs/yr, with approximately 428 lbs/yr attributable to Waltham.

As discussed previously, the study did not separate the phosphorus loads into dry and wet weather periods, so the phosphorus loads presented include both. The phosphorus load attributable to stormwater (i.e., the load that the PCP is concerned about) is only a portion of this total value.

The study also estimated that annual phosphorus load in stormwater entering the Reservoir. The phosphorus load was calculated using the same data and methods that EPA used to calculate the baseline phosphorus loads in the MS4 Permit. The study estimated that stormwater entering the Cambridge Reservoir watershed has an average annual phosphorus load of 4,886 lbs/yr, with 1,448 lbs/yr attributable to Waltham.

There is a significant difference between the City's stormwater phosphorus load entering the Reservoir (1,448 lbs/yr) and the total phosphorus load discharged from the Reservoir (428 lbs/yr is attributable to the City). Based on these results, it is estimated that the Reservoir is removing at least 1,020 lbs/yr of phosphorus from the City's stormwater, and probably significantly more because of a portion of the 428 lbs/yr discharged from the reservoir is not due to stormwater.

The water quality study has demonstrated that the Reservoir is providing a significant amount of phosphorus treatment to that water it impounds. As a result, the City's PCP includes a credit of 1,020 lbs/yr that accounts for the phosphorus treatment provided by the Reservoir. The City recognizes that further study is needed to verify the extrapolation of the results from a three-month period to average annual conditions. As such, the City will complete a follow-up, year-long water quality study of waters discharged from the Cambridge Reservoir during the Phase 1 PCP Implementation period. The City plans to engage EPA during the development and execution of the water quality study. In the future, the City may revise the Cambridge Reservoir credit based on the results of the follow-up water quality study, and as part of these efforts, the City may seek to further differentiate the load discharged from the reservoir into stormwater and non-stormwater components so that the reduction in phosphorus loads from stormwater are better accounted for.

6.3 Summary

The City has implemented BMPs to reduce phosphorus loads to its stormwater system. Table 6-5 provides a summary of the estimated phosphorus load reductions by BMP type. Altogether, the BMPs remove approximately 278 pounds of phosphorus each year.

Table 6-5. Existing BMP Phosphorus Reduction Credits	
BMP	Annual Phosphorus Reduction (lbs/yr)
Non Structural BMPs	
Street sweeping[1]	24.25
Catch basin cleaning[1]	42.93
Subtotal	67.18
Structural BMPs	
Private properties[2]	140.40
City-owned properties[2]	70.70
Cambridge Reservoir[3]	1,020.00
Subtotal	1,231.10
Total	1,298.28

Notes:

1. *Credit calculated according to methodology in Attachment 2 of Appendix F of the MS4 Permit.*
2. *Calculated using the methodology in Attachment 3 of Appendix F of the MS4 Permit.*
3. *See Cambridge Reservoir Phosphorus Treatment Study Technical Memorandum (Appendix G).*

7 Planned Phase 1 BMPs

The City plans to implement additional BMPs during Phase 1 of the PCP. This section describes the BMPs and provides cost estimates and an implementation timeline.

7.1 Non-structural BMPs

The City has no plans to change its existing non-structural BMPs for Phase 1. The City will continue to clean its streets and catch basins and track the frequency of these activities.

7.2 Structural BMPs

This section details structural BMPs that the City plans to implement during Phase 1 of the Phosphorus Control Plan. The City has already developed designs for three BMPs that are either under construction or will be constructed soon. These BMPs will be discussed first. That will be followed by a discussion of a City-wide site suitability analysis that was performed to identify and prioritize City-owned properties for BMP retrofits. This led to the identification and conceptual design of three additional BMPs.

7.2.1 Designed BMPs

The City has three structural BMPs that have been designed and are either under construction will or will be constructed in the near future. Details related to the BMPs are provided in Table 7-1.

Table 7-1. Proposed Structural BMP Summary

Planned Structural BMP	Year	Phosphorus Reduction Credit (lb/yr)	Cost[1]	Cost Per Pound of Annual Phosphorus Reduction ($/lb/yr)
Summit Ave BMPs	2023	1.69	$300,000	$177,515
High School BMPs	2024	17.80	$1,780,000	$100,000
Embassy Parking Lot	2025	2.00	$350,000	$175,000

Notes:

1. *These BMPs are part of larger redevelopment projects. Costs specifically related to the BMPs were not available. Values shown are best estimates of the BMP-related costs.*

These BMPs are part of redevelopment projects. These projects are briefly described below:

Summit Avenue – This project consists of various water, sewer and drainage improvements to Summit Avenue. It includes the installation of five new subsurface stormwater infiltration systems. Once the stormwater systems are installed, Summit Avenue will be reconstructed and repaved. The Town anticipates that the BMPs will be complete by fall of 2023.

High School - The Town is renovating and expanding its public High School. The design includes several BMPs including a water quality swale, two subsurface recharge systems, four engineered tree boxes and six bioretention basins. It is anticipated that the BMPs will be complete by the spring of 2024.

Embassy Parking Lot - The Embassy Parking Lot is a municipal parking lot adjacent to the Charles River. This project includes the construction five bioretention/bioswale areas around the parking lot area. In addition, a new 1,390 ft^3 infiltration system is being installed that will infiltrate flow from the upper deck of the parking garage. The Town anticipates that the BMP will be completed by 2024.

The phosphorus reductions shown in Table 7-1 are the estimated phosphorus reductions of the BMPs and do not take into account net changes in exported phosphorus loads due to redevelopment. The changes in exported phosphorus loads from sites due to redevelopment will be incorporated into the Town's phosphorus load estimated during the Phase 2 PCP.

7.2.2 Planned BMPs

In addition to the designed BMPs discussed in the previous section, the City sought additional sites that could be retrofitted with BMPs during Phase 1 of the PCP. As part of this effort, the City performed a City-wide site suitability analysis. This led to the identification and development of conceptual designs for three planned BMPs.

7.2.2.1 Site Suitability

The overall goal of this BMP site suitability analysis was to identify and prioritize cost-effective BMPs that could be retrofitted on City-owned properties to provide significant phosphorus reductions. The analysis focused on cost-effective BMPs that can provide significant phosphorus reductions at a single site. These "high-impact" BMPs provide centralized treatment for large upstream areas (e.g., 10+ acres). The high-impact BMPs provide special advantages that make them good candidates for Phase 1 PCP projects:

- Construction costs – Constructing a large BMP at one site tends to be more cost-effective than building small BMPs at multiple sites.
- Operations and maintenance (O&M) – Performing O&M at one large BMP is typically easier than performing O&M at many smaller BMPs.
- Implementation – Constructing a large BMP at one site tends to be easier than building small BMPs at multiple sites.

While these advantages make centralized, high-impact BMPs desirable, there are a limited number of locations in the City where they are possible. The goal of this first phase of the planning process was to develop a priority ranking of areas and infrastructure within the City for potential implementation of structural BMPs during Phase 1. The priority ranking process included a detailed assessment of site suitability for the potential BMPs. Once the sites were deemed feasible, conceptual designs were developed and incorporated here into the City's Phase 1 PCP. The following methodology and assumptions were used to prioritize the sites and determine BMP site suitability.

The analysis focused on properties suitable for surface and subsurface infiltration practices. The first step included a GIS desktop analysis to identify large areas of open land throughout the City of Waltham that were publicly owned. The City's parcel GIS layer was utilized for this analysis which contained 231 publicly owned parcels. The City's stormwater drainage network layers were also reviewed to help identify locations where stormwater could be diverted from the stormwater drains to surface of subsurface infiltration practices on publicly owned lands.

An initial screening was performed on the publicly owned open areas to eliminate those believed not to be suitable. Example criteria that deprioritized parcels located on existing conservation land, parcels with existing stormwater BMPS and parcels with limited amounts of stormwater runoff.

Once the most suitable open land areas were identified, potential infiltration BMP footprint areas were delineated within the available space. Next, using the City's stormwater drainage network, the approximate drainage area upstream of the potential BMPs was delineated.

Following the initial GIS desktop analysis and delineation of the potential BMP footprint and upstream drainage areas, simple infiltration BMP calculations were performed using the following design assumptions:

- The loading ratios (drainage area to BMP footprint area) were calculated and checked. The loading ratio between contributing impervious area to footprint of proposed infiltration surface was held to no more than 25:1 where possible.
- For subsurface infiltration practices:
    - A proprietary product for underground infiltration chambers (e.g., ADS StormTech chambers) was assumed to be used and have 6 inches of stone wrap both above and below the chambers (1 foot total).
    - A minimum soil cover of 18 inches over top of the infiltration BMP and a groundwater depth 7 feet below the ground surface elevation were assumed.
    - Using available LIDAR elevation data and existing storm drain pipe invert depths per the City's GIS data, initial elevation checks were performed to confirm that the bottom of the potential infiltration BMP was at least 2 feet above the assume groundwater elevation.
    - The upstream drain pipe invert elevation was looked at to confirm that it was greater than the proposed elevation at the bottom of the infiltration BMP to allow for flow conveyance to the BMP.
- Google Street View at each potential BMP site was reviewed to identify any other possible challenges/concerns.

If the potential BMP sites did not meet the design assumptions described above, they were deemed not suitable and removed from the priority ranking. Through this screening process, a list of 7 potential BMP sites were identified:

- Nahum Hardy Residences
- Beaver Brook Reservation
- Leary Field
- Yetten Field
- Monsignor McCabe Playground
- Bobby Connors Playground
- Koutoujian Playground

The potential BMP site locations are displayed in Figure 7-1 along with the City's publicly owned parcels, which are shown in pink.

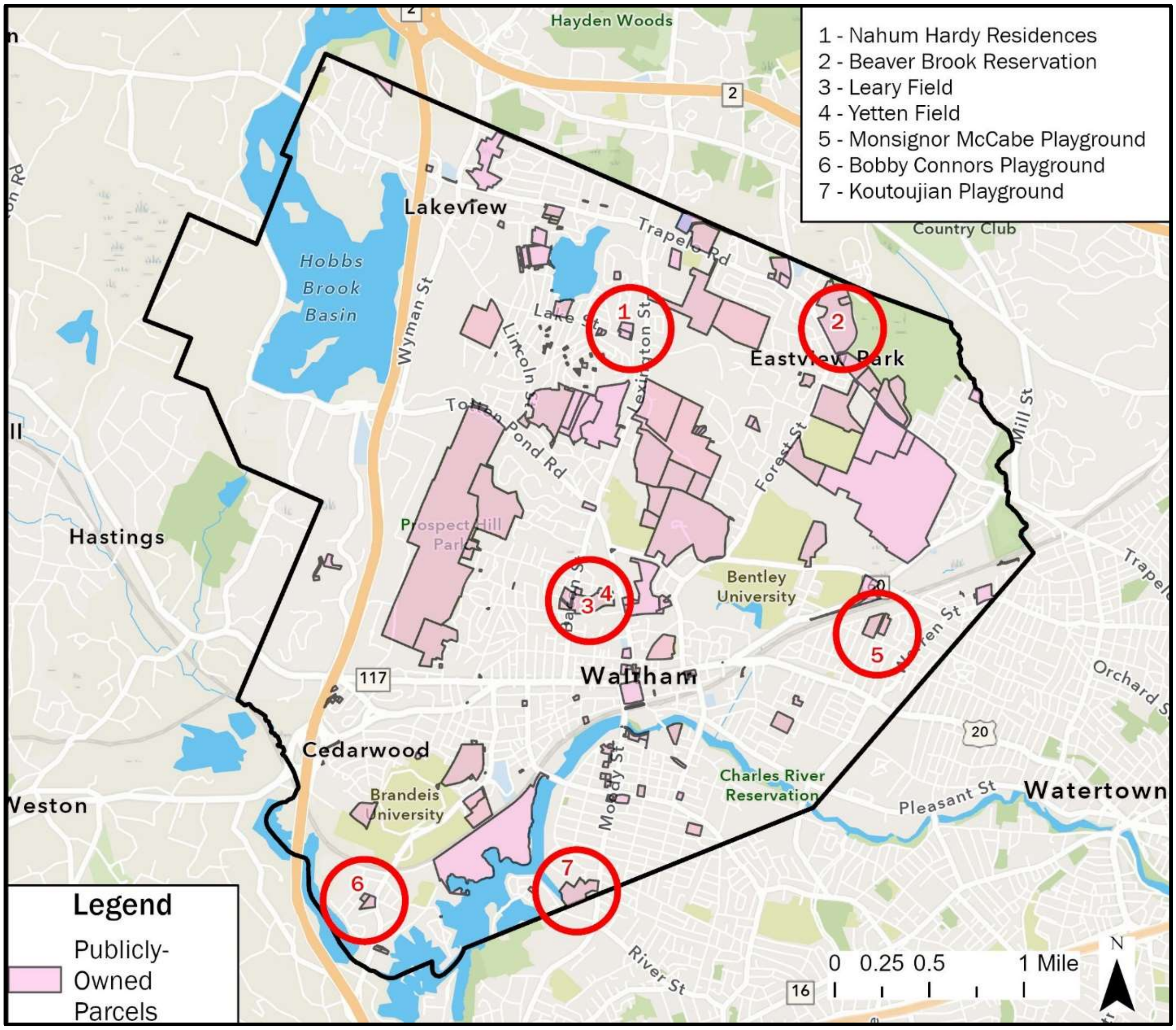


Figure 7-1. Potential BMP Locations

Once the 7 potential BMP sites were identified, they were reviewed with the City for discussion and feedback. Of the 7 potential BMP sites, 4 sites were eliminated from further consideration for various reasons, which included the following:

- Leary Field and Yetten Field – These two potential BMP sites were not pursued due to ongoing renovation of the football and baseball fields.
- Koutoujian Playground – This site was not pursued due to possible site contamination/hazardous waste in the area.
- Nahum Hardy Residences – This site was considered a possibility but was not as strong of a candidate as the selected sites (discussed in the following section).

7.2.2.2 Proposed Sites

Based on the results of the priority ranking and site suitability analysis, the three proposed BMP sites selected for further analysis and conceptual design development included the following:

- Monsignor McCabe Playground
- Bobby Connors Playground
- Beaver Brook Reservation

The proposed BMP site locations within the City are shown in Figure 7-2.

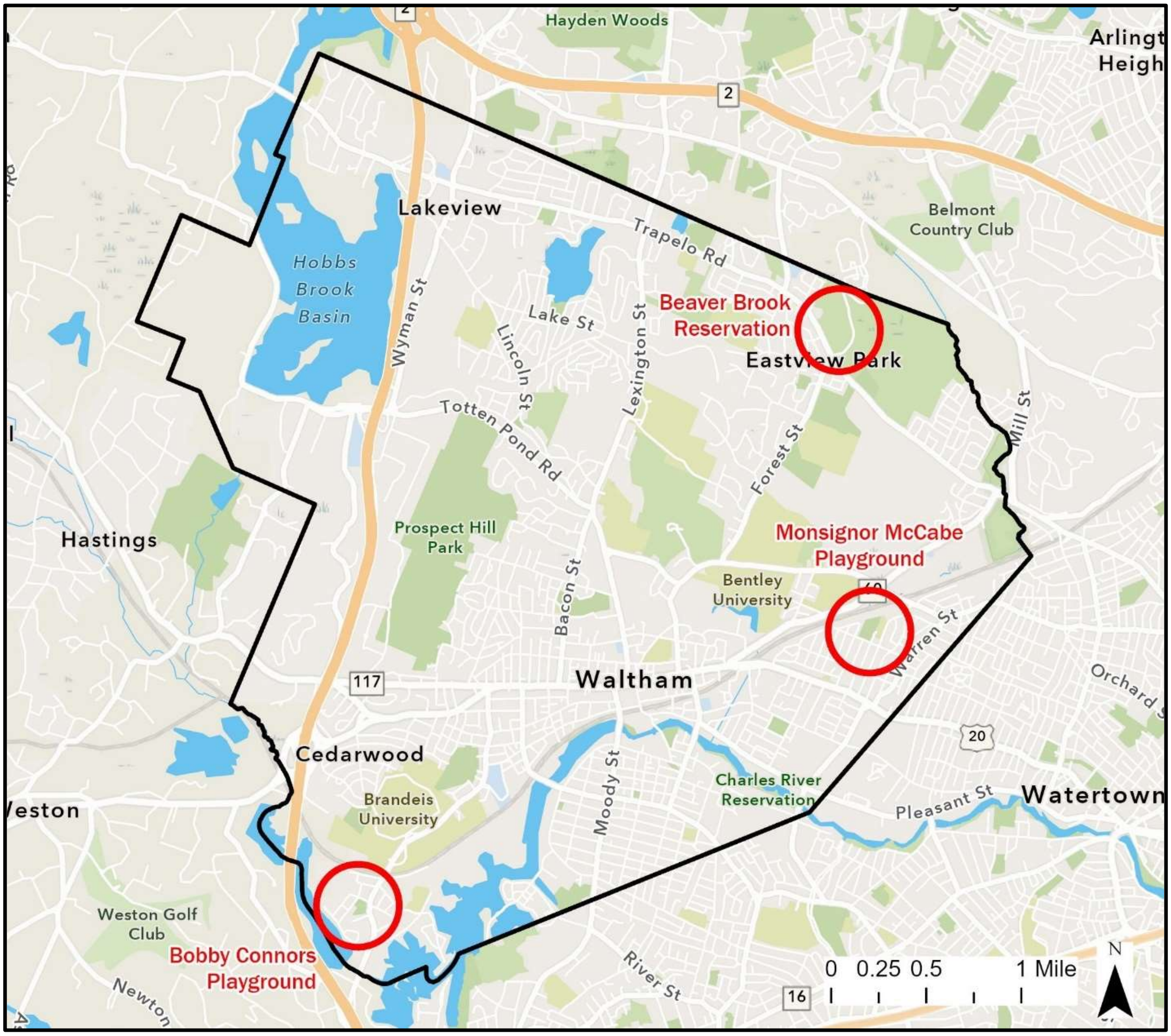


Figure 7-2. Proposed BMP Locations

The City provided available record drawings for the three sites and performed manhole measure downs at select locations to verify rim to pipe invert depths. The planning team also performed field visits at each site to photograph existing conditions. The record drawings and field data were reviewed and used to confirm hydraulic feasibility and inform the BMP concepts.

Appendix F of this report provides conceptual design packets for each of the proposed BMP sites. The packets include figures showing the proposed BMP site location, drainage area, and conceptual design layout, a narrative describing the proposed BMP, calculations used to size and evaluate the performance of the proposed BMP, and a planning level cost estimate.

Table 7-2 summarizes the proposed BMPs. Treatment efficiencies were estimated using Table 3-7 of Appendix F, Attachment 3 of the MS4 Permit. It is estimated that the three BMPs will remove an average annual phosphorus load 98.36 lbs/yr.

Table 7-2. Proposed Structural BMPs

	Monsignor McCabe Playground	Bobby Connors Playground	Beaver Brook Reservation
Drainage Area Characteristics			
Area	23.45 acres	16.34 acres	88.93 acres
Percent Impervious	39%	38%	38%
Estimated Annual Phosphorus Export Load in Drainage Area	22.30 lbs/yr	14.34 lbs/yr	78.25 lbs/yr
Proposed BMP Characteristics			
Technology	Underground infiltration chambers	Underground infiltration chambers	Surface infiltration basin
Runoff Volume	1.0-inch storm	1.0-inch storm	0.4-inch storm
Treatment Volume	40,198 CF	28,821 CF	61,856 CF
Estimated Phosphorus Treatment Efficiency	90%	90%	81%
Estimated Annual Phosphorus Removal	20.07 lbs/yr	12.91 lbs/yr	63.38 lbs/yr
Cost Estimate[1]			
Total Construction Cost	$2,010,700	$1,555,500	$1,995,400
Total Construction Cost AACE Class 4 Cost Range (2023 Dollars)	$1,608,600 to $2,815,000	$1,244,400 to $2,177,700	$1,596,400 to $2,793,600
Annual O&M[2]	$40,300	$31,200	$40,000
20-Year Life Cycle Cost	$2,816,700	$2,179,500	$2,795,400
Construction Dollars Per Acre of Drainage Area	$85,800	$95,200	$75,100
Construction Dollars Per Annual Pound of Phosphorus Removed	$100,300	$120,600	$31,500
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$7,100	$8,500	$2,300

Notes:

1. *AACE Class 4 cost estimate. Its expected accuracy range is -20% to +40%. The cost estimate was developed in June 2023.*
2. *Annual O&M was estimated at 2% of the total construction cost.*

A conceptual opinion of probable construction cost, probable annual operational cost, and probable 20-year life cycle costs were prepared for the BMPs. The opinion of probable construction cost is considered a Level 4 estimate as defined by AACE International, and as such, has an expected range (after application of contingency; 30 percent was applied) of -20 percent to +40 percent. The estimated construction cost for all three projects is $5,561,600 ($4,,449,280 to $7,786,240).

The conceptual designs are preliminary in nature. Additional data needs to be collected and analysis performed during preliminary design to finalize design parameters. The next steps would be detailed design consisting of engineering analysis, geotechnical investigations, and hydraulic modeling to further evaluate the hydraulics of the proposed system and confirm site feasibility.

7.3 Planned BMP Summary and Implementation Schedule

The planned BMPs discussed in this section are planned to be designed and constructed by the end of Phase 1 in 2028. The implementation schedule and total estimated phosphorus load reductions from each are collectively presented in Table 7-3.

Table 7-3. Summary & Implementation Schedule

Planned Structural BMP	Implementation Schedule						Cost[1]	Phosphorus Reduction Credit (lb/yr)	Cost Per Pound of Annual Phosphorus Reduction ($/lb/yr)
	2023	2024	2025	2026	2027	2028			
Summit Ave BMPs							$300,000[2]	1.69	$177,515
High School BMPs							$1,780,000[2]	17.80	$100,000
Embassy Parking Lot							$350,000[2]	2.00	$175,000
Bobby Connors Playground BMP							$1,555,500	12.91	$120,600
Monsignor McCabe Playground BMP							$2,010,700	20.07	$100,300
Beaver Brook Reservation BMP							$1,995,400	63.38	$31,500
Total							$7,991,600	117.85	

Notes:

1. *BMP costs include design and construction costs. Operations and maintenance costs are not included.*
2. *These BMPs are part of larger redevelopment projects. Costs specifically related to the BMPs were not available. Values shown are best estimate of the BMP-related costs.*

8 Operation and Maintenance Program

Operation and maintenance ensure that structural BMPs function as intended and retain their ability to treat phosphorus over time. The City's Department of Public Works (DPW) is responsible for ongoing operation and maintenance of the City's structural BMPs. The City's planned and existing structural BMPs consist of infiltration chambers, infiltration trenches, wet ponds, bioretention, and swales. Table 8-1 includes a high-level summary of maintenance schedules for each BMP type. Specific O&M schedules are detailed in each subsection.

Table 8-1. Summary Inspection & Maintenance Schedule

BMP Type	Maintenance Activities	Frequency
Subsurface Infiltration Chambers & Trenches	Inspection and cleanout as needed	Annual (section 7.1)
Wet Ponds	Inspection, landscaping, and dredging as needed	Annual / biannual / as needed (section 7.2)
Bioretention	Inspection, landscaping, and media replacement as needed	Monthly / annual / as needed (section 7.3)
Swales	Inspection and landscaping	Annual (section 7.4)

8.1 Subsurface Infiltration Chambers & Trenches

Maintenance needs for subsurface infiltration chambers and trenches can vary depending on product and manufacturer. The City has constructed multiple StormTech subsurface infiltration chambers, plans to implement more, and maintains them in accordance with the applicable manufacturer recommendations (see example in Appendix H - StormTech Isolator Row Manual). OSHA rules pertaining to confined space entry shall be followed if confined space entry is required. Table 8-2 provides an inspection and maintenance schedule.

Table 8-2. Annual Inspection & Maintenance Schedule

Feature	Inspection Activity	Maintenance
Inlet	Inspect inlet for debris	Remove debris that may clog the inlet orifice
Access Manholes	Measure sedimentation depth in chamber rows	If sedimentation depth exceeds 3", follow water jet vacuum cleanout procedure outlined in manufacturer documentation
Inspection Ports (If applicable)	Measure sedimentation depth in chamber rows	If sedimentation depth exceeds 3", follow water jet vacuum cleanout procedure outlined in manufacturer documentation

8.2 Wet Ponds

Wet ponds should be maintained in accordance with the MA Stormwater Manual Volume 2, Chapter 2, Wet Basins O&M Guidance. Inspection logs should be stored to provide a record of changes to the BMP over time. Table 8-3 and Table 8-4 provide annual and biannual inspection and maintenance schedules.

Table 8-3. Annual Maintenance Schedule		
Feature	**Inspection Activity**	**Maintenance**
Outlet Control Structure	Inspect for: - Clogging - Erosion - Sedimentation around orifice - Structural Damage	Perform or schedule work immediately as necessary: - Removing clogs / trash / debris - Removing sedimentation around orifice - Repair / replace damaged structures - Restore eroded surfaces
Embankment	Inspect for: - Plant health - Invasive species - Tree roots - Erosion - Subsidence	Perform or schedule work immediately as necessary: - Removing invasive plant species - Replanting struggling plants - Shoring / restoration of eroded or subsided embankments
Pond Surface	Inspect for: - Floating Debris	Perform or schedule work immediately as necessary: - Removing floating debris

Table 8-4. Biannual Maintenance Schedule	
Feature	**Maintenance**
Outlet Control Structure	- Remove clogs / trash /debris from OCS
Embankment	- Remove trash / debris - Mow upper stage, side slopes, embankment, emergency spillway - Replant bare soil areas
Forebay	- Remove trash / debris

In addition, it is recommended to perform inspections following large storm events to ensure pond functionality and conditions of pipes and orifices (e.g., check for clogs, leaks or cracks).

Sediments should be removed as needed, at least once every 10 years. Annual inspections should note accumulation of sediment.

8.3 Bioretention

Bioretention cells should be maintained in accordance with the MA Stormwater Manual Volume 2, Chapter 2, Bioretention Areas O&M Guidance. To ensure initial plant growth, vegetation should be watered once every 2-3 days for the first 1-2 months of installation. Vegetation may be watered sporadically after the vegetation establishes, based on precipitation and visual plant health. Table 8-5 provides a maintenance schedule.

Table 8-5. Maintenance Schedule	
Activity	**Frequency**
Inspect / Unclog Inlet & Outlet	Monthly
Remove Trash / Debris / Invasive Species	Monthly
Mulching / Weeding	Annual
Remove & Replant Dead Vegetation	Annual
Pruning	Annual
Replace Media	As Needed

Additionally, the area should be mowed as needed depending on location and aesthetics appeal. If ponding occurs for more than 48 hours, the top few inches of filter media should be replaced to reduce sediment accumulation.

8.4 Swales

Swales should be maintained in accordance with the MA Stormwater Manual Volume 2, Chapter 2, Water Quality Swales O&M Guidance. This includes both inspections and routine maintenance. Inspections should be performed biannually to evaluate the following features of each swale:

- Slope integrity
- Soil Moisture
- Vegetative Health
- Soil Stability
- Soil Compaction
- Soil Erosion
- Ponding
- Sedimentation

Table 8-6 provides a maintenance schedule:

Table 8-6. Maintenance Schedule	
Activity	Frequency
Mowing	Annual
Remove Sediment / Debris	Annual
Pest Control	Annual
Fertilizing	Annual
Pruning	Annual
Embankment Restoration	As Needed

9 Phase 1 Plan Summary

This report constitutes the Town's Phase 1 PCP. The adjusted phosphorus reduction requirements that need to be achieved in Phase 1 are provided in Table 9-1.

Table 9-1. Adjusted Phosphorus Reduction Requirements

Phosphorus Load/Reduction Requirement	Average Annual Phosphorus Load (lbs/yr)
EPA Baseline Phosphorus Reduction Requirement[1]	3,861
Increase in Phosphorus Due to Redevelopment (2005 – 2020)	265
Phosphorus Reduction Required by 2026[2]	1,037
Phosphorus Reduction Required by 2028[3]	1,230

Notes:

1. *This is the total amount of phosphorus that must be reduced by 2038. Any additional phosphorus generated by redevelopment after 2005 will also need to be offset.*
2. *The MS4 Permit requires a 20 percent reduction in the baseline load by 2026. In addition, any increases in phosphorus due to redevelopment must also be offset. The value was calculated as follows: 3,861 x 0.2 + 265 = 1,037.*
3. *The MS4 Permit requires a 25 percent reduction in the baseline load by 2026. In addition, any increases in phosphorus due to redevelopment must also be offset. The value was calculated as follows: 3,861 x 0.25 + 265 = 1,230.*

The phosphorus reduction credits from the Town's existing non-structural and structural BMPs are shown in Table 9-2. Table 9-2 also includes the BMPs that the Town plans to implement during Phase 1 of the PCP.

Table 9-2. Phase 1 BMPs

BMP Description	Avg. Annual Phosphorus Removal (lbs/yr)
Existing BMPs	1,298
Planned BMPs	
Summit Ave	2
High School	18
Embassy Parking Lot	2
Monsignor McCabe Playground	20
Bobby Connors Playground	13
Beaver Brook Reservation	63
Subtotal	118
Total	1,416

Table 9-3 provides cost estimates for the BMPs that will be implemented during Phase 1. These are Class 4 cost estimates as defined by AACE International and as such has an expected range (after application of contingency, 30% used) of -20% to +40%. The implementation costs include design, construction and other studies and efforts (e.g., public outreach) that may be needed to implement the project. In total, the Town plans to invest about $8 million in BMPs over the next five years.

Table 9-3. Planned BMP Cost Estimates

Planned BMPs	Year Complete	Average Annual Phosphorus Reduction[1] (lbs/yr)	Construction Cost Estimate[2]	Construction Cost Per Pound of Annual Phosphorus Removal ($/lbs/yr)
Summit Ave	2023	2	$300,000	$177,515
High School	2024	18	$1,780,000	$100,000
Embassy Parking Lot	2024	2	$350,000	$175,000
Monsignor McCabe Playground	2025	20	$2,010,700	$100,184
Bobby Connors Playground	2026	13	$1,555,500	$120,600
Beaver Brook Reservation	2028	63	$1,995,400	$31,483
Total		118	$7,991,600	

Notes:

1. *Values rounded to nearest whole number.*
2. *AACE Class 4 cost estimate. Its expected accuracy range is -20% to +40%. The cost estimate was developed in June 2023.*

The construction cost per pound of annual phosphorus removal is shown in Table 9-3. A recent survey of the costs of BMPs in the Charles River Watershed found that mean values are approximately $100,000 per pound of annual phosphorus removal. This value can be considered a useful benchmark for evaluating the cost-effectiveness of the planned BMPs. The Beaver Brook Reservation project is a very cost-effective project with an estimated implementation cost of $31,483 per pound of annual phosphorus removal. The Playground BMPs, while not as cost-effective as the Beaver Brook Reservation, are expected be slightly above $100,000 per pound of phosphorus removal and are close to the previously mentioned median BMP costs in the Charles River Watershed. The Summit Avenue, High School and Embassy Parking Lot BMPs are part of larger projects and the cost related to just the BMPs were not available. The values shown in the tables are best estimates of the BMP-related costs.

The implementation schedule of the planned BMPs is shown in Table 9-4.

Table 9-4. Planned BMP Schedule						
Planned BMPs	Implementation Schedule					
	2023	2024	2025	2026	2027	2028
Summit Avenue BMPs	■					
High School BMPs		■				
Embassy Parking Lot BMP		■				
Bobby Connors Playground BMP			■	■		
Monsignor McCabe Playground BMP					■	■
Beaver Brook Reservation BMP		■	■			

10 Public Comment

In conformance with the Permit's requirements for each Phase of the PCP, Waltham made the draft written Phase 1 PCP available for public comment. The PCP is posted online on the City's stormwater webpage and the City will hold public meetings for each planned BMP to inform the community and gather input.

Appendix A: Baseline Phosphorus Load Revision Request

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T: 978.794.0336

Technical Memorandum

Prepared for: City of Waltham

Project Title: Stormwater Task Order

Project No.: 158735

Technical Memorandum

Subject: Baseline Phosphorus Load Revision Request to EPA

Date: September 27, 2022

To: Robert Winn, P.E.

From: Matthew Davis, P.E.

Section 1: Introduction

The 2016 Massachusetts MS4 Permit (*Permit*) requires that the City of Waltham develop a Phosphorus Control Plan (*PCP*) in accordance with the requirements contained within Appendix F of the Permit. The goal of the PCP is to reduce the phosphorus load contained in the City's stormwater that is discharged to the Charles River. The City's baseline phosphorus load and reduction requirements are shown in Table 1.

Table 1. City of Waltham Stormwater Phosphorus Reduction Requirements to Charles River (Source: 2016 MS4 Permit, Appendix F, Table F-2)

Description	Value[1]
Baseline phosphorus load	6,382 lb/yr
Stormwater phosphorus load reduction requirement	3,861 lb/yr
Allowable phosphorus load	2,521 lb/yr
Stormwater percent reduction in phosphorus load	60%

Notes:

1. *The annual loading rates in the Permit are provided in units of kg/yr. For convenience, the rates have been converted to lb/yr.*

The baseline phosphorus loads shown in Table 1 were developed using the methodology detailed in Mark Voorhees' draft memo dated January 14, 2014 (*Subject: Overview of Methodology to Calculate Baseline Stormwater Phosphorus Loads and Phosphorus Load Reduction Requirements for Charles River Watershed – Draft MA MS4 Permit)*. Several GIS layers representing 2005 conditions provide the basis for the phosphorus load calculations including the following: land use, impervious surface cover and hydrologic soil groups. These GIS layers are available through the MassGIS website.

The Permit allows permittees to request a revision of baseline phosphorus loads if the permittee has GIS data that is more accurate than the GIS data used to calculate the loads in the Permit. The revision request must be made in Year 4 as part of the annual reporting process as detailed below:

> *The Permittee may submit more accurate land use data from 2005, which is the year chosen as the baseline land use for the purposes of permit compliance, for EPA to recalculate baseline phosphorus stormwater loads for use in future permit reissuances. Updated land use maps, land areas, characteristics, and MS4 area and catchment delineations shall be submitted to EPA along with the year 4 annual report in electronic GIS data layer form for consideration for future permit requirements. Until such a time as future permit requirements reflect information submitted in the year 4 annual report, the permittee shall use the Baseline Phosphorus Load, Stormwater Phosphorus Reduction Requirement and Allowable Phosphorus Load Table F-2 (if its PCP Area is the permittee's entire jurisdiction) or Table F-3 (if its PCP Area is the regulated area only) to calculate compliance with milestones for Phase 1, 2, and 3 of the PCP.*
> *(Source: 2016 MS4 Permit, Appendix F, page 5)*

We have reviewed the GIS layers that were used to estimate the baseline phosphorus loads. Through a comparison of these layers against 2005 orthophotos, we have identified several inaccuracies in the 2005 impervious surface and land use GIS layers and we have revised these layers to more accurately reflect 2005 conditions. In addition, the recently updated NRCS soils GIS layer (available through MassGIS website) assigns hydrologic soil types to many soils that were previously 'unknown' in the hydrologic soils GIS layer used to calculate the phosphorus loads contained in the Permit.

We believe that the revised GIS layers (land use, impervious surface, and soils) more accurately reflect 2005 conditions than the layers used to develop the baseline phosphorus loads in the Permit. We recommend that the City submit these revised GIS layers to EPA and request a revision of the City's baseline phosphorus load.

The Permit, as quoted in the excerpt above, specifically requests updated *land use data* but does not specifically request the other GIS data used to calculate the phosphorus loads, namely, impervious surface and hydrologic soil groups. However, the Permit does request updated 'land areas, characteristics' and both impervious surface cover and hydrologic soil groups fall within these categories and are equally important in estimating phosphorus loads. Our review found that the land use layer needed the fewest revisions, while the impervious surface cover and hydrologic soil group GIS layers required more updates and a larger overall impact on the baseline phosphorus load estimate. We recommend that the City submit the revised GIS layers to EPA so that the most accurate baseline phosphorus load can be estimated.

Section 2: GIS Data Submission

To facilitate the baseline phosphorus load revision request, this technical memorandum is accompanied by a USB drive containing the revised and original GIS data. Table 2 provides a summary of the files.

Table 2.GIS Data to Accompany Baseline Phosphorus Load Revision Request

GIS Layer	Original	Revised
Impervious surface	\gis_data\original_2005\waltham_impervious_cover_2005.tif[1]	\gis_data\revised_2005\waltham_impervious_cover_2005_rev.tif[3]
Land use	\gis_data\original_2005\ waltham_LU_2005.shp[1]	\gis_data\revised_2005\ waltham_LU_2005_rev.shp[3]
Soils	\gis_data\original_2005\ waltham_SSURGO_MA_Diss.shp[2]	\gis_data\revised_2005\ waltham_soils_nrcs_2021.shp[4]

Notes:

1. *Source: MassGIS website: https://www.mass.gov/info-details/massgis-data-layers. Clipped to Waltham border.*
2. *The soils layer used to develop the Permit baseline phosphorus load is no longer available on MassGIS website. The GIS layer was provided by Mark Voorhees to Matt Davis in an email dated April 26, 2021.*
3. *Brown and Caldwell used a 2005 orthophotograph of the City to revise inaccuracies in the original layer.*
4. *Source: MassGIS website: https://www.mass.gov/info-details/massgis-data-layers. MassGIS released the updated NRCS soil layer on November 23, 2021.*

In addition, we are also submitting additional GIS layers to facilitate EPA's review. These layers are identified in Table 3. Two of the layers (*imp_area_2005_add.shp* and *imp_area_2005_subtract.shp*) identify areas that were revised in the original impervious surface layer. The other layers were used to identify MassDOT and DCR properties. The City of Waltham is not responsible for managing the stormwater phosphorus loads from these properties.

Table 3. Supplementary GIS Layers	
Path	Description
\gis_data\revised_2005\imp_area_revisions\imp_area_2005_add.shp	GIS layer containing areas that the original 2005 impervious surface GIS layer identified as pervious that were actually impervious.
\gis_data\revised_2005\imp_area_revisions\imp_area_2005_subtract.shp	GIS layer containing areas that the original 2005 impervious surface GIS layer identified as impervious that were actually pervious.
\gis_data\mass_dot_dcr_properties\dcr_properties.shp	GIS layer containing properties owned DCR. The City of Waltham is not responsible for managing stormwater phosphorus loads from these properties. DCR properties were determined by matching DCR properties shown on their website[3] with the City's parcels.
\gis_data\mass_dot_dcr_properties\massdot_properties.shp	GIS layer containing properties owned MassDOT. The City of Waltham is not responsible for managing stormwater phosphorus loads from these properties. MassDOT properties were determined from the MassDOT inventory website[4].

Notes:

1. *Source: MassGIS website: https://www.mass.gov/info-details/massgis-data-layers. Clipped to Waltham border.*
2. *The soils layer used to develop the Permit baseline phosphorus load is no longer available on MassGIS website. The GIS layer was provided by Mark Voorhees to Matt Davis in an email dated April 26, 2021.*
3. *https://mass-eoeea.maps.arcgis.com/apps/webappviewer/index.html?id=fa6826d091ad46869cc597c98aab1184*
4. *https://gis.massdot.state.ma.us/roadinventory/*

Section 3: Comparison of Original and Revised GIS Layers

Figures 1 and 2 overlay the original impervious surface layer on top of orthophotos from 2005. These figures provide examples of where the original impervious surface GIS layer misidentified areas as being impervious. In the case of Figure 1, ball fields were mistaken for impervious areas while in Figure 2, it was the shadows cast from buildings. Figure 3 shows an example of the opposite situation where the original impervious surface layer misidentified a rooftop as being pervious when it should be impervious. The original impervious surface layer was revised to correct the surface conditions for these locations.

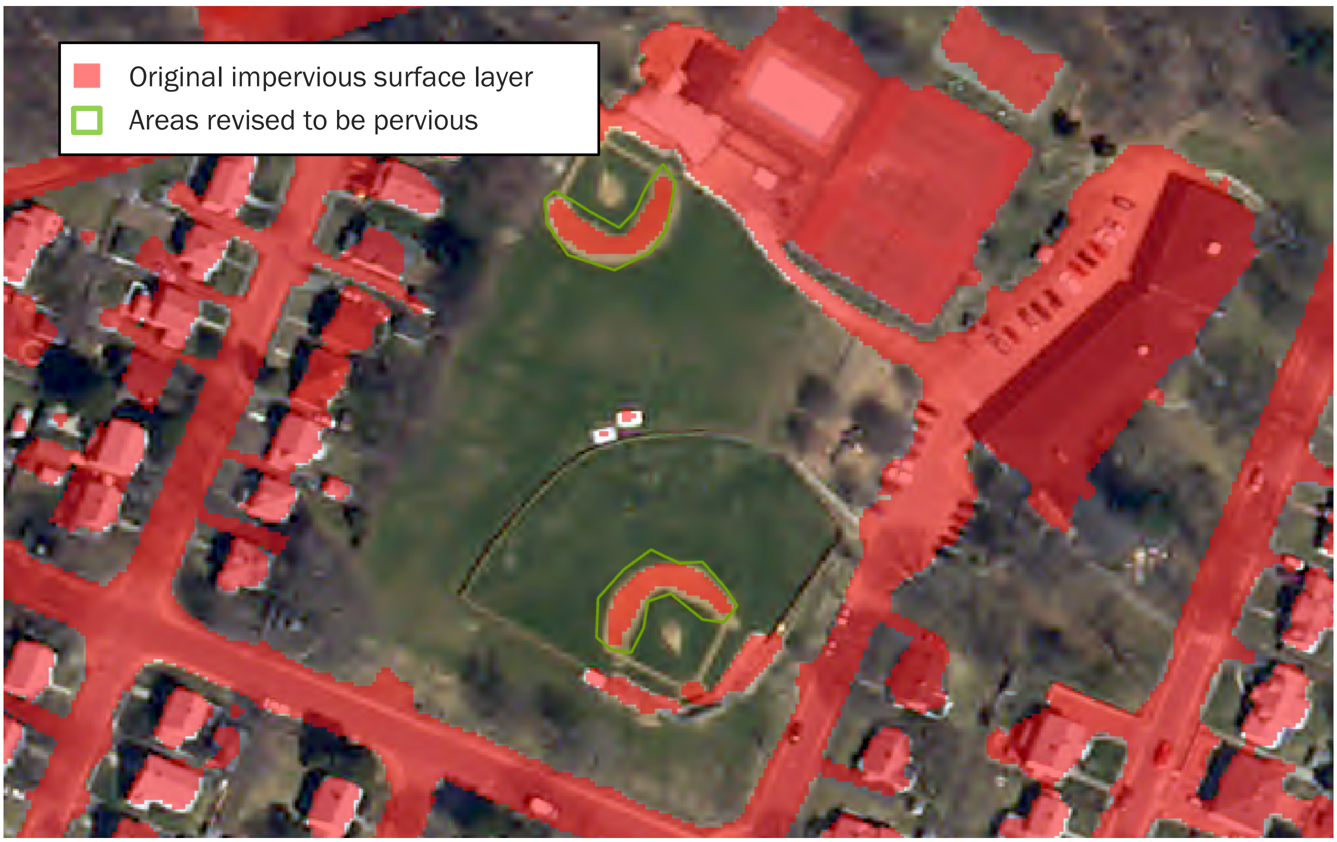


Figure 1. Athletic fields identified as impervious in the Original 2005 Impervious Surface GIS Layer were revised to be pervious in the Revised 2005 Impervious Surface GIS Layer

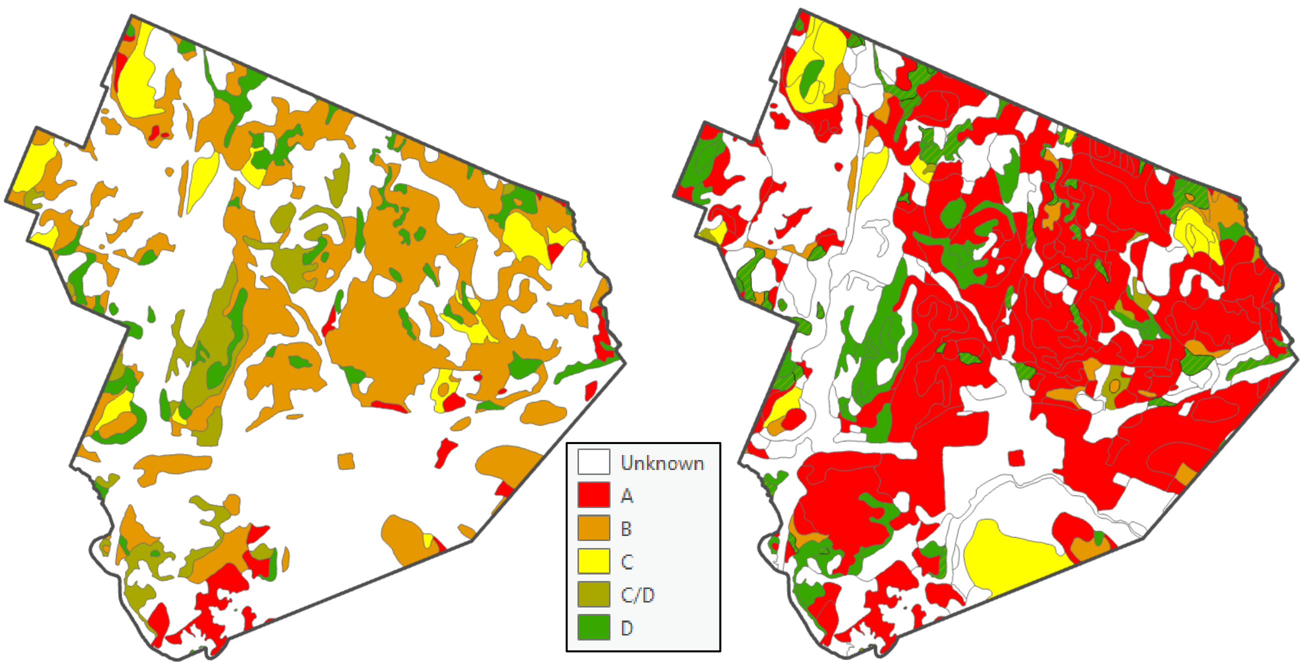
Figure 2. Areas with riprap identified as impervious in the Original 2005 Impervious Surface GIS Layer that were revised to be pervious in the Revised 2005 Impervious Surface GIS Layer

Figure 3. Rooftop identified as pervious in the Original 2005 Impervious Surface GIS Layer that was revised to be impervious in the Revised 2005 Impervious Surface GIS Layer

Only minor revisions were made to the original land use GIS layer. For example, the water bodies shown in Figure 4 were coded as 'Very Low Density Residential'. These areas were revised to the land use type code 'Water'.

Figure 4. The area shown with a dashed white line were coded as 'Industrial' in the original land use GIS layer, but was revised to 'Open Land' in the revised land use GIS layer

There are significant differences in the hydrologic soil group layers as shown in Figure 5. Most of the soils in the original hydrologic soil group layer in the City of Waltham were unknown (i.e., purple-colored areas), whereas the revised hydrologic soil group layer has assigned hydrologic soil groups to many of these areas, resulting in a significant increase in type A and B soils throughout the City.



Original Hydrologic Soil Groups

Revised Hydrologic Soil Groups

Figure 5. Comparison of Hydrologic Soil Groups

Type A and B soils are conducive to infiltration and result in lower stormwater phosphorus export rates. This is demonstrated in Table 4 which provides the phosphorus export rates for developed pervious lands. Type A soils have a loading rate of 0.03 lb/ac/yr whereas unknown soils are assumed to have a loading rate of 0.21 lb/ac/yr. Properly categorizing a soil as *Type A* rather than *Unknown* reduces the phosphorus export from pervious surfaces by a factor of 7. Updating the City's baseline phosphorus load with the revised hydrologic soil groups will provide a more accurate assessment of the City's stormwater phosphorus load to the Charles River.

Table 4. Phosphorus Export Rates for Developed Pervious Land (Source: 2016 MS4 Permit, Appendix F, Attachment 1, Table 1-2)

Hydrologic Soil Group	Phosphorus Load Export Rate (lb/ac/year)
A	0.03
B	0.12
C	0.21
C/D	0.29
D	0.37
Unknown	0.21

Notes:

1. *Unknown soils are assumed to have the same phosphorus export load rate as hydrologic soil group C.*

Section 4: Baseline Phosphorus Load Calculations

The phosphorus load calculations are based on land areas and phosphorus loading rates. We have calculated all of these values using the original and the revised GIS data. The results are shown in Tables A-1 and A-2 of Attachment A, respectively. These tables may be helpful to EPA as they review the revision request. The baseline phosphorus load calculated with the original GIS data is 6,397 lb/yr, which is 15 pounds more than the value calculated by EPA and contained in the Appendix F of the Permit.

The difference between the baseline phosphorus load in the Permit and the value estimated here is likely due to differences in the MassDOT and DCR property GIS layers. There is not a readily available GIS data source of MassDOT and DCR properties, so we created these layers from the City's parcel GIS layer, an inventory of MassDOT roads available from their website and DCR websites that identify parks in Waltham. We requested EPA's MassDOT and DCR layer used for the 2005 load estimates so that we could compare it with ours, but it was not available for review. It is likely that there are differences between EPA and our MassDOT/DCR datasets.

The baseline phosphorus load calculated with the revised GIS data is 5,909 lb/yr, a reduction of 488 lb/yr from our baseline estimate (6,397 – 5,909 = 488).

Attachment A: Phosphorus Load Calculations

Table A-1. Baseline Phosphorus Loads based on Original GIS Data [1]

Phosphorus Land Use Type	Area (ac)		Sutherland Coefficients		DCIA				Pervious Area (ac)							Pervious Area Export Rate (lb/ac/yr)						Pervious Area Export Load (lb/yr)							Disconnected Impervious Area			Total Export Load (lb/yr)
	Total	Impervious	a	b	Percent	Area (ac)	Loading rate (lb/ac/yr)	Load (lb/yr)	HSG A	HSG B	HSG C	HSG C/D	HSG D	USG Unk	Total	HSG A	HSG B	HSG C	HSG C/D	HSG D	USG Unk	HSG A	HSG B	HSG C	HSG C/D	HSG D	USG Unk	Total	Area (ac)	Export Rate (lb/ac/yr)	Export Load (lb/yr)	
Commercial	1,507.9	974.1 (65%)	0.4	1.2	59%	896.8	1.78	1,596.3	5.3	152.3	12.8	23.7	8.3	331.4	533.9	0.04	0.17	0.36	0.45	0.55	0.36	0.2	26.6	4.6	10.7	4.5	118.6	165.2	77.3	0.309	23.9	1,785.4
Industrial	566.0	431.6 (76%)	0.4	1.2	73%	410.8	1.78	731.3	4.0	19.5	6.0	1.9	3.5	99.4	134.4	0.04	0.17	0.36	0.45	0.55	0.36	0.2	3.4	2.2	0.9	1.9	35.6	44.1	20.8	0.328	6.8	782.2
High-Density Residential	2,556.9	1,216.6 (48%)	0.4	1.2	41%	1,053.6	2.32	2,444.4	15.3	365.2	20.2	38.3	18.6	882.7	1,340.3	0.04	0.17	0.36	0.45	0.55	0.36	0.6	63.7	7.2	17.3	10.1	316.0	415.0	163.0	0.310	50.5	2,909.8
Medium-Density Residential	540.4	176.5 (33%)	0.1	1.5	19%	100.9	1.96	197.8	14.0	156.1	50.0	8.2	10.0	125.6	363.9	0.04	0.17	0.36	0.45	0.55	0.36	0.6	27.2	17.9	3.7	5.5	45.0	99.8	75.6	0.274	20.7	318.3
Low-Density Residential	53.8	15.2 (28%)	0.1	1.5	15%	8.1	1.52	12.3	0.5	22.5	3.6	2.4	1.1	8.5	38.6	0.04	0.17	0.36	0.45	0.55	0.36	0.0	3.9	1.3	1.1	0.6	3.0	9.9	7.1	0.257	1.8	24.1
Highway	77.6	49.9 (64%)	0.1	1.5	52%	40.0	1.34	53.6	0.1	5.2	-	0.5	1.6	20.3	27.7	0.04	0.17	0.36	0.45	0.55	0.36	0.0	0.9	-	0.2	0.9	7.3	9.3	9.9	0.335	3.3	66.2
Forest	1,971.6	88.8 (5%)	0.01	2	0%	4.0	1.52	6.1	52.2	844.1	124.4	280.2	334.2	247.8	1,882.8	0.11	0.14	0.19	0.21	0.23	0.19	5.8	118.8	23.2	58.1	76.2	46.2	328.3	84.8	0.174	14.8	349.2
Open Land	304.1	94.8 (31%)	0.1	1.5	17%	52.9	1.52	80.5	41.4	85.5	13.8	4.1	7.6	56.9	209.3	0.04	0.17	0.36	0.45	0.55	0.36	1.7	14.9	5.0	1.9	4.1	20.4	48.0	41.9	0.229	9.6	138.0
Agriculture	75.8	6.0 (8%)	0.01	2	1%	0.5	1.52	0.7	9.9	52.6	0.1	-	1.9	5.2	69.8	0.07	0.29	0.60	0.75	0.91	0.60	0.7	15.3	0.1	-	1.7	3.1	20.9	5.5	0.300	1.7	23.3
Water	654.4	1.8 (0%)	0	0	0%	-	0	-	4.0	23.8	0.5	1.8	6.2	616.3	652.6	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	1.8	0.000	-	-
	8,308.5	3,055.4				2,567.6		5,122.9	146.8	1,726.7	231.5	361.2	392.9	2,394.1	5,253.1							9.8	274.7	61.4	93.9	105.5	595.2	1,140.5	487.8		133.1	6,396.5

Notes:

1. Calculations based on GIS data used to develop the baseline phosphorus loads for the 2016 MS4 Permit.

Table A-2. Baseline Phosphorus Loads based on Revised GIS Data[1]

Phosphorus Land Use Type	Area (ac)		Sutherland Coefficients		DCIA				Pervious Area (ac)									Pervious Area Export Rate (lb/ac/yr)								Pervious Area Export Load (lb/yr)									Disconnected Impervious Area			Total Export Load (lb/yr)
	Total	Impervious	a	b	Percent	Area (ac)	Loading rate (lb/ac/yr)	Load (lb/yr)	HSG A	HSG A/D	HSG B	HSG B/D	HSG C	HSG C/D	HSG D	HSG Unk	Total	HSG A	HSG A/D	HSG B	HSG B/D	HSG C	HSG C/D	HSG D	HSG Unk	HSG A	HSG A/D	HSG B	HSG B/D	HSG C	HSG C/D	HSG D	HSG Unk	Total	Area (ac)	Export Rate (lb/ac/yr)	Export Load (lb/yr)	
Commercial	1,496.8	965.3 (64%)	0.4	1.2	59%	888.4	1.78	1,581.3	228.8	1.7	18.4	3.3	11.2	1.5	27.6	239.0	531.6	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	9.6	0.6	3.2	1.2	4.0	0.7	15.1	85.6	119.9	76.9	0.2	17.3	1,718.6
Industrial	559.1	430.7 (77%)	0.4	1.2	73%	410.8	1.78	731.2	19.3	0.1	0.0	2.3	3.3	1.7	1.9	99.8	128.4	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	0.8	0.1	0.0	0.8	1.2	0.8	1.0	35.7	40.4	20.0	0.3	6.3	777.8
High-Density Residential	2,556.9	1,215.1 (48%)	0.4	1.2	41%	1,052.1	2.32	2,440.9	1,010.4	4.0	7.1	12.0	84.6	3.0	41.1	179.7	1,341.7	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	42.3	1.4	1.2	4.3	30.3	1.3	22.4	64.3	167.6	163.0	0.1	20.4	2,628.9
Medium-Density Residential	540.4	176.4 (33%)	0.1	1.5	19%	100.8	1.96	197.6	234.0	3.2	7.4	6.9	61.0	1.1	27.5	22.9	364.0	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	9.8	1.1	1.3	2.5	21.8	0.5	15.0	8.2	60.2	75.6	0.2	12.5	270.4
Low-Density Residential	53.8	15.1 (28%)	0.1	1.5	15%	8.0	1.52	12.2	28.7	0.2	0.9	0.4	0.1	-	5.8	2.4	38.7	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	1.2	0.1	0.2	0.1	0.1	-	3.2	0.9	5.7	7.1	0.1	1.0	18.9
Highway	77.5	8.8 (11%)	0.1	1.5	4%	3.0	1.34	4.0	4.8	-	0.2	2.4	-	-	1.7	59.6	68.7	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	0.2	-	0.0	0.9	-	-	0.9	21.4	23.4	5.9	0.3	2.0	29.4
Forest	1,975.4	83.2 (4%)	0.01	2	0%	3.5	1.52	5.3	850.3	20.2	73.4	216.2	67.3	24.3	337.6	302.7	1,892.1	0.11	0.19	0.14	0.19	0.19	0.21	0.23	0.19	94.0	3.8	10.3	40.3	12.6	5.0	76.9	56.5	299.4	79.7	0.2	12.6	317.4
Open Land	317.7	77.1 (24%)	0.1	1.5	12%	38.0	1.52	57.8	67.4	-	19.3	7.9	4.4	12.0	10.4	119.2	240.6	0.04	0.36	0.17	0.36	0.36	0.45	0.55	0.36	2.8	-	3.4	2.8	1.6	5.4	5.6	42.7	64.4	39.1	0.3	10.5	132.6
Agriculture	75.8	6.0 (8%)	0.01	2	1%	0.5	1.52	0.7	49.1	-	9.0	3.8	0.0	0.0	0.1	7.8	69.8	0.07	0.60	0.29	0.60	0.60	0.75	0.91	0.60	3.4	-	2.6	2.2	0.0	0.0	0.1	4.6	13.1	5.5	0.2	1.0	14.8
Water	658.4	1.8 (0%)	0	0	0%	-	0	-	26.2	0.4	1.8	5.9	0.1	1.4	2.3	618.4	656.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-	-	1.8	-	-	-
	8,311.8	2,979.6				2,505.0		5,031.0	2,519.1	29.9	137.6	261.0	232.1		456.0	1,651.5	5,332.2																	794.1	474.5		83.6	5,908.7

Notes:

1. Calculations based on revised impervious surface, land use and hydrologic soil group GIS data.

Appendix B: Legal Analysis

Waltham, Massachusetts Regulatory Review

Review of existing ordinances to identify opportunities for climate resiliency regulations, guidance, or provisions.

June 29, 2021

Introduction

The following document provides a comprehensive review of existing ordinances in Waltham Massachusetts in order to identify opportunities to enhance the resilience of the stormwater system and the City as a whole. The following ordinances were reviewed and opportunities to update the regulatory language to include accommodations for climate resilience were identified. Suggestions vary from general assessments of potential new standards to specific, rule-based language.

The City departments charged with stormwater management include the Director of Consolidated Public Works or the City Engineer. In addition, The Conservation Commission has authority over projects that fall within their jurisdiction under the Wetland Protection Act. The Building Department also has limited responsibilities for stormwater management. The Board of Survey and Planning has authority over the review and approval of subdivisions. References to the Stormwater Enforcement Agent refer back to the City Engineer.

ORDINANCES

Ordinance 32081: Chapter 16 Sewers, Drains, and Sewage Disposal

Purpose: The purpose of this ordinance is to regulate the discharge of stormwater or other non-sewer drainage and to ensure proper operations and maintenance of the sewers, drains, and sewer disposal process.

Enabling Legislation: Not explicitly stated except to appoint the Director of CPW or Engineer as the Commissioner of Sewers via MGL Ch.41.

Enforcement Authority: Director of Consolidated Public Works or City Engineer

Section	Summary	Suggestions/Opportunity
16-3b	Stormwater and all other unpolluted drainage shall be discharged to such sewers that are specifically designated as combined sewers or storm sewers or to a natural outlet approved by the Director, but only after determination by the City Engineer. Combined sewers or storm sewers must have sufficient capacity to accommodate such discharge and all federal, state or local laws, regulations, and administrative or judicial orders, agreements or judgments must be complied with.	Waltham could require the reduction or elimination of inflow through stormwater management practices that capture and retain stormwater onsite (through low impact development [LID]). This could help to reduce associated combined and sanitary sewer overflows, which could increase as precipitation becomes more extreme. The City can require that a user design, construct, install, operate and maintain best management practices (BMPs) that provide regulation and control of the rate, volume and pollution discharge of the stormwater, prior to discharge to the City's storm drainage system. These BMPs must be approved by the Engineering Division. The City could develop assessment tools for more effectively understanding the capacity of storm sewers.
16-28	Connection of sources of surface runoff or groundwater to a sewer or drain connected directly or indirectly to the sewer is prohibited.	Adequate as written.
16-32	Infiltration and inflow mitigation fee: projects must mitigate additional wastewater infiltration/inflow sources, which add extraneous water to the City's sewer system thereby reducing its capacity and capability, at a specified rate of four gallons of infiltration/inflow removal for each additional gallon of wastewater that will be discharged to the sewer system, or pay a one-time infiltration/inflow mitigation fee per unit.	The City could require a higher ratio of I/I removal. The designated I/I removal ration could be lower for developments which implement BMPs.

Chapter 25 Stormwater Ordinance

Purpose: This ordinance authorizes the City to promulgate stormwater management standards for development and redevelopment projects to minimize adverse impacts to the public health, safety and welfare of Waltham residents, and protect the natural resources, water bodies, groundwater resources, environment and municipal facilities of the City, as required for the National Pollutant Discharge Elimination System (NPDES) general permit for stormwater discharges issued by the U.S. Environmental Protection Agency.

Enabling Legislation: Home Rule Amendment and Clean Water Act

Enforcement Authority: Stormwater Enforcement Agent

Regulatory Tool: Stormwater management permit, authorizes Stormwater Enforcement Agent to develop rules and regulations. Authorization power can be delegated in writing to employees or agents. Rules and regulations are amended through a public hearing and public notice.

The Stormwater Management Ordinance can further incorporate climate adaptation and resilience goals into the language by specifying performance standards for development projects.

Section	Summary	Suggestions/Opportunity
25-1 C	Details the objectives of article.	The City can expand upon the objectives of the article to include the following: To require practices to control the flow of stormwater from new and redeveloped sites into the municipal storm drainage system to prevent flooding and erosion *informed by the best available climate data.* To ensure the stormwater system is adequately designed to handle increased precipitation loads caused by climate change. To promote the incorporation of both green and grey infrastructure solutions to reduce the peak load on the stormwater management system, mitigate flooding, contribute to the quality of stormwater, and the reduction of urban heat islands.
25-3 A	Sets the requirements for large-scale developments over 1-acre. Any disturbance to land 1-acre or over draining to the City's MS4 must have a stormwater management permit from the Stormwater Enforcement Agent	Change to allow the threshold of disturbance to be defined in the Stormwater Rules and Regulations developed by the Stormwater Enforcement Agent; or Reduce the disturbance threshold to ~10,000 SF, given the density of development in Waltham. Amend the ordinance to allow the Stormwater Enforcement Agent to have jurisdiction of projects ranging from 10-000 to greater than or equal to 1 acre.

City of Waltham Site Plan Review and Permit Application Requirements

Purpose: This City's Site Plan Review and Permit Application Requirements include all documentation required of owners or developers prior to permit award. The required documents aid the City in evaluating whether the proposed design meets utility requirements, complies with Massachusetts State Building Code, and stormwater and drainage requirements.

Enabling Legislation: Massachusetts State Building Code.

Enforcement Authority: Director of Consolidated Public Works and City Engineer

Section	Summary	Suggestions/Opportunity
Plan and Utility Requirement #7	Peak storm flow rates shall be determined for pre- and post development conditions for the 10-., 25- and 100- year storm events. Piped drainage systems shall be designed with capacity for a 25-year. storm event. Detention basins, tanks, and pits shall be designed to be capable of safely storing and infiltrating the 100-yr. storm event. (See Policy on Drainage Calculations) In general it is required that all impervious surface drainage be retained or recharged on site for a 100-year storm with no connection to city system.	Waltham could require the reduction or elimination of inflow through stormwater management practices that capture and retain stormwater onsite through low impact development [LID]. The City can require that a user design, construct, install, operate and maintain best management practices (BMPs) that provide regulation and control of the rate, volume and pollution discharge of the stormwater, prior to discharge to the City's storm drainage system. These BMPs must be approved by the Engineering Division. Require applicant to submit a statement regarding how climate change projections were considered in the design or require that design storm events for future conditions using the Resilient Massachusetts's Action Team's Climate Resilient Design Standards and Guidelines.
Plan and Utility Requirement #8	Large development projects shall consider the use of detention basins or underground storage tanks to retain any flows, and if allowed, discharge either on-site or off-site to existing waterways, with flows not to be discharged directly or indirectly to existing municipal storm drainage systems. Smaller parcels can consider use of underground storage tanks with orifice regulated outflows.	'Large development projects' should be defined by square footage Large developments should incorporate nature-based solutions, green infrastructure, or other Low Impact Development techniques. Site plans should be reviewed for landscape measures that will reduce urban heat island impacts and mitigate flooding. Waltham could consider developing climate resilience design guidelines that are used to aid the review of new development plans.

Section	Summary	Suggestions/Opportunity
		Incorporation of climate resilience measures could be considered based on the size of the project. For example, large development projects would be required to implement a greater amount of square footage of landscape features contributing to the mitigation of climate impacts.
Plan and Utility Requirement #10	All drainage designs shall comply with the City of Waltham requirements and guidance set forth in the Massachusetts Department of Environmental Protection Stormwater Standards and Policies.	Drainage designs should incorporate projected loads under climate change.
Plan and Utility Requirement #21	All plans must be followed by a SURVEY RECORD (as-built plan) at the completion of final inspection (survey record to be certified with stamp, signed in ink, by a MA Registered Land Surveyor and stating the date of the record field survey).	As-built plans could be reviewed to ensure incorporation of proposed climate resilience measures if required by the climate resilience design guidelines for large developments. (Contingent on the implementation of the above recommendation for climate resilience design guidelines.)
Policy on Drainage Calculations #2	Plans for all residential projects involving the construction of new buildings, additions to existing buildings or addition/modification to impervious surface where the proposed roof exceeds 150 square feet, shall be accompanied by drainage calculations.	This requirement could be incorporated into the City's proposed Stormwater Rules and Regulations. New residential construction plans could be reviewed in relationship to the projected flood elevation for that parcel. The City can recommend that designs are adapted so that the ground level of the building is above the design flood elevation which is equal to the projected 100-year flood elevation plus 1ft of freeboard.
Policy on Drainage Calculations #3	Drainage calculations shall include calculations showing the proposed drainage system ability to remove 60% of the phosphorus load from additional and modified impervious areas. Owner occupied single family residential permit submissions are not required to show phosphorus load reduction calculations.	This requirement could be incorporated into the City's proposed Stormwater Rules and Regulations. The City could add a description of the methodology to show the removal of phosphorus control.

Waltham, Massachusetts Chapter Z, Zoning Code

Purpose: This ordinance regulates land use, structures, water, and open space to promote the health, safety, convenience, morals and welfare of its inhabitants. The zoning code is organized by regulations for Districts (Section 3), Dimensional Requirements (Section 4), Land, Buildings, Wetlands, Floodplain, Parking (Section 5), and Incentive Zoning (Section 8).

Enforcement Authority: Building Department

Section	Summary	Suggestions/Opportunity
1.3	Objectives	The City could consider adding climate resilience objectives including: - Flood resilient new development - Mitigation of flooding through the limitation of impervious area - Integration of green building practices to limit green house gas impacts - Integration of climate resilience design standards into new sites. Amend 1.31 to include 'floodplain'
2.3	Definitions	The City could add definitions for the following terms which relate to climate resilience and flood mitigation measures and reference these throughout the zoning code: - 100-year flood - Design flood elevation - Green infrastructure - Impervious surfaces - Urban heat island impacts - Solar reflectance index (SRI)
3.12	Establishes a floodplain district.	The City could update the ordinance language to require the regular update of the floodplain district extents based on the best available data for future flood projections, rather than relying on FEMA maps which use historical data.
3.5	Special permits	The City could consider requiring large developments seek a special permit. Special permits could be issued only when certain climate resilience targets were met through the site and building design. Boston Article 37 Green Buildings as a precedent example.
4.218	Lot area. This section lays out lot area requirements such as setbacks and side yards.	This section could be updated to account for dimensional requirements that facilitate the creation of congruent open spaces across properties. Additionally, this section could require that a certain ratio of the lot are be designated to planted areas to contribute to flood mitigation and urban heat island reduction.

		A new section could be added for lot area requirements in the floodplain to accommodate additional buffer area around waterways and high probability flood areas.
4.22	Dimensional requirements for residential properties.	The City could update this section to include dimensional requirements for the ground level of a new residence to meet the design flood elevation.
5.4	Design of parking areas for 5 or more cars.	This section of the zoning code could be updated to include requirements for pervious paving, high SRI paving, or green infrastructure to mitigate the impacts of heat and stormwater flooding.
8.5	Riverfront Overlay District lays out design requirements for Riverwalk and associated public area.	Design guidelines for bank stabilization can be updated to include flood mitigation measures and recommendations based on projected flood elevations. Planting guidance should be updated to include best practices for riverine floodplain management.

Other amendments to the Zoning Code could include the addition of a Tree Protection Ordinance; an ordinance to promote the reduction of urban heat island impacts through site and building strategies; incentive-based zoning for implementation of BMPs on properties; climate resilience design guidelines; the expansion of the Floodplain Overlay District based on future-looking flood projections; updates to area requirements to include formula-based limitations on impervious area.

STORMWATER MANAGEMENT PLAN

Purpose: The City of Waltham developed this Stormwater Management Plan (SWMP) to satisfy the requirements of the US EPA Phase II stormwater permit that is effective July 1, 2018. The SWMP describes and details the activities and measures that will be implemented to meet the terms and conditions of the permit. This plan provides a status update and timeline for implementation of the stormwater management programs, policies, guidelines required by the Environmental Protection Agency for the 2016 MS4 Permit.

Stormwater Management Rules and Regulations

The Stormwater Management Rules and Regulations are in draft-form as of June 2021 and have yet to be adopted by the City. Because this language has not yet been adopted as a singular regulatory document, the review of this was as comprehensive as the draft format allowed. Further assessment of the standards could be completed when the regulation is in a finalized format.

Enabling Legislation: Home Rule Amendment of MA Constitution; Clean Water Act (40 CFR 122.34); EPA NPDES Requirements; Waltham General Ordinance Chapter 16 Sewers, Drains and Sewage Disposal; and Waltham General Ordinance Chapter 25 Stormwater Management

Purpose: These regulations establish stormwater management standards and permitting processes for development and redevelopment projects to minimize stormwater runoff and associated impacts to abutters and the general public, as authorized by Article 1, Sections 25-4 and 25-20 of the City of Waltham General Ordinances.

Enforcement Authority: City Engineer and Stormwater Enforcement Agent

Regulatory Tool: Stormwater Management Permit (SWMP)

The first seven sections of the Stormwater Management Rules and Regulations define the purpose, authorizing statutes, applicable projects, administration, and permit processes for developments to reduce adverse impacts from stormwater. Section 8 sets requirements for stormwater management plans, plot plans, and performance standards for each project to meet the Standards of the Massachusetts Stormwater Management Policy. Section 9 sets requirements for operation and maintenance plans to ensure compliance with the City's Stormwater Ordinance and Massachusetts Surface Water Quality Standards. Section 10 sets requirements for the Waste, Erosion, and Sediment Control Plans to prevent erosion and sediment from reaching neighboring water bodies. The final sections (11-16) discuss inspections and enforcement procedures. Sections 8 and 10 provide the greatest opportunity to use the Stormwater Rules and Regulations as a climate resilience tool.

Section	Summary	Suggestions/Opportunity
Section 1 Purpose	Lists objectives of the rules and regulations for stormwater management	Include climate resilience as a stated objective.
Sec 8.a Stormwater Management Plan	Section 8 outlines components required of a stormwater management plan.	
Sec 8.a.7	Designates contours at one-foot intervals	Adequate as written.
Sec 8.a.9	Stormwater conveyances and wetlands on or connected to the site	Delineation of projected wetlands, floodplains, and other regulated areas could be used to identify preferred future development areas that are less vulnerable or sensitive under climate change. Rules could be used that enable wetlands to migrate with the expansion of the floodplain.
Sec 8.a.11	Defines the floodplain by the FEMA 100-year flood zone	Update to define the floodplain as the 500-year FEMA flood zone.
Sec 8.a.12	Includes the estimated seasonal high groundwater elevation	Estimates should incorporate projections of increased precipitation under climate change
Sec 8.a. 13	Includes the existing and proposed vegetation and ground surfaces with runoff coefficient for each.	Include a site landscape plan which includes a planting plan with species called out. Consider species that have benefits such as water-tolerance in the instance of flood submersion or drought tolerance in upland areas.
Sec 8.a.15F	The 10-yr, 25-yr, and 100-yr storm events should be used to determine peak storm flow rates	Consider adding 500-year storm event to peak storm flow rates to understand severe or future conditions.
Sec. 8.a.15	Drawings of drainage system should include onsite stormwater retention and detention measures	Plan can identify areas that would benefit from disconnected impervious surfaces, open channel design, and LID. The City could add language limiting the ratio of impervious

Section	Summary	Suggestions/Opportunity
		surfaces on various sites based on parcel size or use. The City should require onsite disposal and treatment of up to 2 inch of rain as often as possible, providing guidance on LID techniques to achieve this. The City might include language stating that the Director of Water and Sewer could also require the owner to disconnect its building storm drain and replace the connection with onsite LID practices.
	Soil conditions are not required as part of stormwater management plan	Require description of soil conditions in plan to allow annual recharge rates to be calculated based on soil types (in Sec 8.c.3); or, suggest in Sec 8.c.3 using the soil description in the erosion and sediment control plan.
Sec 8.c. Performance Standards	Prohibits discharging stormwater directly to wetlands or water; requires that post-development does not exceed peak discharge rates and maintains recharge rate from existing conditions; encourages maximum infiltration; requires 80% of TSS removed; requires erosion and sediment controls and operation and maintenance plan	Consider incorporating a "green ratio" requirement into stormwater guidelines. This criterion may be expanded to include greater than 1:1 offset criterion to increase retention capacity over time. Consider requiring each project to evaluate cumulative effects from future development, in addition to the individual project impacts. Include in Sec 8.c.8 a reference to the City's Erosion and Sedimentation Control Standard Operating Procedures (SOP 6) document for recommended stormwater management practices Consider making BMPs listed in the SOP 6 required Include language that addresses the impact of increased stormwater on soil erosion and sediment control and encourage the use of best available data to understand future conditions and use best practices for operations and maintenance.
Sec 10 Waste, Erosion, and Sediment Control Plan	BMPs described in the plan shall follow the MA DEP Report on Erosion and Sediment Control in Urban and Suburban Areas	Consider making BMPs listed in the SOP 6 required
Sec 10.b	Waste, Erosion, and Sediment Control Plan's required elements	Include reference to the City's Erosion and Sedimentation Control Standard Operating Procedures document for recommended

Section	Summary	Suggestions/Opportunity
		stormwater management practices and considerations
Sec 10.b.4	Soil Description should describe drainage conditions and soils that will be exposed during grading.	Could recognize Natural Resource Conservation Service soils classification system which identifies soils susceptible to high erosion and runoff. This may be a useful source of information for project design standards and guidelines.

The following appendices to the Stormwater Management Plan are described below but were not reviewed as a component of this regulatory review. However, it should be noted that catch basin cleaning, street sweeping, and deicing are important procedures that contribute to the proper functioning of the stormwater system, which in turn mitigates flood impacts. By keeping a standard cleaning schedule, the City can reduce opportunities for catch basins to become clogged and result in flooding and water quality impairments. .

Catch Basin Cleaning Standard Operating Procedures (Stormwater Management Plan Appendix E)

Purpose: These procedures guide municipal operations and good housekeeping practices for catch basin cleaning to ensure effective capture of stormwater runoff.

Street Sweeping and Deicing Standard Operating Procedures (Stormwater Management Plan Appendix F & G)

Purpose: These procedures guide municipal operations and good housekeeping practices for street sweeping and deicing to ensure effective capture of stormwater runoff and contribution to water quality.

Construction Site Inspection Standard Operating Procedures (Stormwater Management Plan Appendix H, SOP 5)

Purpose: The Standard Operating Procedures guide municipal operations for a municipal Stormwater Construction Inspection Plan and provides guidance on evaluating compliance of stormwater controls at construction sites.

Enforcement Authority: City Engineer and Stormwater Enforcement Agent

Section	Summary	Suggestion/Opportunity
Stormwater Construction Inspection Plan	Requires staff conducting sections to be trained	Require inspectors to be certified

Erosion and Sedimentation Control Standard Operating Procedures (Stormwater Management Plan Appendix H, SOP 6)

Purpose: This section discusses methods for reducing or eliminating pollutant loading from development activities and guidance for design and planning, construction, and post-construction operations to ensure all permanent BMPs function over the long term.

Enforcement Authority: City Engineer and Stormwater Enforcement Agent

Section	Summary	Suggestions/Opportunity
Section 1 Controlling Erosion and Sediment through Design and Planning	Guidelines encourage building footprints to avoid highly erodible, high permeability soils.	Could specify Soil Groups A and B; could also limit site designs to areas farther from watercourse Set limits on allowable disturbance of existing vegetation. Consider adding provisions to include measures to identify and prevent soil compaction of soils with the highest infiltration capacity, and to require the identification and use of specified travel paths for heavy construction equipment to limit overall site compaction, in addition to preventing and controlling soil erosion and sedimentation. Also require the placement of temporary construction trailers to be shown on plans to ensure they are placed outside of environmentally sensitive areas and off soils with the highest infiltration capacity.
Section 2 Controlling Erosion and Sediment on Construction Sites	Requires maintenance of old and establishment of new vegetation to minimize exposed soil (Section 2: #5, #7, #11) Soils should be stabilized by mulching and/or seeding (Section 2: #12) Encourages avoiding soil compaction from heavy machinery (Section 2:#15)	Recommend using native plantings and preserving existing trees to provide shade, reduce erosion, reduce urban heat island impacts, and contribute to flood mitigation. Limit the total open space are that can be turf grass, encouraging planting that will provide great resilience benefits. The EPA's Watersense program recommends 40%:https://www.epa.gov/sites/production/files/2017-01/documents/ws-outdoor-home-turfgrass-report.pdf. Provide guidance on the proper use and handling of fertilizers, herbicides, and watering practices. Consider revising as-built inspection process to ensure that soil compaction is addressed and mediated prior to the issuance of occupancy.

BMP Inspection Standard Operating Procedures (Stormwater Management Plan Appendix H, SOP 9)

Purpose: These procedures state the frequency, maintenance standards, and required inspection forms for eight types of constructed BMPs.

Enforcement Authority: City Engineer and Stormwater Enforcement Agent

OTHER REGULATIONS

Land Subdivision Rules and Regulations

Enabling Legislation: 81-Q of Chapter 41 of MGL

Reviewers: BSP, Engineering Department via BSP

Purpose: This regulation establishes standards for subdivision layout and construction to protect the safety and welfare of Waltham residents. Sec. 2: Procedures/Plans; 3; Sec 4: design standards (Streets, open space), Sec 5: required improvements and standards

Enforcement Authority: Board of Survey and Planning

Section	Summary	Suggestions/Opportunity
2.5 Subdivision standards for Flood Plain Districts and Water Resource Areas	Proposed development projects must be reasonably safe from flooding. Development proposals in the Floodplain District or Water Resource Area must minimize flood or stormwater damage. Drainage systems should be designed to adequately manage project stormwater loads from the latest FEMA 100-year zone.	Encourage the use of the 500-year storm event as the design storm for proposed development projects. Encourage site designs that island future development and use topography to manage onsite floodwaters. Integrate green infrastructure into landscape plans.
3.1 and 3.2	Submission and Definitive Plan – Details elements that must be submitted in drawing set for review.	Included with plan set should be flood maps overlaid on to the site plan. Include language that states that the proposed design and associate drawing set will be reviewed for climate resilience and green building practice considerations. Incorporation of such practices if favorable for all proposed developments and required for developments with the Flood Plain District or Water Resources Area.
3.1.28 Preliminary plan	Designates that contours are shown at 10-foot intervals or less	Language could be updated to be more specific, requiring 1' contours.
3.1.29	Major site features must be submitted, including large trees (12' canopy)	Adequate as written but could encourage the preservation of small to medium tree canopy as well, if in good health.

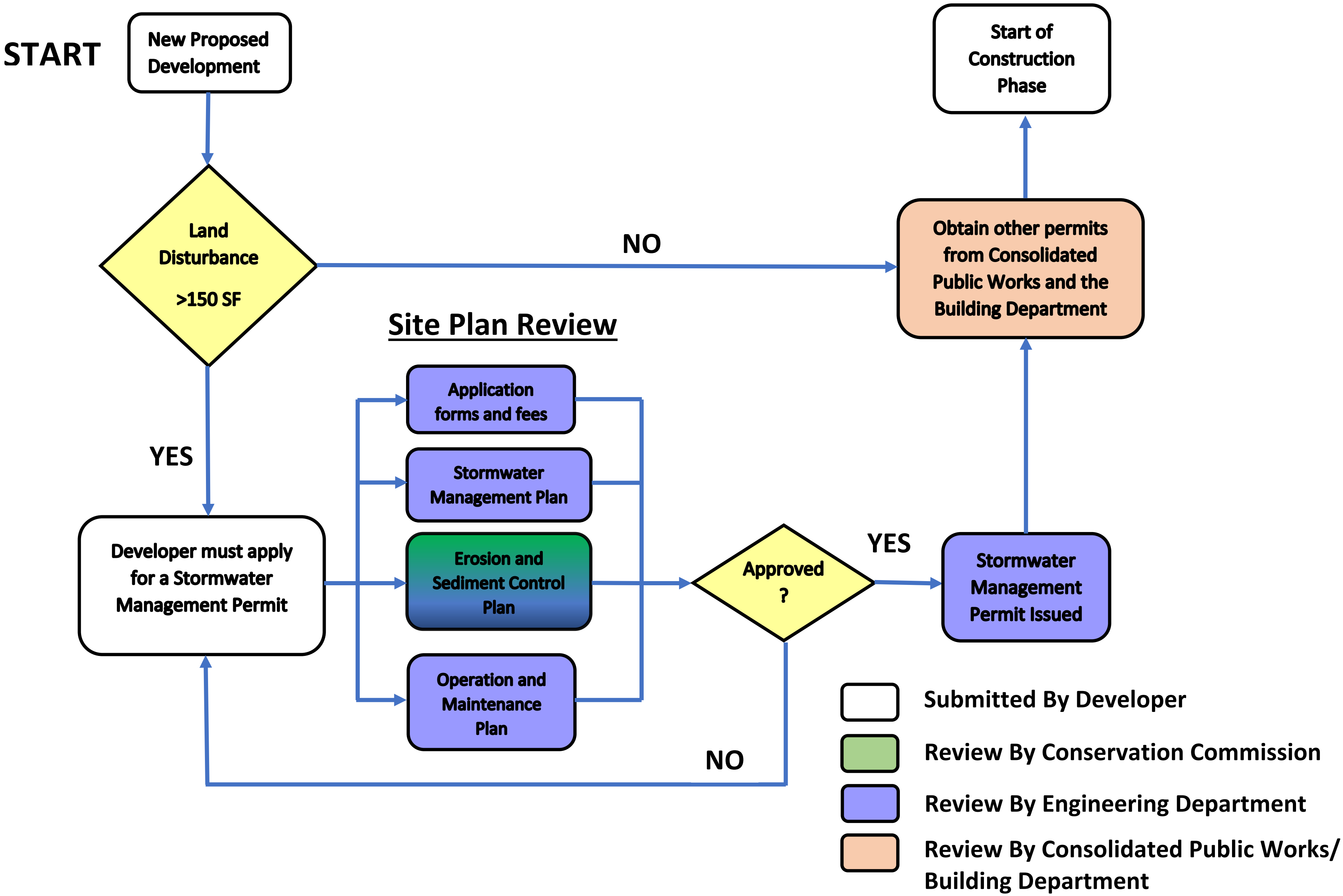
Section	Summary	Suggestions/Opportunity
		Include language that review of major site features will include identification of large tree species for preservation.
3.2.112 Definitive Plan	Maintains that the locations and species of existing trees of 12' tree canopy or greater should be identified.	Adequate as written but could encourage the preservation of small to medium tree canopy as well, if in good health. Include language that review of major site features will include identification of large tree species for preservation.
3.2.119 and 3.2.2.5	Designates that contours are shown at two-foot intervals	Update to require 1' contour intervals.
4.2.3	Provides Right of Way width requirements.	Streets should be laid out with a public right of way with adequate dimension for the implementation of green infrastructure such as tree box filters, bioswales, and urban tree canopy.
4.3	Details requirements for Easements	A section could be added to 4.3 easements that requires a buffer from existing waterways or waterbodies; or a buffer around the extents of the projected floodplain for the 50-year flood event.
4.4	Details requirements for open spaces onsite.	Section 4.4 should be expanded upon to include open space requirements related to the ratio of are that is covered with vegetation that cools surface temperature, mitigates flood impacts, and provides shaded areas for residents. Section 4.4 could also include topographic requirements for proper site drainage and the encouragement of green infrastructure. This section could use rule-based language or provide general design guidance.
4.5	Details expectations for the protection of natural resources.	This section could be expanded upon to explicitly detail the value of natural resource preservation to climate resilience. It should be emphasized that existing, healthy trees should be maintained and that waterbodies should be protected. Waterways and waterbodies should have an adequate buffer between the extents of their bank and the proposed development.
4.5.1	Requires the protection of trees from removal during construction.	Section 4.51 should be updated to include specific tree calipers that should be maintained. Large and medium size trees should be preserved.
5.4.3	Details requirements for subgrade preparation	Subgrade preparation should include consideration of the natural water table level and take reasonable measures to mitigate impacts to the water table with the addition of new construction.

Section	Summary	Suggestions/Opportunity
5.4.4	Details design criteria for roadways	Criteria for roadways could include ratio requirements for pervious pavement or pavement with a high Solar Reflectance Index (SRI).
5.5.1	Details design requirements for storm drains	Storm drains should be designed to address stormwater loads based on future flood projections.
5.8	Details design requirements for curbing.	This section should include curb cut requirements that facilitate stormwater management
9.2 Site Plans	Requires two-foot contour intervals	Update to require 1' contour intervals.

Waltham, MA

Stormwater Management Permit for Construction with Land Disturbances

Permitting/Approval Flow Chart – June 2021



Engineering Department

- Site Plan Review Application
- Stormwater Management Plan Guidelines https://www.city.waltham.ma.us/clean-stormwater-initiative/pages/stormwater-management-plan
- Erosion and Sediment Control Plan Guidelines https://www.city.waltham.ma.us/clean-stormwater-initiative/pages/stormwater-management-plan
- Operation and Maintenance Plan Guidelines https://www.city.waltham.ma.us/clean-stormwater-initiative/pages/stormwater-management-plan

Building Department

- Building Permit Application Requirements
- How to Apply for a Building Permit (video)
- Building Department Forms

Consolidated Public Works

- Driveway and Parking Lot Paving Permit
- Curb Cut Opening Permit
- Utility Permit Application to Connect, Repair, Relay or Disconnect Services with the Water/Sewer Division
- Street Opening Permit Application
- Dumpster or Pod Permit Application
- Trench or Excavation Permit

Appendix C: Funding Source Assessment

55 Walkers Brook Drive, Suite 100, Reading, MA 01867
Tel: 978.532.1900

MEMORANDUM

TO: Catherine Cagle, Planning Director, City of Waltham

FROM: Amanda Kohn and Steve Roy, Weston and Sampson

DATE: June 29, 2021

SUBJECT: Stormwater Capital Improvement Plan Implementation

The City of Waltham is dedicated to reducing the impacts of natural hazards to the City's buildings and infrastructure, environment, and vulnerable populations. According to the City of Waltham's *Hazard Mitigation Plan – Municipal Vulnerability Preparedness Plan 2019 (HMP-MVP Plan)*, flooding is the most prevalent and serious natural hazard. Flooding in Waltham occurs both by inland/riverine flooding and as urban stormwater flooding. Both types of flooding are expected to worsen with the more intense precipitation projected to occur under climate change.

Waltham was awarded an MVP Action Grant for FY20/FY21 to develop a Resilient Stormwater Action and Implementation Plan (RSAIP) to identify projects to reduce flooding and urban heat island in six subbasins. The RSAIP includes this Capital Improvement Plan (CIP) Memo, which lays out a recommended implementation plan over a 10-year period. The RSAIP met the following high priority actions from the HMP-MVP plan:

- Reduce the impact of riverine and stormwater flooding on roads, floodplains, and adjacent properties.
    - Assess and inventory stream crossings such as culverts and bridges.
    - Recommend improvements and develop an implementation plan for projects such as replacement of culverts and storm drainage structures that cause flood hazards and areas where elevation of roads would improve resilience.
    - Identify and upgrade infrastructure to handle flooding, maintain drains, and create upstream storage to reduce flooding.
    - Invest in low impact development to reduce flooding.
    - Work locally, and in cooperation with, surrounding communities to reduce flooding through watershed management, stormwater management, flood mitigation, and roadway improvements.
- Promote and collaborate between City departments and private entities to plan stormwater improvements.
- Restore wetlands and floodplains for flood mitigation and flood storage. As an example, restoring wetlands and floodplains to reduce flooding risk downstream of Beaver Brook. Wetlands can provide flood protection for culverts.

CAPITAL IMPROVEMENT PLANNING BACKGROUND

The Engineering and Public Works Departments complete capital improvements and perform operation and maintenance of the City's Stormwater Infrastructure. Financial planning, and the creation of this capital improvement plan, will allow for the allocation of resources to complete projects by providing a roadmap to focus efforts on high priority projects. This CIP along with MVP planning information, identifies short term and long- term needs, solutions, and implementation costs. The primary projects in the capital improvement plan were developed primarily concentrating on flood mitigation projects; however, culvert maintenance and repair and stream maintenance are also needed. Projects were prioritized based on flood mitigation improvements, asset condition, and risk of failure.

Yoon S. Byun/Globe Staff

Images of 2018 Flooding of Linden Street

CAPITAL IMPROVEMENT PLAN PROJECT TYPES

This section provides a breakdown of the types of projects incorporated into the capital improvement plan.

Stream Maintenance

- Removal of sediment along the bottom of the stream bed restricting flow (assuming required permit approvals can be obtained)
- Removal of debris, such as downed tree limbs
- Cutting back of overgrowth along embankments
- Bank stabilization
- Repair of retaining walls

BMP Retrofits

- Retrofit of the existing drainage system to incorporate green infrastructure to assist in meeting MS4 Permit requirements

Flood Mitigation

- Based on evaluation and hydrologic/hydraulic modeling of catchment areas, proposed solutions developed to address localized flooding.
- Based on inspection of existing drainage infrastructure, maintenance projects identified to alleviate localized flooding

Culvert Rehabilitation and Upgrades

- Cleaning of culverts to remove sediment obstructing flow and preventing a comprehensive visual inspection of the culvert
- Follow-up TV inspection of longer pipe culverts that could not be viewed with the ZoomCAM
- Structural evaluation of road-width culverts to document condition and assess need for repair/ replacement
- Rehabilitation or replacement of failing culverts and culverts that are undersized

Culvert inspection – Stanley Road

CIP IMPLEMENTATION

The Capital Improvement Plan is divided in yearly segments with estimated individual project costs ranging from $200 thousand to over $5.5 million. The capital improvement plan has a 10-year outlook assuming consistent funding is available into the future. Tables 1 and 2 summarize the stormwater management and implementation plan prioritization based on flood mitigation, stream and culvert assessments, and City needs.

Culvert Replacement - Beaver Street

As the City performs more detailed analysis and collects more condition assessment data in the early years of the program, especially as it pertains to larger projects where outside consultant/contractor support is needed for implementation, the City will need to re-evaluate whether the allocated budget amounts are still adequate to meet the City's drainage infrastructure needs.

If additional evaluation or changes in the drainage infrastructure system requires that the schedule be reprioritized or additional projects added early in the program or there is an immediate need, the City will need to re- evaluate the funding sources at that time, and explore changes to the capital improvement plan that condenses the implementation timeframes and increases the amount of capital available annually to direct towards these critical projects.

Many of the recommended stream and culvert improvements projects incorporated into the CIP are smaller and therefore are combined into larger capital project which will help assure competitive pricing is received. Implementation of this plan will require coordination with various City departments.

The full capital improvement plan is summarized in Table 3 and includes projects through Year 10.

CAPITAL IMPROVEMENT PLAN UPDATES

The capital improvement plan is a living document, and should be periodically reviewed and updated as new project priorities arise and as new information becomes available. For instance, the capital improvement plan currently includes funding for further inspection, assessment, and preliminary design, which will ultimately inform the final design and construction cost of new projects or changes that will need to be incorporated into the plan. In addition, TV inspection and comprehensive structural inspections are being recommended for numerous culverts to gain additional insight on the extent of defects noted and potential repairs. Once the evaluations are complete in the early years of the plan, the design and construction project costs will need to be incorporated.

COMPLETING IDENTIFIED STORMWATER DRAINAGE PROJECTS

The Capital Improvement Plan implementation included in Table 3 summarizes recommended stormwater improvement projects that were identified during development of the RSAIP.

Tables 1 and 2 summarize the recommended stormwater scenarios for stormwater management and implementation. Based on the recommendations of the City's Stormwater Team, a 10-year timeline for individual project implementation was developed. As described elsewhere, the scenarios summarized in Tables 1 and 2 were primarily ranked based on City need and preliminary hydrologic and hydraulic modeling that showed areas of greater flood mitigation.

The City has several capital projects that are currently underway and identified for implementation during Year 1. In addition to the evaluation factors taken into account in Tables 1 and 2, it is recommended that the City consider risk (likelihood and consequence of failure), based on input from future investigations, to further prioritize critical known infrastructure that needs maintenance/replacement within each of the recommended scenarios. Additional investigations are required to finalize the risk assessment.

Over the past decades, the City has knowledge of the number and severity of existing flooding issues within the City's watersheds. Based on this and the MVP evaluation, Beaver Brook, Chester and West Chester Brooks are considered priority watersheds that have significant flow conveyance restrictions due to sediment and debris in stream channel, vegetation overgrowth, undersized culverts and/or restricted opening due to sediment and debris.

Other factors that will need to be further considered include identifying planned capital projects such as roadway improvements and paving, park and open space construction, schools, public utility upgrade projects etc. by other City departments and pair them with the stormwater projects in the area.

Stormdrain Replacement and Improvements – Ash and Lowell Streets – Completed in Year 2020

OPERATION AND MAINTENANCE

The development and implementation of this Capital Improvements Plan partially fulfills the requirements of the City's MS4 Permit and also is an important component for maintaining the stormwater drainage system. Each permittee is required to develop a written program detailing the activities and procedures that will be implemented to ensure that MS4 infrastructure is maintained in a timely manner to reduce the discharge of pollutants. In addition, the City has developed separate written operation and maintenance procedures for municipal facilities and activities in accordance with MS4 Permit requirements. These include procedures for the following:

- Parks and Open Space
- Catch Basin Cleaning
- Street Sweeping
- Winter Road Maintenance
- Municipal Buildings and Facilities
- Municipal Vehicles and Equipment
- Structural BMPs

As the City moves forward with implementation of the Improvements Plan, emphasis will be placed on developing a routine maintenance schedule such that drainage infrastructure is maintained in a timely manner and the City can move from reactive to proactive maintenance. The City should strive to accomplish the following when it comes to operation and maintenance of the drainage system:

- Inspect and maintain streams once every 3 to 5 years to ensure that flow of water is not being hindered, which can contribute to localized flooding.
- Clean sediment and debris from culverts every 2 to 4 years and conduct basic structural assessments to monitor for further deterioration that warrants more immediate replacement or rehabilitation.
- Inspect BMPs following proper procedures and recommended frequency of inspection and maintenance. The MS4 Permit requires annual inspection of BMPs at a minimum.
- Identify and televise critical drainage infrastructure to gain a baseline condition assessment. Most of the City's drainage piping has never been inspected and its condition is unknown. As a mitigation measure, City staff may complete a focused inspection of the condition of critical drainage infrastructure to identify potential problems and schedule future improvements.

OPTIONS FOR FUNDING

The City may also explore funding mechanisms such as Stormwater Enterprise Fund to secure dedicated revenues to implement projects. This would provide a reliable and recurring revenue source that could significantly increase the City's ability to plan and execute stormwater system maintenance, flood controls, and water quality improvement projects.

The City could also apply for various Federal and State Agency Grants that are typically available every year. Below is a summary of the grant opportunities:

Category	Grant	Description
Infrastructure	EPA's Clean Water State Revolving Fund (CWSRF)	Low-interest source of funding for stormwater management projects that includes traditional stormwater conveyance pipe, storage, and treatment systems and green infrastructure for water quality
	Flood Mitigation Assistance Grant Program (FMA)	Implement cost-effective measures that reduce or eliminate the long-term risk of flood damage, including localized flood control and stormwater management.
	Building Resilient Infrastructure & Communities (BRIC)	Provides funds for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event, with a focus on infrastructure projects and "community lifelines." Replaced FEMA's Pre-Disaster Mitigation (PDM) Program.
	DER Culvert Replacement Municipal Assistance Grant Program	Grant to replace undersized, perched, and/or degraded culverts located in an area of high ecological value.
Stream Restoration and Green Infrastructure	DER Priority Projects	Funds projects that offer ecological value and community benefits, including river restoration.
	Municipal Vulnerability Preparedness (MVP) Action Grant	Provides support to implement climate change resiliency priority projects. Project types include planning, assessment and regulatory updates; nature-based solutions; and resilient redesigns and retrofits for critical facilities and infrastructure.
	USDA Natural Resources Conservation Services Watershed and Flood Prevention Operations Program	Financial and technical assistance for projects including erosion and sediment control and flood prevention.
Water Quality	Federal Clean Water Act, 604b Grant Program: Water Quality Management Planning	Funds nonpoint source assessment and planning projects, including projects related to green infrastructure.
	Federal Clean Water Act, Section 319 Nonpoint Source (NPS) Competitive Grants Program	Funds implementation projects that address the prevention, control, and abatement of NPS pollution.

Tree Planting	Arbor Day Foundation TD Green Space Grant	Supports green infrastructure development, tree planting, forestry stewardship, and community green space expansion as a way to advance environmental and economic benefits toward a low-carbon economy. $20,000 is available. The program's annual themes may vary. Applicants are encouraged to apply with community partners.
Parks & Recreation	Massachusetts Land and Water Conservation Fund Grant Program	Funding for the acquisition, development, and renovation of parks, trails, and conservation areas.
	EEA Parkland Acquisitions and Renovations for Communities (PARC) Program	Aids in acquisition and developing land for park and outdoor recreation purposes. Can be used to acquire parkland, build a new park, or renovate an existing park.
	EEA Local Acquisitions for Natural Diversity (LAND) Grant Program	Helps cities acquire land for conservation and passive recreation.

Table 1 Stormwater Implementation Plan – Flood Mitigation Co-Benefits

Scenario	Community Resilience Factor	Environmental Justice Neighborhood	Reduction of Urban Heat	Placemaking	Pedestrian Improvements	Biodiversity
Scenario 1 – Northern Second Ave	2	5	2	2	3	2
Scenario 2 – Southern Second Ave	1	5	1	2	3	1
Scenario 3 – Upper Masters/Sibley Brook	1	5	2	2	2	2
Scenario 4 – Middle Masters/Sibley Brook	2	3	2	4	4	4
Scenario 5 – Lower Masters/Sibley Brook	3	3	2	2	3	2
Scenario 6 – Hardy Pond	4	4	1	2	1	3
Scenario 7 – Falzone Memorial Park and Shady's Pond Conservation Area	1	3	1	3	2	4
Scenario 8 – Upper Chester Brook	4	5	2	3	5	4
Scenario 9 – Lake Street Neighborhood	4	5	1	1	3	1
Scenario 10 – Middle Chester Brook	1	2	2	4	2	4
Scenario 11 – Upper West Chester Brook	2	5	3	3	4	4
Scenario 12 – Prospect Hill Park	3	1	3	5	4	5
Scenario 13 – Totten Pond Road	1	1	1	1	3	3
Scenario 14 – Pond End Road	1	1	2	2	1	3
Scenario 15 – Lexington and Bacon St	3	1	1	2	1	3
Scenario 16 – Plympton Brook	3	4	2	4	3	4
Scenario 17 – Lexington and Church St	1	5	4	3	3	2
Scenario 18 – North of Lyman Pond	1	2	2	2	5	3
Scenario 19 – Lower Chester Brook	3	5	2	2	1	3
Scenario 20 – Upper Beaver Brook	5	2	4	4	2	4
Scenario 21 – Middle Beaver Brook	3	1	5	5	4	4
Scenario 22 – Upper Clematis Brook	1	1	3	3	3	3
Scenario 23 – Fernald Campus	5	1	5	5	2	5
Scenario 24 – Lower Clematis Brook	1	1	1	2	2	2
Scenario 25 – Warrendale	1	1	2	4	3	4
Scenario 26 – Waverly Oaks and Linden	5	3	2	4	4	4
Scenario 27 – Lower Beaver Brook	3	3	3	2	4	2

Table 2 Stormwater Management Implementation – Flood Mitigation Benefits – Gray Infrastructure

Watershed	Gray Infrastructure Project	Description / Justification	Near-term % Reduction Total Volume (MG)	Long-term % Reduction Total Volume MG)	H&H Performance 1: Minimal to 5: Very Significant
Stony Brook / 2nd Ave	None	NA	-	-	-
Masters / Sibley Brook	Prospect St at Highland/ Felton St	The proposed change is to widen those conduits to 10 feet wide or otherwise create a comparable increase in cross-sectional flow area.	100.0%	100.0%	5
Chester Brook	None	Noted in the discussions of Scenarios 6, 8, and 10 in Appendix A, several green infrastructure scenarios included modifications to the culverts or other outlet structures that impound ponds or wetlands within the Chester Brook watershed	-	-	-
West Chester Brook	Craig Ln. & Totten Pond Road Storm Drain Improvements	Increase the capacity of the storm drains in Totten Pond Rd. and Craig Ln	100.0%	100.0%	4
	Culvert Improvements	Increase the discharge capacity at Worcester Ln., Bacon St., and Lexington St. , (3) 4-foot diameter culverts at all four road crossings	11450.0%	1473.0%	5
Beaver Brook & Clematis Brook	Culverts near Waverly Oaks Rd and Linden St	This concept incorporates widening of the channel in this trouble area (likely to the south) so that it is consistent with upstream and downstream reaches.	-	7.0%	3

City of Waltham Resilient Stormwater Action and Implementation Plan
Years 2022-2028 (updated 9/25/23)

	2022 Year #1	2023 Year #2	2024 Year #3	2025 Year #4	2026 Year #5	2027 Year #6	2028 Year #7
Projects							
Engineering Evaluation, Stormwater Infrastructure Assessment and Green Infrastructure Projects							
CCTV and inspection of infrastructure		$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000
Sub-Total	**$ -**	**$ 100,000**	**$ 100,000**	**$ 100,000**	**$ 100,000**	**$ 100,000**	**$ 100,000**
Infrastructure Projects							
Fernald Wetland Pond and Stream Daylighting	$ 2,500,000						
Culvert replacement under 260 Lexington Street and culvert extension	$ -			$ 3,000,000			
Beaver Brook - Waverley Oaks and Linden Street flood reduction					$ 5,500,000		
Replace/rehab/install flow control strucrures to create storage from YMCA to Clarks Pond			$ 1,600,000				
Modify Hardy Pond flow control structure to create additional storage			$ 1,250,000				
Lowell St area drainage improvements					$ 1,000,000		
Summit Ave		$ 1,700,000					
Embassy parking Lot			400,000				
Bobby Connors Playground						$ 1,500,000	
Monsignor McCabe Playground							$ 2,500,000
Beaver Brook Reservation			2,000,000				
Sub-Total	**$ 2,500,000**	**$ 1,700,000**	**$ 5,250,000**	**$ 3,000,000**	**$ 6,500,000**	**$ 1,500,000**	**$ 2,500,000**
Culvert and Drain System Repair and Replacement (No Upsize)							
Scenario 20 - Trapelo Road Beaver Brook Culvert Replacement		$ 1,600,000					
Scenario 4 - In-Situ Rehabilition of 36" CMP Storm Drain in Easement - Cabot and Fiske Avenue			$ 500,000				
Sub-Total	**$ -**	**$ 1,600,000**	**$ 500,000**	**$ -**	**$ -**	**$ -**	**$ -**
Total Annual Estimated Cost	**$ 2,500,000**	**$ 3,400,000**	**$ 5,850,000**	**$ 3,100,000**	**$ 6,600,000**	**$ 1,600,000**	**$ 2,600,000**

Appendix D: Private Property Structural BMP Load Calculations

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP01	148 Hawthorne Rd	Infiltration Trench	2273	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP04	65 Miriam Rd		297	0.27	High Density Residential	2.32	0.02	0.92	0.01
BMP05	150 Marguerite Ave	Infiltration Trench	2641	1.02	High Density Residential	2.32	0.14	0.96	0.14
BMP06	12 Fairmont Ave	Infiltration Trench	2262	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP07	28 Taylor St	Infiltration Trench	4702	0.27	Urban Public/Institutional	1.78	0.19	0.92	0.18
BMP08	36 Taylor St	Infiltration Trench	4702	0.27	Urban Public/Institutional	1.78	0.19	0.92	0.18
BMP09	185 Willow St	Infiltration Trench	11166	1.02	Multi-Family Residential	2.32	0.59	0.96	0.57
BMP100	85 Copeland St	Infiltration Trench	3562	1.02	High Density Residential	2.32	0.19	0.96	0.18
BMP101	44 Piedmont Ave		2728	1.02	High Density Residential	2.32	0.15	0.96	0.14
BMP102	46 Piedmont Ave		2728	1.02	High Density Residential	2.32	0.15	0.96	0.14
BMP103	58 Hiawatha Ave		436	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP104	63-65 Cherry St	Infiltration Trench	6728	0.27	Multi-Family Residential	2.32	0.36	0.92	0.33
BMP105	57-59 Cherry St	Infiltration Trench	6728	0.27	Multi-Family Residential	2.32	0.36	0.92	0.33
BMP107	12 Candace Ave	Infiltration Trench	650	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP108	150 Florence Rd		159	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP109	84 Mokema Ave		537	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP153	180 Mallard way		300	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP112	30 Rosemont Ave		1649	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP113	33 Wheelock Rd		2498	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP114	20 Tip Top Terrace		315	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP115	68 Beal Rd	Infiltration Trench	724	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP116	125 Ash St	Infiltration Trench	3466	0.27	High Density Residential	2.32	0.18	0.92	0.17
BMP117	11 Massasoit Ct		3256	1.02	Multi-Family Residential	2.32	0.17	0.96	0.17
BMP118	3 Kingston Terrace		380	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP119	31 Hatherly Rd		2380	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP110	82 Greer St	Infiltration Trench	1950	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP120	27 Wilmot Rd		2393	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP121	276-278 River St		1511	1.02	Multi-Family Residential	2.32	0.08	0.96	0.08
BMP122	34 Rosemont Ave		1500	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP123	20 Dale Circle	Infiltration Trench	350	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP124	60-62 Taylor St		3236	0.27	Multi-Family Residential	2.32	0.17	0.92	0.16
BMP125	92 Barbara Rd	Infiltration Trench	2576	1.02	High Density Residential	2.32	0.14	0.96	0.13
BMP126	78 Central St	Infiltration Trench	3384	0.27	High Density Residential	2.32	0.18	0.92	0.17
BMP127	19 Baldwin Rd	Infiltration Trench	2250	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP128	182 Temple Rd		1200	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP129	8 Day St	Infiltration Trench	3544	1.02	Multi-Family Residential	2.32	0.19	0.96	0.18
BMP13	790 Main st		9442	0.27	Commercial	1.78	0.39	0.92	0.35
BMP130	8,10 Day St	Infiltration Trench	3544	1.02	Multi-Family Residential	2.32	0.19	0.96	0.18
BMP131	85 Mokema Ave		1568	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP132	99 Moody St		9297	0.27	Commercial	1.78	0.38	0.92	0.35
BMP133	12 Circuit Ln	Infiltration Trench	2212	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP134	5 Weir Rd		368	1.02	Medium Density Residential	1.96	0.02	0.96	0.02
BMP135	36 Oakley Lane		832	1.02	Medium Density Residential	1.96	0.04	0.96	0.04
BMP136	16 Charlotte Rd	Infiltration Trench	426	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP137	21 John St		690	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP138	110 Cushing St	Infiltration Trench	400	0.27	Multi-Family Residential	2.32	0.02	0.92	0.02
BMP139	120 Kingston Rd		600	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP140	39 Farnum Rd	Infiltration Trench	1300	1.02	High Density Residential	2.32	0.07	0.96	0.07

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP141	42 Boynton St	Infiltration Trench	930	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP12	452 Lincoln St		4465	1.02	High Density Residential	2.32	0.24	0.96	0.23
BMP565	452 Lincoln St		576	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP144	14 Rumford Ave		4326	1.02	Multi-Family Residential	2.32	0.23	0.96	0.22
BMP145	27 Middle St		4595	0.27	Multi-Family Residential	2.32	0.24	0.92	0.23
BMP146	84 Upton Rd		1586	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP147	269 Dale	Infiltration Trench	350	1.02	Multi-Family Residential	2.32	0.02	0.96	0.02
BMP148	37 Wilmot Rd		400	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP14	61 Gale St	Infiltration Trench	3550	1.02	High Density Residential	2.32	0.19	0.96	0.18
BMP151	103 College Farm Rd	Infiltration Trench	2931	0.17	Very Low Density Residential	1.52	0.10	0.90	0.09
BMP152	111 College Farm Rd	Infiltration Trench	2250	1.02	Very Low Density Residential	1.52	0.08	0.96	0.08
BMP143	58 Edwin Rd	Infiltration Trench	709	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP154	110 Alder St	Infiltration Trench	4076	0.27	High Density Residential	2.32	0.22	0.92	0.20
BMP155	117 College Farm Rd	Infiltration Trench	2011	1.02	Very Low Density Residential	1.52	0.07	0.96	0.07
BMP156	117 Thornton Rd		1666	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP157	55 Raffaele Drive	Infiltration Trench	198	1.02	Medium Density Residential	1.96	0.01	0.96	0.01
BMP149	24 Gale St	Infiltration Trench	3260	1.02	High Density Residential	2.32	0.17	0.96	0.17
BMP159	47 Alderwood Rd	Infiltration Trench	3047	1.02	High Density Residential	2.32	0.16	0.96	0.16
BMP16	279 Grove St	Infiltration Trench	1306	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP160	69 Briarwood Rd	Infiltration Trench	1306	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP161	93 Calvary St	Infiltration Trench	4920	0.27	Multi-Family Residential	2.32	0.26	0.92	0.24
BMP162	29 Van Vechten St		1544	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP163	84 Prospect St		1346	0.27	Multi-Family Residential	2.32	0.07	0.92	0.07
BMP164	343 River St		4038	1.02	High Density Residential	2.32	0.22	0.96	0.21
BMP165	44 Wimbledon Cir		361	1.02	Medium Density Residential	1.96	0.02	0.96	0.02
BMP166	28 Hollace St		2132	1.02	High Density Residential	2.32	0.11	0.96	0.11
BMP167	113 Farnum Rd	Infiltration Trench	587	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP168	145 Circle Dr	Infiltration Trench	2781	1.02	High Density Residential	2.32	0.15	0.96	0.14
BMP17	115 Copeland St	Infiltration Trench	312	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP170	166 Circle Dr	Infiltration Trench	4814	1.02	High Density Residential	2.32	0.26	0.96	0.25
BMP171	61 Clark Ln	Infiltration Trench	3345	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP172	265 Beaver St	Infiltration Trench	400	0.17	Forest	1.52	0.01	0.90	0.01
BMP173	48 Glen Cir	Infiltration Trench	7883	0.17	Medium Density Residential	1.96	0.35	0.90	0.32
BMP174	52 Glen Cir	Infiltration Trench	3192	0.17	Medium Density Residential	1.96	0.14	0.90	0.13
BMP175	56 Oak St		5155	1.02	Multi-Family Residential	2.32	0.27	0.96	0.26
BMP176	123 Felton St		350	0.27	Industrial	1.78	0.01	0.92	0.01
BMP177	80 Clark Ln	Infiltration Trench	1281	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP178	16 Common St	Infiltration Trench	5609	0.27	Commercial	1.78	0.23	0.92	0.21
BMP179	23-25 Orange St		3423	0.27	Multi-Family Residential	2.32	0.18	0.92	0.17
BMP18	64 leslie Road		1440	0.27	Medium Density Residential	1.96	0.06	0.92	0.06
BMP180	110 Berkley St	Infiltration Trench	2880	1.02	High Density Residential	2.32	0.15	0.96	0.15
BMP181	41 Ellison Park	Infiltration Trench	648	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP182	42 Beechwood Rd	Infiltration Trench	600	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP183	26 Charlotte Rd	Infiltration Trench	500	1.02	High Density Residential	2.32	0.03	0.96	0.03

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP184	70 Colburn St	Infiltration Trench	2655	1.02	Medium Density Residential	1.96	0.12	0.96	0.11
BMP89	177 Grove St		3490	1.02	Multi-Family Residential	2.32	0.19	0.96	0.18
BMP187	46 Wetherbee St		580	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP188	166 Ash St	Infiltration Trench	2362	0.27	High Density Residential	2.32	0.13	0.92	0.12
BMP189	136 Clark St	Infiltration Trench	3710	1.02	Multi-Family Residential	2.32	0.20	0.96	0.19
BMP19	248 Beal Rd	Infiltration Trench	755	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP190	10 Wall St		3325	0.27	Multi-Family Residential	2.32	0.18	0.92	0.16
BMP191	99 Candlewood Dr	Infiltration Trench	5530	0.27	Medium Density Residential	1.96	0.25	0.92	0.23
BMP192	106 Westgate Rd		395	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP193	100 Taylor St		3000	0.27	Multi-Family Residential	2.32	0.16	0.92	0.15
BMP194	12 Arcadia Ave	Infiltration Trench	1244	1.02	High Density Residential	2.32	0.07	0.96	0.06
BMP195	26 Brookfield Rd	Infiltration Trench	2054	1.02	High Density Residential	2.32	0.11	0.96	0.11
BMP196	3 Freemont Terrace		292.5	1.02	High Density Residential	2.32	0.02	0.96	0.01
BMP197	114 Brewster Rd	Infiltration Trench	600	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP198	3 Lowell St		6172	0.27	Multi-Family Residential	2.32	0.33	0.92	0.30
BMP199	471 Forest St		1757	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP20	39 Brightwood Rd	Infiltration Trench	500	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP200	95 Gregory St	Infiltration Trench	250	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP201	13 Cabot St	Infiltration Trench	179	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP169	12 Arbor Ln	Infiltration Trench	2556	1.02	High Density Residential	2.32	0.14	0.96	0.13
BMP185	9 Grant Pl	Infiltration Trench	2400	1.02	Multi-Family Residential	2.32	0.13	0.96	0.12
BMP205	14 Lot 3 LeBlane Ln		9166	1.02	Medium Density Residential	1.96	0.41	0.96	0.40
BMP206	22 Wamsutta Ave		1362	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP208	1101 Main st		3360	0.27	High Density Residential	2.32	0.18	0.92	0.16
BMP209	7 Marguerite Ave		1679	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP21	89 Vernon St		3054	1.02	Multi-Family Residential	2.32	0.16	0.96	0.16
BMP210	49 Canterbury Rd	Infiltration Trench	2520	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP211	15 Orange St		1520	0.27	High Density Residential	2.32	0.08	0.92	0.07
BMP212	24 Rando Lane	Infiltration Trench	1565	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP213	29 Wadsworth Ave		3543	0.27	High Density Residential	2.32	0.19	0.92	0.17
BMP214	156 Ash St	Infiltration Trench	4840	0.27	Multi-Family Residential	2.32	0.26	0.92	0.24
BMP216	315 College Farm Rd	Infiltration Trench	7260	0.17	Commercial	1.78	0.30	0.90	0.27
BMP217	180 Main st		380	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP219	300 College Farm Rd	Infiltration Trench	6361	1.02	Multi-Family Residential	2.32	0.34	0.96	0.33
BMP22	117 Summer St		4554	1.02	Multi-Family Residential	2.32	0.24	0.96	0.23
BMP220	61 Crescent St	Infiltration Trench	9064	0.27	Multi-Family Residential	2.32	0.48	0.92	0.44
BMP221	83 Boynton St	Infiltration Trench	2168	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP222	87 Boynton St	Infiltration Trench	2168	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP223	24 Cross St	Infiltration Trench	3468	0.27	High Density Residential	2.32	0.18	0.92	0.17
BMP224	20 Lauricella Lane		3940	1.02	Forest	1.52	0.14	0.96	0.13
BMP225	32 Lauricella Lane		2942	1.02	Forest	1.52	0.10	0.96	0.10
BMP226	243 Brown St	Infiltration Trench	3145	0.27	High Density Residential	2.32	0.17	0.92	0.15
BMP227	66 Hardy Pond Rd		165	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP228	55 Chestnut St	Infiltration Trench	4158	0.27	Multi-Family Residential	2.32	0.22	0.92	0.20
BMP229	33 Auburn St	Infiltration Trench	3369	1.02	Multi-Family Residential	2.32	0.18	0.96	0.17
BMP23	70 Mount Walley Rd		2235	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP230	146 Harrington Rd		885	1.02	Medium Density Residential	1.96	0.04	0.96	0.04
BMP231	15 Bradford St	Infiltration Trench	400	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP202	39 Galen St	Infiltration Trench	4326	1.02	High Density Residential	2.32	0.23	0.96	0.22

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP572	39 Galen St	Infiltration Trench	2056	1.02	High Density Residential	2.32	0.11	0.96	0.11
BMP234	45 Colonial Ave	Infiltration Trench	524	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP204	37 Banks St	Infiltration Trench	800	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP237	29 Orange St		1300	0.27	Multi-Family Residential	2.32	0.07	0.92	0.06
BMP238	17 Smart Street		363	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP239	5 Plant Rd		1444	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP24	174 Temple Rd		264	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP240	36 Charlotte Rd	Infiltration Trench	644	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP241	12 Rosewood Dr		2130	1.02	Medium Density Residential	1.96	0.10	0.96	0.09
BMP242	155 Copeland St	Infiltration Trench	161	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP243	44 Azalea Rd	Infiltration Trench	341	1.02	Medium Density Residential	1.96	0.02	0.96	0.01
BMP244	12 Michaelchris Dr		2629	0.27	Transitional	1.52	0.09	0.92	0.08
BMP245	91 Thornton Rd		195	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP246	32 Tudor St		2517	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP232	44 Gale St	Infiltration Trench	3413	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP249	63 Florence Rd	Infiltration Trench	1062	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP25	6 Neighbores Ln		1446	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP250	120 Circle Dr	Infiltration Trench	870	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP251	67 Ash St	Infiltration Trench	1482	0.27	High Density Residential	2.32	0.08	0.92	0.07
BMP252	35 Winthrop St		180	1.02	Multi-Family Residential	2.32	0.01	0.96	0.01
BMP253	167 Barbara Rd	Infiltration Trench	528	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP254	17 Charles Street Ave	Infiltration Trench	910	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP255	142 Massasoit St		2964	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP256	22 Newton St		287	0.27	High Density Residential	2.32	0.02	0.92	0.01
BMP257	17 Pleasant st		180	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP258	30 Sanders Lane	Infiltration Trench	2964	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP235	28 Goldencrest Ave	Infiltration Trench	4208	0.27	Medium Density Residential	1.96	0.19	0.92	0.17
BMP26	18 Pleasant st		1132	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP260	648 Beaver St	Infiltration Trench	3877	1.02	Low Density Residential	1.52	0.14	0.96	0.13
BMP261	200 Linden Park Drive		550	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP262	372-378 River St		2570	0.27	Multi-Family Residential	2.32	0.14	0.92	0.13
BMP263	143 Rumford Ave		71430	1.02	Multi-Family Residential	2.32	3.80	0.96	3.65
BMP264	73 Hiawatha Ave		1227	1.02	High Density Residential	2.32	0.07	0.96	0.06
BMP265	148 Lakeview Ave		1276	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP266	34 Old Lexington Rd		306	1.02	Medium Density Residential	1.96	0.01	0.96	0.01
BMP267	103 Beal Rd	Infiltration Trench	650	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP269	10 Gale St	Infiltration Trench	3635	1.02	Multi-Family Residential	2.32	0.19	0.96	0.19
BMP247	337 Crescent St	Infiltration Trench	493	0.27	Multi-Family Residential	2.32	0.03	0.92	0.02
BMP270	4 Gale St	Infiltration Trench	3443	1.02	Multi-Family Residential	2.32	0.18	0.96	0.18
BMP272	40 Sanderson Rd		1055	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP273	78 Hardy Pond Rd	Infiltration Trench	756	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP275	66 Canterbury Rd	Infiltration Trench	560	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP276	39 Marlton Rd		825	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP277	26 Berkley St	Infiltration Trench	579	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP259	654 Beaver St	Infiltration Trench	4356	1.02	Low Density Residential	1.52	0.15	0.96	0.15

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BMP320	654 Beaver St	Infiltration Trench	5650	1.02	Low Density Residential	1.52	0.20	0.96	0.19
BMP268	14 Gale St	Infiltration Trench	3223	1.02	High Density Residential	2.32	0.17	0.96	0.16
BMP283	79 Temple Rd		392	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP284	20-22 Francis St		2621	1.02	Multi-Family Residential	2.32	0.14	0.96	0.13
BMP285	220 Ash St	Infiltration Trench	1490	0.27	High Density Residential	2.32	0.08	0.92	0.07
BMP286	294 Warren St		1215	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP287	410 Forest St	Infiltration Trench	874	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP288	18 Palmer St		871	1.02	Multi-Family Residential	2.32	0.05	0.96	0.04
BMP289	152 Grove St	Infiltration Trench	265706	0.27	Industrial	1.78	10.86	0.92	9.99
BMP29	59 Clements Rd	Infiltration Trench	361	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP290	276 Beal Rd	Infiltration Trench	1045	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP291	15 Marlton Rd		340	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP27	17 Warwick Ave		640	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP293	126 Pond St		936	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP294	10 Park St		1592	1.02	Multi-Family Residential	2.32	0.08	0.96	0.08
BMP295	50 Beal Rd	Infiltration Trench	851	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP296	59 Midland Dr		4992	0.27	Medium Density Residential	1.96	0.22	0.92	0.21
BMP297	31-33 Eddy St	Infiltration Trench	3305	1.02	Multi-Family Residential	2.32	0.18	0.96	0.17
BMP298	48 Richgrain Ave		210	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP299	26 Tudor St		2380	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP30	61 Robbins St		7766	0.27	Multi-Family Residential	2.32	0.41	0.92	0.38
BMP300	141 Clark St	Infiltration Trench	3912	1.02	High Density Residential	2.32	0.21	0.96	0.20
BMP301	23 Palmer St		3479	1.02	Multi-Family Residential	2.32	0.19	0.96	0.18
BMP302	37 Bradford St	Infiltration Trench	2750	1.02	Forest	1.52	0.10	0.96	0.09
BMP303	132 Lauricella Lane		6443	1.02	Medium Density Residential	1.96	0.29	0.96	0.28
BMP304	45 Linden Park Drive		702	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP305	70-72 Central St	Infiltration Trench	6003	0.27	Multi-Family Residential	2.32	0.32	0.92	0.29
BMP515	17 Warwick Ave		360	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP279	76 Hibiscus Ave	Infiltration Trench	1514	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP308	141 Ash St	Infiltration Trench	3795	0.27	Multi-Family Residential	2.32	0.20	0.92	0.19
BMP309	49 Hillcroft Rd	Infiltration Trench	170	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP31	76 Arcadia Ave	Infiltration Trench	1972	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP310	111 Vernon St		2284	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP311	109 Marlborugh Rd		365	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP312	648 Beaver St	Infiltration Trench	3413	1.02	Low Density Residential	1.52	0.12	0.96	0.11
BMP313	190 Lyman		3435	1.02	Low Density Residential	1.52	0.12	0.96	0.12
BMP314	186 Lyman		5550	1.02	Low Density Residential	1.52	0.19	0.96	0.19
BMP316	83 Hammond St	Infiltration Trench	2887	1.02	Multi-Family Residential	2.32	0.15	0.96	0.15
BMP317	46 Summer St		1344	1.02	Multi-Family Residential	2.32	0.07	0.96	0.07
BMP318	30 Nutting Rd		400	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP319	42 Summer St		1344	1.02	Multi-Family Residential	2.32	0.07	0.96	0.07
BMP32	80 Arcadia Ave	Infiltration Trench	1972	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP280	80 Hibiscus Ave	Infiltration Trench	1944	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP321	51 Sheffield Rd		2180	0.27	High Density Residential	2.32	0.12	0.92	0.11
BMP323	315 Propect Hill Rd		2170	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP324	39 Braemore Rd	Infiltration Trench	1980	0.17	High Density Residential	2.32	0.11	0.90	0.09
BMP292	13 Gale St	Infiltration Trench	2422	1.02	High Density Residential	2.32	0.13	0.96	0.12

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BMP326	66 Ash St	Infiltration Trench	2900	0.27	High Density Residential	2.32	0.15	0.92	0.14
BMP327	54 Sartell Road	Infiltration Trench	192	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP328	87 Old Conant Rd		13608	1.02	Forest	1.52	0.47	0.96	0.46
BMP329	22 Mt. Ida Terreace		1316	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP33	2 Day St		3608	1.02	Multi-Family Residential	2.32	0.19	0.96	0.18
BMP330	55 Arcadia Ave	Infiltration Trench	1562	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP331	400 Beaver St	Infiltration Trench	113512	0.27	Participation Recreation	1.52	3.96	0.92	3.64
BMP332	188 Hammond St	Infiltration Trench	218	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP333	198 Lowell St	Infiltration Trench	3340	0.27	Multi-Family Residential	2.32	0.18	0.92	0.16
BMP335	34 Malvern St		1228	1.02	High Density Residential	2.32	0.07	0.96	0.06
BMP336	30 Malvern St		1228	1.02	High Density Residential	2.32	0.07	0.96	0.06
BMP337	28 Nutting Rd		1606	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP338	10 Reyem St		2465	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP34	133-135 Ash St	Infiltration Trench	5815	0.27	Multi-Family Residential	2.32	0.31	0.92	0.28
BMP307	84 Ellery Rd	Infiltration Trench	1692	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP341	317 Propect Hill Rd		2022	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP342	131 River St		17534	0.27	Commercial	1.78	0.72	0.92	0.66
BMP343	321 Propect Hill Rd		2180	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP344	66 Mayall Road		350	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP345	31 Oak St		3262	1.02	High Density Residential	2.32	0.17	0.96	0.17
BMP346	88 Temple Rd		784	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP347	23 Caldwell Rd	Infiltration Trench	756	1.02	Medium Density Residential	1.96	0.03	0.96	0.03
BMP348	43 Lafayette St		1661	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP349	20 leslie Drive		5900	0.17	Medium Density Residential	1.96	0.27	0.90	0.24
BMP35	6 Virginia Rd		476	1.02	High Density Residential	2.32	0.03	0.96	0.02
BMP350	90 Amherst Ave	Infiltration Trench	845	0.17	High Density Residential	2.32	0.05	0.90	0.04
BMP351	36 Thornton Rd		1594	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP325	91 Hamilton Rd	Infiltration Trench	236	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP354	66 Hatherly Rd	Infiltration Trench	191	0.27	High Density Residential	2.32	0.01	0.92	0.01
BMP355	427 Lincoln St		1880	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP356	431 Lincoln St		2441	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP357	63 Alderwood Rd	Infiltration Trench	1954	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP359	9 Alder St	Infiltration Trench	24844	1.02	High Density Residential	2.32	1.32	0.96	1.27
BMP36	86 Wilbur St		410	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP360	341 Warren St		483	1.02	High Density Residential	2.32	0.03	0.96	0.02
BMP361	40 Clements Rd	Infiltration Trench	146	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP362	319 Grove St	Infiltration Trench	2050	1.02	Multi-Family Residential	2.32	0.11	0.96	0.10
BMP363	166-172 Bright St	Infiltration Trench	8618	1.02	Multi-Family Residential	2.32	0.46	0.96	0.44
BMP364	118 Berkley St	Infiltration Trench	1080	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP365	127 Russel St		4086	1.02	Multi-Family Residential	2.32	0.22	0.96	0.21
BMP366	9 Lawton Place		1970	0.27	Multi-Family Residential	2.32	0.10	0.92	0.10
BMP367	135 Second Ave		68754	0.27	Industrial	1.78	2.81	0.92	2.58
BMP368	40 Cushing St	Infiltration Trench	3466	0.27	Urban Public/Institutional	1.78	0.14	0.92	0.13
BMP334	140 Hawthorne Rd		2751	1.02	High Density Residential	2.32	0.15	0.96	0.14
BMP37	17 Elinor Cir	Infiltration Trench	4800	1.02	Medium Density Residential	1.96	0.22	0.96	0.21
BMP683	140 Hawthorne Rd	Infiltration Trench	2015	1.02	High Density Residential	2.32	0.11	0.96	0.10

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BMP339	37 Humboldt St	Infiltration Trench	200	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP373	51 Hall St (Lot III)		2126	0.27	Urban Public/Institutional	1.78	0.09	0.92	0.08
BMP374	99 Bright St	Infiltration Trench	4110	1.02	High Density Residential	2.32	0.22	0.96	0.21
BMP375	293 Newton St		3205	0.27	Multi-Family Residential	2.32	0.17	0.92	0.16
BMP376	5 Rock Lane		2270	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP377	27 Drury Ln	Infiltration Trench	288	1.02	High Density Residential	2.32	0.02	0.96	0.01
BMP378	62-64 School St		870	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP379	4 Larchmont Ave		1320	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP38	67 Silver Hill Lane	Infiltration Trench	5116	0.27	Medium Density Residential	1.96	0.23	0.92	0.21
BMP380	8 Larchmont Ave		1170	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP381	19 School Ave		1656	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP382	81 Sheffield Rd		4385	1.02	High Density Residential	2.32	0.23	0.96	0.22
BMP383	28 Lafayette St		2365	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP384	167 Prospect St		10300	1.02	Commercial	1.78	0.42	0.96	0.40
BMP352	136 Hardy Pond Rd	Infiltration Trench	1156	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP388	54 Charlotte Rd	Infiltration Trench	1157	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP389	59 Candace Ave	Infiltration Trench	220	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP39	120 Brewster Rd	Infiltration Trench	1300	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP390	20 Rich St		2803	1.02	Multi-Family Residential	2.32	0.15	0.96	0.14
BMP391	66 Rose Hill Way		1660	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP393	6 Marlton Rd		624	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP371	49 Hall St		3079	0.27	High Density Residential	2.32	0.16	0.92	0.15
BMP370	43 Hall St	Infiltration Trench	2726	0.27	Urban Public/Institutional	1.78	0.11	0.92	0.10
BMP387	67 Hillcrest St		2380	0.17	High Density Residential	2.32	0.13	0.90	0.11
BMP399	17 Wadsworth Ave		4188	0.27	High Density Residential	2.32	0.22	0.92	0.21
BMP40	46 Mokema Ave		1648	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP631	30 Hardy Pond Rd	Infiltration Trench	204	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP402	33 Harrington Rd		2170	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP403	33 Harrington St	Infiltration Trench	2170	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP404	152 Seminole Ave		1168	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP405	150 Seminole Ave		1168	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP394	96 Greenwood Ln	Infiltration Trench	2288	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP407	12 Cedar St	Infiltration Trench	2882	1.02	Multi-Family Residential	2.32	0.15	0.96	0.15
BMP396	10 Huntington St	Infiltration Trench	1138	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP41	4 Boynton St	Infiltration Trench	3318	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP410	21 Banbury Ave	Infiltration Trench	3400	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP411	20 Cooper St	Infiltration Trench	132490	0.27	Industrial	1.78	5.41	0.92	4.98
BMP414	13 Clark Ln	Infiltration Trench	737	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP406	14 Huntington St	Infiltration Trench	1138	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP417	212 Pine Hill Cir		2124	0.17	High Density Residential	2.32	0.11	0.90	0.10
BMP418	37 Lafayette St		784	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP419	33, former LOT447&446 Cunningham Cir	Infiltration Trench	5485	1.02	High Density Residential	2.32	0.29	0.96	0.28
BMP42	307 Warren St		2025	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP420	40 Smart Street		3400	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP421	57 Leitha Drive		2926	0.27	High Density Residential	2.32	0.16	0.92	0.14
BMP422	111 Villa St		270	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP423	31 Willington St		3068	1.02	Multi-Family Residential	2.32	0.16	0.96	0.16
BMP424	29 Piedmont Ave		1436	1.02	High Density Residential	2.32	0.08	0.96	0.07

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BMP425	152 Hawthorne Rd	Infiltration Trench	1862	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP400	70 Hiawatha Ave	Infiltration Trench	2921	1.02	Multi-Family Residential	2.32	0.16	0.96	0.15
BMP428	66 Newton St		57380	1.02	Urban Public/Institutional	1.78	2.34	0.96	2.25
BMP429	79 Rockridge Rd		2490	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP43	120 Bright St	Infiltration Trench	4000	1.02	Multi-Family Residential	2.32	0.21	0.96	0.20
BMP430	45 Brightwood Rd	Infiltration Trench	2630	1.02	High Density Residential	2.32	0.14	0.96	0.13
BMP431	26 Rich St		2803	1.02	Multi-Family Residential	2.32	0.15	0.96	0.14
BMP432	8-40 Grove St	Wet Pond	45302	0.27	Urban Public/Institutional	1.78	1.85	0.53	0.98
BMP433	40 Cowasset Ln	Infiltration Trench	2600	1.02	Forest	1.52	0.09	0.96	0.09
BMP434	96 Summit St		1720	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP435	219 Smart Street		424	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP436	143-145 Ash St	Infiltration Trench	3300	0.27	Multi-Family Residential	2.32	0.18	0.92	0.16
BMP437	18 Wadsworth Ave		3374	0.27	Multi-Family Residential	2.32	0.18	0.92	0.17
BMP438	42 Felton St	Infiltration Trench	11392	0.27	Commercial	1.78	0.47	0.92	0.43
BMP439	210 Ash St	Infiltration Trench	4024	0.27	Multi-Family Residential	2.32	0.21	0.92	0.20
BMP44	77 Wilbur St		2272	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP408	16 Graymore Rd	Infiltration Trench	624	1.02	Medium Density Residential	1.96	0.03	0.96	0.03
BMP442	40 Jones Rd		10182	0.27	Industrial	1.78	0.42	0.92	0.38
BMP915	16 Graymore Rd	Infiltration Trench	3194	1.02	Medium Density Residential	1.96	0.14	0.96	0.14
BMP445	108 Myrtle St		3764	0.27	High Density Residential	2.32	0.20	0.92	0.18
BMP446	10 Sterling Rd		965	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP447	19 Everett St	Infiltration Trench	3393	1.02	Multi-Family Residential	2.32	0.18	0.96	0.17
BMP448	143 Calvary St	Infiltration Trench	2068	0.27	Multi-Family Residential	2.32	0.11	0.92	0.10
BMP412	12 Hemlock Terrace	Infiltration Trench	1622	1.02	Medium Density Residential	1.96	0.07	0.96	0.07
BMP452	31 Lura Ln		1063	1.02	Medium Density Residential	1.96	0.05	0.96	0.05
BMP453	14 Abbott Rd	Infiltration Trench	3706	1.02	High Density Residential	2.32	0.20	0.96	0.19
BMP454	48 Temple Rd		256	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP455	233 Grove St	Infiltration Trench	2650	1.02	High Density Residential	2.32	0.14	0.96	0.14
BMP456	259 Lowell St		3587	0.27	High Density Residential	2.32	0.19	0.92	0.18
BMP457	27 Chestnut St	Infiltration Trench	3354	0.27	Multi-Family Residential	2.32	0.18	0.92	0.16
BMP458	115 Clark Ln	Infiltration Trench	535	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP459	27 Brennan Ave	Infiltration Trench	948	0.27	Medium Density Residential	1.96	0.04	0.92	0.04
BMP46	39 Ellery Rd	Infiltration Trench	195	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP460	47 Charles St	Infiltration Trench	2322	0.27	Multi-Family Residential	2.32	0.12	0.92	0.11
BMP461	18 Rock Lane		2460	1.02	Forest	1.52	0.09	0.96	0.08
BMP462	140 Seminole Ave		1210	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP463	138 Seminole Ave		1210	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP464	88 Lake St		2470	0.17	High Density Residential	2.32	0.13	0.90	0.12
BMP465	31 Bowker Rd	Infiltration Trench	870	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP466	187 Longfellow Rd		496	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP467	92 Marlborugh Rd		2275	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP416	7 Hillcroft Rd		2104	0.27	Medium Density Residential	1.96	0.09	0.92	0.09
BMP440	56 Hibiscus Ave	Infiltration Trench	1740	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP47	67 Bright St	Infiltration Trench	914	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP470	83 Oak St		3862	1.02	Multi-Family Residential	2.32	0.21	0.96	0.20
BMP471	88 Willow St		5695	1.02	High Density Residential	2.32	0.30	0.96	0.29
BMP472	180 Worcester Ln		1984	1.02	Medium Density Residential	1.96	0.09	0.96	0.09
BMP473	151 Beal Rd	Infiltration Trench	922	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP474	154 Hardy Pond Rd		1578	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP475	52 Taylor St		6458	0.27	Urban Public/Institutional	1.78	0.26	0.92	0.24
BMP476	50 Taylor St		6458	0.27	Urban Public/Institutional	1.78	0.26	0.92	0.24

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BMP477	51 Charles St	Infiltration Trench	1789	0.27	High Density Residential	2.32	0.10	0.92	0.09
BMP478	245 Lowell St		1050	0.27	High Density Residential	2.32	0.06	0.92	0.05
BMP479	46 Willington St		3373	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP480	31 Brewster Rd	Infiltration Trench	2420	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP481	30 Charlotte Rd	Infiltration Trench	345	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP482	132 Church St	Infiltration Trench	1212	1.02	Low Density Residential	1.52	0.04	0.96	0.04
BMP483	17 Augustus Rd	Infiltration Trench	729	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP484	27 Clark Ln	Infiltration Trench	2178	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP486	52 Madison Rd		3472	1.02	High Density Residential	2.32	0.18	0.96	0.18
BMP487	21 Brightwood Rd	Infiltration Trench	317	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP488	41 Mountain Rd		2196	0.27	Medium Density Residential	1.96	0.10	0.92	0.09
BMP489	132 Lake St		1640	0.17	High Density Residential	2.32	0.09	0.90	0.08
BMP49	66, former 56/Lot 1 Brewster Rd	Infiltration Trench	2840	1.02	Urban Public/Institutional	1.78	0.12	0.96	0.11
BMP490	44 Matthew Lane		5000	0.27	Transitional	1.52	0.17	0.92	0.16
BMP491	50 Matthew Lane		5000	0.27	Transitional	1.52	0.17	0.92	0.16
BMP492	66 Arcadia Ave	Infiltration Trench	1168	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP493	68 Arcadia Ave	Infiltration Trench	1168	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP494	85 Miriam Rd		165	0.27	High Density Residential	2.32	0.01	0.92	0.01
BMP495	6 Michaelchris Dr		2500	0.27	Transitional	1.52	0.09	0.92	0.08
BMP496	67 Hillcrest Road		2380	0.17	High Density Residential	2.32	0.13	0.90	0.11
BMP497	Lot 290 & 291 Braemore Rd	Infiltration Trench	1980	0.17	Forest	1.52	0.07	0.90	0.06
BMP498	51 Columbus Ave	Infiltration Trench	1220	1.02	Multi-Family Residential	2.32	0.06	0.96	0.06
BMP499	22 Addison Rd	Infiltration Trench	400	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP50	14 Clements Rd	Infiltration Trench	260	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP500	19 Orange St		3248	0.27	High Density Residential	2.32	0.17	0.92	0.16
BMP501	126-128 Church St	Infiltration Trench	10512	1.02	Low Density Residential	1.52	0.37	0.96	0.35
BMP502	23 Cedar Hill Ln	Infiltration Trench	396	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP503	17 Whittier Rd		320	0.27	High Density Residential	2.32	0.02	0.92	0.02
BMP504	10 Rock Lane (Lot#3)		1715	1.02	Forest	1.52	0.06	0.96	0.06
BMP505	17 Washington Ave		5835	0.27	Multi-Family Residential	2.32	0.31	0.92	0.29
BMP506	26 Wyola Prospect		1880	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP507	30 Wyola Prospect		2024	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP508	625 Moody St		4120	0.27	Commercial	1.78	0.17	0.92	0.15
BMP443	40 Ellery Rd	Infiltration Trench	327	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP51	133 Worcester Ln		3750	1.02	Forest	1.52	0.13	0.96	0.13
BMP510	17 Hardy Pond Rd		1310	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP511	91 Summit St		5247	1.02	High Density Residential	2.32	0.28	0.96	0.27
BMP512	23 Whittier Rd		2512	0.27	High Density Residential	2.32	0.13	0.92	0.12
BMP513	80 Washington Ave		557	0.27	High Density Residential	2.32	0.03	0.92	0.03
BMP514	39 Briarwood Rd	Infiltration Trench	456	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP444	40 Ellery Rd	Infiltration Trench	1167.5	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP517	10 Caughey St	Infiltration Trench	2360	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP518	24 Bowker Rd	Infiltration Trench	240	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP519	19 Tomlin St		2004	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP52	143 Worcester Ln		6650	1.02	High Density Residential	2.32	0.35	0.96	0.34
BMP520	23 Tomlin St		2004	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP450	35 Hatherly Rd		1635	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP468	48 Gilbert St	Infiltration Trench	2220	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP523	41 Cedar St	Infiltration Trench	1846	1.02	Multi-Family Residential	2.32	0.10	0.96	0.09
BMP525	159 Summer St		5990	0.27	Multi-Family Residential	2.32	0.32	0.92	0.29
BMP526	43 Hamilton Rd		5220	1.02	High Density Residential	2.32	0.28	0.96	0.27

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BMP527	27 Michaelchris Dr		5280	1.02	Transitional	1.52	0.18	0.96	0.18
BMP528	31 Robbins St		1084	0.27	Multi-Family Residential	2.32	0.06	0.92	0.05
BMP529	66-68 Central St	Infiltration Trench	5834	0.27	Multi-Family Residential	2.32	0.31	0.92	0.29
BMP53	54 Albermarle Rd	Infiltration Trench	1528	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP530	21 Farnum Rd	Infiltration Trench	825	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP531	85 Knollwood Dr		4890	1.02	Medium Density Residential	1.96	0.22	0.96	0.21
BMP485	4 Fuller St		3980	0.27	High Density Residential	2.32	0.21	0.92	0.20
BMP534	250 Lake St		1184	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP535	56 Matthew Lane		3500	1.02	Transitional	1.52	0.12	0.96	0.12
BMP536	18 Clinton St	Infiltration Trench	874	1.02	Multi-Family Residential	2.32	0.05	0.96	0.04
BMP537	431 River St		35203	0.27	Forest	1.52	1.23	0.92	1.13
BMP539	32 Manning Rd		1000	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP54	56 Albermarle Rd	Infiltration Trench	1676	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP509	114 Whitman Rd		570	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP543	144 Princeton Ave		2186	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP545	33 Gregory St	Infiltration Trench	1308	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP522	16 Hemlock Terrace		1766	1.02	Medium Density Residential	1.96	0.08	0.96	0.08
BMP547	160 Worcester Ln		402	1.02	Medium Density Residential	1.96	0.02	0.96	0.02
BMP548	18 Kenmore Rd		367	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP549	64 Curve St	Infiltration Trench	2083	1.02	Medium Density Residential	1.96	0.09	0.96	0.09
BMP55	55 Banbury Ave	Infiltration Trench	2465	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP550	514 Lexington St	Infiltration Trench	2250	1.02	Medium Density Residential	1.96	0.10	0.96	0.10
BMP551	176 Charles St	Infiltration Trench	4726	0.27	High Density Residential	2.32	0.25	0.92	0.23
BMP532	21 Hall St	Infiltration Trench	2824	0.27	High Density Residential	2.32	0.15	0.92	0.14
BMP554	60 Brightwood Rd	Infiltration Trench	277	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP555	103 Whitman Rd		600	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP556	12 Van Vechten St		2206	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP541	70 Hollace St	Infiltration Trench	360	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP559	18 Montchair Ave		994	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP56	179 Prospect St		1600	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP560	26 Douglas Rd	Infiltration Trench	315	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP561	34 Lake St		2140	0.27	Commercial	1.78	0.09	0.92	0.08
BMP562	46 Lake St		2180	0.27	Commercial	1.78	0.09	0.92	0.08
BMP563	78 Ash St	Infiltration Trench	2820	0.27	High Density Residential	2.32	0.15	0.92	0.14
BMP564	17-19 Ash St	Infiltration Trench	3790	0.27	Multi-Family Residential	2.32	0.20	0.92	0.19
BMP544	29 Gregory St	Infiltration Trench	1308	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP566	66 Boynton St	Infiltration Trench	800	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP567	84 Warwick Ave		1660	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP568	21 Hillcrest Rd	Infiltration Trench	1882	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP569	21 Hillcrest Road		1882	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP57	59 Hillcroft Rd		3300	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP570	15 Marlborugh Rd		291	1.02	High Density Residential	2.32	0.02	0.96	0.01
BMP571	5 Arbor Ln	Infiltration Trench	388	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP552	86 Hillcroft Rd	Infiltration Trench	2349	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP574	50 Stearn St		6432	0.27	Industrial	1.78	0.26	0.92	0.24
BMP575	52 Stearn St		6432	0.27	Industrial	1.78	0.26	0.92	0.24
BMP577	60 Livemore Rd		620	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP578	9 Wimbledon Cir		2190	0.27	Medium Density Residential	1.96	0.10	0.92	0.09
BMP579	43 Canterbury Rd	Infiltration Trench	3210	1.02	High Density Residential	2.32	0.17	0.96	0.16
BMP58	210-216 Adams St	Infiltration Trench	116	0.27	Multi-Family Residential	2.32	0.01	0.92	0.01

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BMP581	20 Caughey St	Infiltration Trench	413	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP582	47 Hamilton Rd		4448	1.02	High Density Residential	2.32	0.24	0.96	0.23
BMP583	47 Hammond St	Infiltration Trench	4448	1.02	Multi-Family Residential	2.32	0.24	0.96	0.23
BMP584	114 Lakeview Ave		1098	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP585	118 Lakeview Ave		1098	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP586	81 Columbus Ave	Infiltration Trench	1300	1.02	Multi-Family Residential	2.32	0.07	0.96	0.07
BMP587	12 Mountain Rd		1376	0.27	Medium Density Residential	1.96	0.06	0.92	0.06
BMP588	10 Claremont St	Infiltration Trench	1943	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP589	61 Parmenter Rd		1470	0.27	High Density Residential	2.32	0.08	0.92	0.07
BMP59	33 Charlotte Rd	Infiltration Trench	608	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP590	42 School Ave		2154	1.02	High Density Residential	2.32	0.11	0.96	0.11
BMP591	91 Arcadia Ave	Infiltration Trench	1170	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP592	180 Warren St		2370	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP593	211 Pine Hill Cir		1422	0.17	High Density Residential	2.32	0.08	0.90	0.07
BMP594	48 Augustus Rd	Infiltration Trench	220	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP595	291 Dale St	Infiltration Trench	363	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP596	291 Dale Street	Infiltration Trench	363	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP597	156 Barbara Rd	Infiltration Trench	670	1.02	High Density Residential	2.32	0.04	0.96	0.03
BMP598	3 Townsend St		2214	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP599	27 Baldwin Rd	Infiltration Trench	220	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP60	91 Hillcrest St		309	0.17	High Density Residential	2.32	0.02	0.90	0.01
BMP601	39 Gregory St	Infiltration Trench	1308	0.17	High Density Residential	2.32	0.07	0.90	0.06
BMP558	43 Galen St		1723	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP603	18 Melody Lane		1256	0.27	Medium Density Residential	1.96	0.06	0.92	0.05
BMP604	16 Samoset Lane	Infiltration Trench	400	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP605	40 Oak Hill Rd		198	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP606	51 Matthew Lane		3500	0.27	Transitional	1.52	0.12	0.92	0.11
BMP608	58 Madison Rd		1954	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP609	126 Warwick Ave		1601	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP61	257 School St		4570	1.02	Multi-Family Residential	2.32	0.24	0.96	0.23
BMP610	41 Matthew Lane		3500	0.27	Transitional	1.52	0.12	0.92	0.11
BMP611	46 School Ave		6110	1.02	Multi-Family Residential	2.32	0.33	0.96	0.31
BMP612	118 Sheffield Rd		3007	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP613	112 Shirley Road	Infiltration Trench	2797	1.02	High Density Residential	2.32	0.15	0.96	0.14
BMP614	12 Bryant Rd	Infiltration Trench	1656	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP615	54 Mayall Road		280	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP616	37 Cedarwood Ave	Infiltration Trench	192	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP617	140 Lowell St		1950	0.27	Multi-Family Residential	2.32	0.10	0.92	0.10
BMP618	66 Shirley Road	Infiltration Trench	1180	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP619	47 Bedford St	Infiltration Trench	2146	1.02	High Density Residential	2.32	0.11	0.96	0.11
BMP62	56 Valley View Rd		4450	1.02	Low Density Residential	1.52	0.16	0.96	0.15
BMP620	5 Calvary St	Infiltration Trench	715	0.27	High Density Residential	2.32	0.04	0.92	0.04
BMP621	29 Circle Dr	Infiltration Trench	1488	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP622	30 Beaver St	Infiltration Trench	462	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP623	97 Bowdoin Ave	Infiltration Trench	1208	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP624	111 Milner St		1392	0.27	High Density Residential	2.32	0.07	0.92	0.07
BMP625	89 Orange St		2800	0.27	High Density Residential	2.32	0.15	0.92	0.14
BMP626	42 College Farm Rd	Infiltration Trench	1332	0.17	High Density Residential	2.32	0.07	0.90	0.06

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BMP627	38 College Farm Rd	Infiltration Trench	1137	0.17	High Density Residential	2.32	0.06	0.90	0.05
BMP628	71 Mokema Ave	Infiltration Trench	240	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP629	156-164 School St		13878	0.27	Multi-Family Residential	2.32	0.74	0.92	0.68
BMP63	48 Sachum St		2065	0.27	High Density Residential	2.32	0.11	0.92	0.10
BMP630	33 Cheryl Ln	Infiltration Trench	366	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP580	27-29 Guinan St	Infiltration Trench	1520	1.02	Multi-Family Residential	2.32	0.08	0.96	0.08
BMP632	40 Brightwood Rd	Infiltration Trench	468	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP600	35 Gregory St	Infiltration Trench	1308	0.17	High Density Residential	2.32	0.07	0.90	0.06
BMP634	45 Dale Street	Infiltration Trench	1350	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP635	14 Rosemont Ave		1550	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP636	45 Dale St	Infiltration Trench	370	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP637	11 Lory Drive		324	1.02	Medium Density Residential	1.96	0.01	0.96	0.01
BMP638	42 Shirley Road	Infiltration Trench	435	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP639	23 Dix St	Infiltration Trench	3750	1.02	High Density Residential	2.32	0.20	0.96	0.19
BMP64	327 Propect Hill Rd		2320	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP640	18 Grove Rd		356	0.27	Urban Public/Institutional	1.78	0.01	0.92	0.01
BMP642	107 Milner St		1392	0.27	High Density Residential	2.32	0.07	0.92	0.07
BMP643	103 Milner St		1392	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP644	65 Grove St	Infiltration Trench	338	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP645	47 Plant Rd		170	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP646	80 Ash St	Infiltration Trench	3240	0.27	High Density Residential	2.32	0.17	0.92	0.16
BMP647	50 Marivista Ave		1828	1.02	High Density Residential	2.32	0.10	0.96	0.09
BMP648	46 Marivista Ave		1720	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP649	111 Circle Dr	Infiltration Trench	1272	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP65	11 Barbara Rd	Infiltration Trench	2352	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP607	106 Harrington Rd		290	1.02	Medium Density Residential	1.96	0.01	0.96	0.01
BMP651	5 Bigelow Rd	Infiltration Trench	2654	1.02	Medium Density Residential	1.96	0.12	0.96	0.11
BMP652	28 Thayer Rd		6630	0.27	Industrial	1.78	0.27	0.92	0.25
BMP653	10 Lot 2 LeBlane Ln		2900	0.27	Medium Density Residential	1.96	0.13	0.92	0.12
BMP654	58 Wheellock Rd		975	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP655	12 Hagar St		3410	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP656	184 College Farm Rd	Infiltration Trench	1460	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP657	95-99 Francis St		2850	1.02	Multi-Family Residential	2.32	0.15	0.96	0.15
BMP658	91 Francis St	Infiltration Trench	1772	1.02	Multi-Family Residential	2.32	0.09	0.96	0.09
BMP633	72 Ellery Rd	Infiltration Trench	2520	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP661	239 Warren St		840	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP662	5 High Rock Cir	Infiltration Trench	1086	1.02	Medium Density Residential	1.96	0.05	0.96	0.05
BMP670	785 Beaver St	Infiltration Trench	2960	1.02	Urban Public/Institutional	1.78	0.12	0.96	0.12
BMP665	5 Lot 5 LeBlane Ln		3000	1.02	Medium Density Residential	1.96	0.13	0.96	0.13
BMP666	14 Ash St	Infiltration Trench	10977	0.27	Urban Public/Institutional	1.78	0.45	0.92	0.41
BMP667	35 Matthew Lane		3500	0.27	Transitional	1.52	0.12	0.92	0.11
BMP668	53 Milner St		1444	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP669	57 Milner St		1444	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP67	31 Coolidge Ave	Infiltration Trench	442	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP745	785 Beaver St	Infiltration Trench	432	1.02	Urban Public/Institutional	1.78	0.02	0.96	0.02

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BMP671	325 Bacon St	Infiltration Trench	16873	1.02	Urban Public/Institutional	1.78	0.69	0.96	0.66
BMP672	10 Naviens St		3800	0.27	Multi-Family Residential	2.32	0.20	0.92	0.19
BMP673	52 Virginia Rd		438	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP674	165 Lake St		1278	1.02	Commercial	1.78	0.05	0.96	0.05
BMP675	161 Lake St		1188	1.02	Commercial	1.78	0.05	0.96	0.05
BMP874	785 Beaver St	Infiltration Trench	744	1.02	Urban Public/Institutional	1.78	0.03	0.96	0.03
BMP677	48 Murray St		1800	1.02	High Density Residential	2.32	0.10	0.96	0.09
BMP678	44 Murray St		1800	1.02	High Density Residential	2.32	0.10	0.96	0.09
BMP679	25 Lory Drive		333	1.02	Medium Density Residential	1.96	0.01	0.96	0.01
BMP68	53 Hillcroft Rd		2241	1.02	High Density Residential	2.32	0.12	0.96	0.11
BMP680	54 Sheffield Rd		390	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP659	50 Greer St	Infiltration Trench	1146	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP66	55 Gale St		3810	1.02	High Density Residential	2.32	0.20	0.96	0.19
BMP663	162 Doty St	Infiltration Trench	3513	1.02	High Density Residential	2.32	0.19	0.96	0.18
BMP687	36 Smart Street	Infiltration Trench	1000	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP69	9 hardy St		1160	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP690	14 Elmwood Ave	Infiltration Trench	676	1.02	High Density Residential	2.32	0.04	0.96	0.03
BMP691	17 Lincoln Circle		4766	1.02	Medium Density Residential	1.96	0.21	0.96	0.21
BMP692	49 Pleasant st		10314	1.02	High Density Residential	2.32	0.55	0.96	0.53
BMP693	122 Harrington St	Infiltration Trench	641	1.02	Medium Density Residential	1.96	0.03	0.96	0.03
BMP694	12 (Lot 5) Marlborugh Rd		1532	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP695	27 Matthew Lane		3500	0.27	Transitional	1.52	0.12	0.92	0.11
BMP682	138 Hawthorne Rd	Infiltration Trench	2476	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP698	15 Tavern Rd		2132	1.02	Medium Density Residential	1.96	0.10	0.96	0.09
BMP699	30 Crafts St	Infiltration Trench	400	0.27	High Density Residential	2.32	0.02	0.92	0.02
BMP70	11 Waverley St		1890	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP700	12 Kenwood Line		240	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP701	11 Lincoln Circle		4432	0.17	Medium Density Residential	1.96	0.20	0.90	0.18
BMP685	125 Greer St	Infiltration Trench	462	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP704	27 Vernon St		4297	1.02	Multi-Family Residential	2.32	0.23	0.96	0.22
BMP705	15 (lot 1) Matthew Lane		3500	1.02	Transitional	1.52	0.12	0.96	0.12
BMP706	64 Colburn St	Infiltration Trench	1342	1.02	Medium Density Residential	1.96	0.06	0.96	0.06
BMP688	40 Hamilton Rd	Infiltration Trench	2384	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP709	69 Marivista Ave		1216	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP71	10 Waverley St		1890	1.02	Multi-Family Residential	2.32	0.10	0.96	0.10
BMP710	67 Trimount Ave		1044	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP711	69 Trimount Ave		1044	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP712	373 Lincoln St		407	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP713	26 Oak St		3711	1.02	Multi-Family Residential	2.32	0.20	0.96	0.19
BMP714	27 Cunningham Cir	Infiltration Trench	312	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP715	33 Wildwood Ln		1466	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP716	66 Guinan St		168	1.02	Multi-Family Residential	2.32	0.01	0.96	0.01
BMP717	90 Lincoln Wood Ln		775	0.17	Medium Density Residential	1.96	0.03	0.90	0.03
BMP718	14 Reyem St		2214	0.27	High Density Residential	2.32	0.12	0.92	0.11
BMP72	60 Briarwood Rd	Infiltration Trench	643	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP696	121 Graymore Rd	Infiltration Trench	1110	0.27	Medium Density Residential	1.96	0.05	0.92	0.05
BMP721	120 Worcester Ln		341	1.02	High Density Residential	2.32	0.02	0.96	0.02

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BMP722	21 Old Conant Rd		561	0.17	Low Density Residential	1.52	0.02	0.90	0.02
BMP723	127 Summer St		1600	1.02	Low Density Residential	1.52	0.06	0.96	0.05
BMP725	15 Partridge Cir		3830	1.02	Medium Density Residential	1.96	0.17	0.96	0.17
BMP726	51 Forest Park Drive		979	0.27	Medium Density Residential	1.96	0.04	0.92	0.04
BMP727	65 Farnum Rd	Infiltration Trench	1384	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP728	17 Charlotte Rd	Infiltration Trench	892	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP729	110 Pond St		7930	1.02	Multi-Family Residential	2.32	0.42	0.96	0.41
BMP73	46 Hillcroft Rd		2575	1.02	High Density Residential	2.32	0.14	0.96	0.13
BMP730	22 Florence Rd	Infiltration Trench	1640	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP731	26 Florence Rd	Infiltration Trench	1656	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP732	30 Florence Rd	Infiltration Trench	1610	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP733	7 Hibiscus Ave		280	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP702	163 Grove St	Infiltration Trench	3490	1.02	Multi-Family Residential	2.32	0.19	0.96	0.18
BMP735	28-30 Clinton St	Infiltration Trench	2154	1.02	Multi-Family Residential	2.32	0.11	0.96	0.11
BMP736	179 Florence Rd	Infiltration Trench	1619	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP737	183 Florence Rd	Infiltration Trench	1619	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP738	75 Pine St		364	0.27	High Density Residential	2.32	0.02	0.92	0.02
BMP739	72 Lafayette St		1618	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP74	40 Clark Ln	Infiltration Trench	2296	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP740	78 Trimount Ave		1930	0.17	High Density Residential	2.32	0.10	0.90	0.09
BMP741	82 Amherst Ave	Infiltration Trench	1357	0.17	High Density Residential	2.32	0.07	0.90	0.07
BMP742	86 Amherst Ave	Infiltration Trench	1357	0.17	High Density Residential	2.32	0.07	0.90	0.07
BMP743	51 Marguerite Ave	Infiltration Trench	1428	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP744	55 Marguerite Ave		1380	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP746	96 Mokema Ave		1230	1.02	High Density Residential	2.32	0.07	0.96	0.06
BMP707	5 Bowdoin Ave	Infiltration Trench	1598	1.02	High Density Residential	2.32	0.09	0.96	0.08
BMP749	48 Bowker Rd	Infiltration Trench	1043	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP75	46 Clark Ln	Infiltration Trench	1923	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP750	28 Madison Rd		467	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP751	29 Dobbins St	Infiltration Trench	590	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP753	30 Common St	Infiltration Trench	9475	0.27	Multi-Family Residential	2.32	0.50	0.92	0.46
BMP754	374 Waverley Oaks		288	0.52	Multi-Family Residential	2.32	0.02	0.94	0.01
BMP755	376 Waverley Oaks		288	0.52	Multi-Family Residential	2.32	0.02	0.94	0.01
BMP756	104 Crescent St	Infiltration Trench	3344	0.27	High Density Residential	2.32	0.18	0.92	0.16
BMP757	53 Hiawatha Ave		1170	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP758	18 Clark Ln	Infiltration Trench	682	1.02	High Density Residential	2.32	0.04	0.96	0.03
BMP720	47 Bowker Rd	Infiltration Trench	863	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP76	52 Clark Ln	Infiltration Trench	2589	1.02	High Density Residential	2.32	0.14	0.96	0.13
BMP724	105 Barbara Rd	Infiltration Trench	416	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP761	5 Cedarcroft Ln	Infiltration Trench	1738	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP762	226 Beal Rd	Infiltration Trench	1300	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP763	25 Flood St	Infiltration Trench	252	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP764	93 Potter Rd		2650	1.02	High Density Residential	2.32	0.14	0.96	0.14
BMP765	12 Woodlown Ave		2967	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP766	203-205 River St		8418	1.02	Multi-Family Residential	2.32	0.45	0.96	0.43
BMP767	144 Berkley St	Infiltration Trench	1893	1.02	Multi-Family Residential	2.32	0.10	0.96	0.10
BMP768	15 Berkley St	Infiltration Trench	3007	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP769	174 Willow St		5860	1.02	Multi-Family Residential	2.32	0.31	0.96	0.30
BMP77	89 Lincoln Wood Ln		768	0.17	Medium Density Residential	1.96	0.03	0.90	0.03
BMP770	14 Buxton Ln	Infiltration Trench	588	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP773	73 Trimount Ave		1044	1.02	High Density Residential	2.32	0.06	0.96	0.05
BMP774	75 Trimount Ave		802	1.02	High Density Residential	2.32	0.04	0.96	0.04

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BMP775	15 Candace Ave	Infiltration Trench	216	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP776	129 Church St	Infiltration Trench	595	0.27	High Density Residential	2.32	0.03	0.92	0.03
BMP778	76 Canterbury Rd	Infiltration Trench	2405	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP779	48 Arlington Rd	Infiltration Trench	3361	0.27	Multi-Family Residential	2.32	0.18	0.92	0.16
BMP78	57 Gale St	Infiltration Trench	3810	1.02	High Density Residential	2.32	0.20	0.96	0.19
BMP780	208 Beal Rd	Infiltration Trench	360	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP782	59 Orange St		7940	0.27	Multi-Family Residential	2.32	0.42	0.92	0.39
BMP783	16 Montchair Ave		994	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP784	53 Whitman Rd		209	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP785	29 Ash St	Infiltration Trench	504	0.27	High Density Residential	2.32	0.03	0.92	0.02
BMP786	287 Crescent St	Infiltration Trench	17726	0.27	Commercial	1.78	0.72	0.92	0.67
BMP787	77 Copeland St	Infiltration Trench	692	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP789	16 Farnum Rd	Infiltration Trench	507	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP747	108-110 Felton St	Infiltration Trench	5091	0.27	Commercial	1.78	0.21	0.92	0.19
BMP790	42 Bolton St	Infiltration Trench	2308	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP791	20-24 Gill Rd	Porous Pavement	1560	1.02	Multi-Family Residential	2.32	0.08	0.62	0.05
BMP792	170 High St	Infiltration Trench	925	1.02	Commercial	1.78	0.04	0.96	0.04
BMP794	221 Worcester Ln		6900	1.02	Urban Public/Institutional	1.78	0.28	0.96	0.27
BMP795	339 Bacon St	Infiltration Trench	192	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP796	30 Gilbert St	Infiltration Trench	196	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP797	247 Brown St	Infiltration Trench	3414	0.27	High Density Residential	2.32	0.18	0.92	0.17
BMP798	95 Colonial Ave	Infiltration Trench	244	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP799	54 Weston St		2470	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP80	4 Pine Hill Cir		352	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP800	160 Circle Dr	Infiltration Trench	2504	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP801	17 College Farm Rd	Infiltration Trench	2342	1.02	Multi-Family Residential	2.32	0.12	0.96	0.12
BMP802	82 Forest St	Infiltration Trench	582	1.02	Medium Density Residential	1.96	0.03	0.96	0.03
BMP803	40 Porter Rd		1878	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP805	147 Berkley St	Infiltration Trench	360	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP806	23 Candlewood Dr	Infiltration Trench	390	0.17	Medium Density Residential	1.96	0.02	0.90	0.02
BMP807	18 Crestview Rd	Infiltration Trench	400	0.27	Medium Density Residential	1.96	0.02	0.92	0.02
BMP809	324 Forest St	Infiltration Trench	273	0.27	Medium Density Residential	1.96	0.01	0.92	0.01
BMP81	20 Thornton Rd		1132	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP810	75 Candlewood Dr	Infiltration Trench	225	0.27	Medium Density Residential	1.96	0.01	0.92	0.01
BMP811	209 Worcester Ln		4604	1.02	Forest	1.52	0.16	0.96	0.15
BMP812	760 Lincoln St		5370	1.02	Medium Density Residential	1.96	0.24	0.96	0.23
BMP814	62 Cedarwood Ave	Infiltration Trench	406	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP815	105 Vernon St		2368	1.02	High Density Residential	2.32	0.13	0.96	0.12
BMP816	6 Arcadia Ave	Infiltration Trench	1086	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP817	8 Arcadia Ave	Infiltration Trench	1086	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP818	7 Centre St	Infiltration Trench	3319	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP819	4 Dartmouth St	Infiltration Trench	2500	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP82	8 Fuller St		711	0.27	Multi-Family Residential	2.32	0.04	0.92	0.03
BMP820	14 Friend St	Infiltration Trench	2010	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP821	74 Albermarle Rd	Infiltration Trench	1140	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP822	78 Albermarle Rd	Infiltration Trench	1140	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP823	14 Temple Rd		200	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP824	107 Adams St	Infiltration Trench	5158	0.27	Multi-Family Residential	2.32	0.27	0.92	0.25
BMP825	81 Woodlown Ave		3265	0.27	High Density Residential	2.32	0.17	0.92	0.16
BMP826	32 Brewster Rd	Infiltration Trench	1424	0.27	High Density Residential	2.32	0.08	0.92	0.07
BMP827	5 Aberdeen Ave	Infiltration Trench	190	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP828	40 Green St	Wet Pond	308964	0.27	Junkyard	1.78	12.63	0.53	6.69
BMP829	29 Gilman Rd	Infiltration Trench	564	1.02	High Density Residential	2.32	0.03	0.96	0.03

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP83	14 Leitha Drive		620	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP830	80 Azalea Rd	Infiltration Trench	3293	0.27	Medium Density Residential	1.96	0.15	0.92	0.14
BMP831	10 Crafts St	Infiltration Trench	190	0.27	High Density Residential	2.32	0.01	0.92	0.01
BMP832	296 College Farm Rd	Infiltration Trench	3033	1.02	Multi-Family Residential	2.32	0.16	0.96	0.16
BMP833	23 Charlotte Rd	Infiltration Trench	2252	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP834	66 Weston St		3498	1.02	High Density Residential	2.32	0.19	0.96	0.18
BMP835	58 Woodland Rd		400	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP836	45 Gilman Rd	Infiltration Trench	3770	1.02	High Density Residential	2.32	0.20	0.96	0.19
BMP837	68 Hobbs Rd	Infiltration Trench	352	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP838	174 Forest St	Infiltration Trench	627	1.02	Medium Density Residential	1.96	0.03	0.96	0.03
BMP84	18 Oda St		380	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP840	499 Forest St	Infiltration Trench	3314	1.02	High Density Residential	2.32	0.18	0.96	0.17
BMP841	101 Grove St	Infiltration Trench	192	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP842	114 Ellison Park	Infiltration Trench	2280	1.02	High Density Residential	2.32	0.12	0.96	0.12
BMP843	66 Bowdoin Ave	Infiltration Trench	1188	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP844	70 Bowdoin Ave	Infiltration Trench	1188	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP845	17 Brigham Rd	Infiltration Trench	1226	1.02	High Density Residential	2.32	0.07	0.96	0.06
BMP846	81-83 Bacon St	Infiltration Trench	3694	1.02	Multi-Family Residential	2.32	0.20	0.96	0.19
BMP847	64 Worcester Ln		896	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP848	229 High St	Infiltration Trench	12855	1.02	Commercial	1.78	0.53	0.96	0.50
BMP849	17 Green St	Infiltration Trench	2450	0.27	Commercial	1.78	0.10	0.92	0.09
BMP85	64 School Ave		2026	0.27	Multi-Family Residential	2.32	0.11	0.92	0.10
BMP850	17 Sioux Ave	Infiltration Trench	996	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP851	138 Beal Rd	Infiltration Trench	27668	1.02	Urban Public/Institutional	1.78	1.13	0.96	1.09
BMP852	144 Clark St	Infiltration Trench	3257	1.02	High Density Residential	2.32	0.17	0.96	0.17
BMP853	12 Crestview Rd	Infiltration Trench	275	0.27	Medium Density Residential	1.96	0.01	0.92	0.01
BMP854	19 Copley Ave	Infiltration Trench	1420	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP855	21 Copley Ave	Infiltration Trench	1420	1.02	High Density Residential	2.32	0.08	0.96	0.07
BMP856	168 Adams St	Infiltration Trench	5228	0.27	Multi-Family Residential	2.32	0.28	0.92	0.26
BMP858	101 Bedford St	Infiltration Trench	411	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP859	9 Walton St		1542	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP861	58 Doty St	Infiltration Trench	770	1.02	Medium Density Residential	1.96	0.03	0.96	0.03
BMP862	271 Florence Rd	Infiltration Trench	331	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP863	50 Bear Hill Rd	Infiltration Trench	25171	0.27	Industrial	1.78	1.03	0.92	0.95
BMP864	131 Greenwood Ln	Infiltration Trench	388	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP865	89 Villa St		1564	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP866	30 Banford Way	Infiltration Trench	240	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP867	83 Bacon St	Infiltration Trench	3253	1.02	Multi-Family Residential	2.32	0.17	0.96	0.17
BMP868	481 Forest St	Infiltration Trench	3100	1.02	High Density Residential	2.32	0.17	0.96	0.16
BMP869	41 Columbus Ave	Infiltration Trench	1692	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP759	23 Baldwin Rd	Infiltration Trench	767	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP870	43 Wamsutta Ave		1212	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP871	39 Wamsutta Ave		1212	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP872	26 Auburn St	Infiltration Trench	3207	1.02	High Density Residential	2.32	0.17	0.96	0.16
BMP875	66 Brightwood Rd		117	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP877	45 Gilbert St	Infiltration Trench	242	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP878	48 Bright St	Infiltration Trench	260	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP879	15 Parker's Lane	Infiltration Trench	1994	1.02	High Density Residential	2.32	0.11	0.96	0.10
BMP88	14 Robbins St		4064	0.27	Multi-Family Residential	2.32	0.22	0.92	0.20

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP880	66 Goldencrest Ave	Infiltration Trench	207	0.27	Medium Density Residential	1.96	0.01	0.92	0.01
BMP881	135 Elm St	Infiltration Trench	53842	0.27	Commercial	1.78	2.20	0.92	2.02
BMP882	15 Seminole Ave		1188	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP777	27 Brightwood Rd	Infiltration Trench	381	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP884	59 Gilman Rd	Infiltration Trench	3005	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP885	35 Hiawatha Ave	Infiltration Trench	1530	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP886	142 Clark St	Infiltration Trench	3157	1.02	High Density Residential	2.32	0.17	0.96	0.16
BMP887	19 Gentleman's Way	Infiltration Trench	6000	1.02	Low Density Residential	1.52	0.21	0.96	0.20
BMP888	90 High St	Infiltration Trench	2320	0.27	High Density Residential	2.32	0.12	0.92	0.11
BMP889	124 Ellison Park	Infiltration Trench	2075	1.02	High Density Residential	2.32	0.11	0.96	0.11
BMP890	34 Helen St	Infiltration Trench	453	0.27	High Density Residential	2.32	0.02	0.92	0.02
BMP891	24 Bank St	Infiltration Trench	520	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP892	201 Doty St	Infiltration Trench	2493	1.02	High Density Residential	2.32	0.13	0.96	0.13
BMP893	130 Forest St	Infiltration Trench	3665	1.02	Medium Density Residential	1.96	0.16	0.96	0.16
BMP894	17 Dix St	Infiltration Trench	418	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP895	105 Hawthorne Rd	Infiltration Trench	242	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP896	37 Hiawatha Ave	Infiltration Trench	747	1.02	High Density Residential	2.32	0.04	0.96	0.04
BMP897	11 Seminole Ave		1188	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP898	30 Colonial Ave	Infiltration Trench	179	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP899	149 Candlewood Dr	Infiltration Trench	200	0.27	Medium Density Residential	1.96	0.01	0.92	0.01
BMP90	25 Fairmont Ave	Infiltration Trench	560	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP900	120 Clark Ln	Infiltration Trench	168	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP901	54 Hollace St	Infiltration Trench	1944	1.02	High Density Residential	2.32	0.10	0.96	0.10
BMP902	58 Hollace St	Infiltration Trench	1716	1.02	High Density Residential	2.32	0.09	0.96	0.09
BMP903	104 Greer St	Infiltration Trench	651	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP904	76 Briarwood Rd	Infiltration Trench	600	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP905	56 Graymore Rd	Infiltration Trench	563	1.02	Medium Density Residential	1.96	0.03	0.96	0.02
BMP906	189 Grove St	Infiltration Trench	3680	1.02	High Density Residential	2.32	0.20	0.96	0.19
BMP907	79 Worcester Ln		2939	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP908	775 Trapelo Rd	Infiltration Trench	395959	1.02	Forest	1.52	13.82	0.96	13.26
BMP86	53 Glen Cir	Infiltration Trench	2808	0.17	Medium Density Residential	1.96	0.13	0.90	0.11
BMP91	12,14 Day St		3164	1.02	Multi-Family Residential	2.32	0.17	0.96	0.16
BMP910	22 Ellery Rd	Infiltration Trench	847	1.02	High Density Residential	2.32	0.05	0.96	0.04
BMP911	73 Hawthorne Rd	Infiltration Trench	1498	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP912	77 Hawthorne Rd	Infiltration Trench	1498	1.02	High Density Residential	2.32	0.08	0.96	0.08
BMP914	75 Wildwood Ln		637	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP916	59 Plympton St		3008	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP917	500 Beaver St	Infiltration Trench	34151	0.52	Urban Public/Institutional	1.78	1.40	0.94	1.31
BMP918	27 Cheryl Ln	Infiltration Trench	345	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP92	152-154 Willow St		5810	1.02	Multi-Family Residential	2.32	0.31	0.96	0.30
BMP920	17-21 Alder St	Infiltration Trench	5996	0.27	Multi-Family Residential	2.32	0.32	0.92	0.29
BMP921	33 Curve St	Infiltration Trench	1211	1.02	Medium Density Residential	1.96	0.05	0.96	0.05
BMP922	203 Florence Rd	Infiltration Trench	441	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP923	117 Temple Rd		509	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP924	123 Beal Rd	Infiltration Trench	450	1.02	High Density Residential	2.32	0.02	0.96	0.02
BMP925	71 Bennett St	Infiltration Trench	2596	1.02	High Density Residential	2.32	0.14	0.96	0.13
BMP926	105 Edgewater Dr	Infiltration Trench	2542	1.02	Medium Density Residential	1.96	0.11	0.96	0.11
BMP927	70 Briarwood Rd	Infiltration Trench	196	1.02	High Density Residential	2.32	0.01	0.96	0.01
BMP928	87 Bowdoin Ave	Infiltration Trench	1220	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP929	80 Princeton Ave		1188	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP93	30 Addison Rd	Infiltration Trench	576	1.02	High Density Residential	2.32	0.03	0.96	0.03
BMP930	82 Princeton Ave		1188	1.02	High Density Residential	2.32	0.06	0.96	0.06
BMP931	66 Crestview Rd	Infiltration Trench	466	0.27	Medium Density Residential	1.96	0.02	0.92	0.02
BMP932	34 Abbott Rd	Infiltration Trench	2930	1.02	High Density Residential	2.32	0.16	0.96	0.15
BMP933	60 Newton St		10613	1.02	Urban Public/Institutional	1.78	0.43	0.96	0.42

BMP ID	BMP Address	BMP Type	Impervious Area Draining to BMP (SF)	Infiltration Rate (in/hr)	Land Use Type	PLER (lb/acre/year)	Phosphorus Loaad to BMP (lb/year)	Treatment Efficiency at 1" Storm (%)	Phosphorus Credit (lb/year)
BMP934	756 Moody St		7642	0.27	Commercial	1.78	0.31	0.92	0.29
BMP936	41 Amherst Ave	Infiltration Trench	1294	1.02	High Density Residential	2.32	0.07	0.96	0.07
BMP937	35 Ash St	Infiltration Trench	2227	0.27	High Density Residential	2.32	0.12	0.92	0.11
BMP95	90 Grant St	Infiltration Trench	3434	1.02	High Density Residential	2.32	0.18	0.96	0.18
BMP97	42 Bowker Rd	Infiltration Trench	902	1.02	High Density Residential	2.32	0.05	0.96	0.05
BMP98	201 Mokema Ave		252	0.27	High Density Residential	2.32	0.01	0.92	0.01
BMP99	100 Bedford St	Infiltration Trench	4393	1.02	High Density Residential	2.32	0.23	0.96	0.22

Total Credit (lb/year)	140.40

Appendix E: City-Owned Property Structural BMP Load Calculations

BMP Number	BMP Address	BMP Type	Impervious Area Draining to BMP (ac)	Site Infiltration Rate (in/hr)	Land Use Type	Site PLER (lb/ac/year)	Phosphorus Load Draining to BMP (lb/year)	Treatment Efficiency for 1" Storm (%)	Phosphorus Credit (lb/year)
BMP-10	250 South Street	Wet Pond	1.73	0.27	Urban Public/Institutional	1.78	3.07	0.53	1.63
BMP-11	250 South Street	Infiltration Trench	1.73	0.27	Urban Public/Institutional	1.78	3.07	0.92	2.82
BMP-12	75 Chruch Street	Infiltration Trench	4.17	0.27	Participation Recreation	1.52	6.34	0.92	5.83
BMP-13	655 Lexington Street	Infiltration Trench	2.18	0.27	Urban Public/Institutional	1.78	3.89	0.92	3.58
BMP-14	655 Lexington Street	Infiltration Trench	2.18	0.27	Urban Public/Institutional	1.78	3.89	0.92	3.58
BMP-167	901 Trapelo Road	Infiltration Trench	0.22	0.27	Participation Recreation	1.52	0.34	0.92	0.31
BMP-168	901 Trapelo Road	Infiltration Trench	0.22	0.27	Participation Recreation	1.52	0.34	0.92	0.31
BMP-169	901 Trapelo Road	Infiltration Trench	0.22	0.27	Participation Recreation	1.52	0.34	0.92	0.31
BMP-178	36B Pine Vale Road	Bioretention	0.24	0.27	Participation Recreation	1.52	0.37	0.53	0.20
BMP-179	36B Pine Vale Road	Bioretention	0.24	0.27	Participation Recreation	1.52	0.37	0.53	0.20
BMP-180	36B Pine Vale Road	Infiltration Trench	0.24	0.27	Participation Recreation	1.52	0.37	0.92	0.34
BMP-181	36B Pine Vale Road	Infiltration Trench	0.24	0.27	Participation Recreation	1.52	0.37	0.92	0.34
BMP-182	36B Pine Vale Road	Infiltration Trench	0.24	0.27	Participation Recreation	1.52	0.37	0.92	0.34
BMP-183	36B Pine Vale Road	Infiltration Trench	0.24	0.27	Participation Recreation	1.52	0.37	0.92	0.34
BMP-184	210 Waverley Oaks road	Infiltration Trench	0.56	0.27	Participation Recreation	1.52	0.84	0.92	0.78
BMP-185	210 Waverley Oaks road	Infiltration Trench	0.56	0.27	Participation Recreation	1.52	0.84	0.92	0.78
BMP-189	90 Hall Street	Infiltration Trench	0.69	0.27	Urban Public/Institutional	1.78	1.23	0.92	1.13
BMP-190	93 Winter Street	Infiltration Trench	0.13	1.02	High Density Residential	2.32	0.30	0.96	0.29
BMP-21	70 Putney Lane	Infiltration Trench	2.06	1.02	Urban Public/Institutional	1.78	3.66	0.96	3.51
BMP-22	655 Lexington Street	Wet Pond	2.18	0.27	Urban Public/Institutional	1.78	3.89	0.53	2.06
BMP-243	533 Moody Street	Infiltration Trench	0.45	0.27	Urban Public/Institutional	1.78	0.80	0.92	0.73
BMP-27	30 Parmenter Road	Infiltration Trench	1.07	0.27	Urban Public/Institutional	1.78	1.90	0.92	1.74
BMP-28	30 Parmenter Road	Infiltration Trench	1.07	0.27	Urban Public/Institutional	1.78	1.90	0.92	1.74
BMP-308	494 Main Street	Infiltration Trench	1.03	0.27	Multi-Family Residential	2.32	2.39	0.92	2.20
BMP-323	Elsie Turner Field - Trapelo Road	Bioretention	0.16	0.27	Participation Recreation	1.52	0.25	0.53	0.13
BMP-324	Elsie Turner Field - Trapelo Road	Bioretention	0.16	0.27	Participation Recreation	1.52	0.25	0.53	0.13
BMP-325	Elsie Turner Field - Trapelo Road	Bioretention	0.16	0.27	Participation Recreation	1.52	0.25	0.53	0.13
BMP-326	Elsie Turner Field - Trapelo Road	Bioretention	0.16	0.27	Forest	1.52	0.25	0.53	0.13
BMP-327	Elsie Turner Field - Trapelo Road	Bioretention	0.16	0.27	Participation Recreation	1.52	0.25	0.53	0.13
BMP-337	155-177 Lexington Street	Wet Pond	6.79	0.27	Industrial	1.78	12.09	0.53	6.41
BMP-343	25 Hillcroft Road	Infiltration Trench	0.45	0.27	Medium Density Residential	1.96	0.89	0.92	0.82
BMP-344	38 Gorham Street	Infiltration Trench	0.03	0.27	Multi-Family Residential	2.32	0.06	0.92	0.05
BMP-345	38 Gorham Street	Infiltration Trench	0.03	0.27	Multi-Family Residential	2.32	0.06	0.92	0.05
BMP-346	14 Ash Street	Infiltration Trench	0.10	0.27	Urban Public/Institutional	1.78	0.18	0.92	0.16
BMP-347	14 Ash Street	Bioretention	0.10	0.27	Urban Public/Institutional	1.78	0.18	0.53	0.09
BMP-348	90 Charlotte Road	Infiltration Trench	0.61	0.27	Participation Recreation	1.52	0.93	0.92	0.85
BMP-349	90 Charlotte Road	Infiltration Trench	0.61	0.27	Participation Recreation	1.52	0.93	0.92	0.85
BMP-350	3 Hazel Street	Infiltration Trench	0.64	0.27	Participation Recreation	1.52	0.97	0.92	0.89
BMP-351	25 Intervale Road	Infiltration Trench	0.22	1.02	Spectator Recreation	1.52	0.33	0.96	0.32
BMP-352	25 Intervale Road	Infiltration Trench	0.22	1.02	Spectator Recreation	1.52	0.33	0.96	0.32
BMP-353	20 Sunnyside Street	Infiltration Trench	0.69	1.02	Participation Recreation	1.52	1.05	0.96	1.01
BMP-354	65 Dartmouth Street	Infiltration Trench	0.76	0.27	Participation Recreation	1.52	1.15	0.92	1.06
BMP-355	65 Dartmouth Street	Infiltration Trench	0.76	0.27	Participation Recreation	1.52	1.15	0.92	1.06
BMP-356	65 Dartmouth Street	Infiltration Trench	0.76	0.27	Participation Recreation	1.52	1.15	0.92	1.06
BMP-357	65 Dartmouth Street	Infiltration Trench	0.76	0.27	Participation Recreation	1.52	1.15	0.92	1.06
BMP-358	314 Totten Pond Road	Bioretention	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.53	0.84
BMP-359	314 Totten Pond Road	Bioretention	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.53	0.84
BMP-360	314 Totten Pond Road	Bioretention	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.53	0.84
BMP-361	314 Totten Pond Road	Bioretention	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.53	0.84

BMP Number	BMP Address	BMP Type	Impervious Area Draining to BMP (ac)	Site Infiltration Rate (in/hr)	Land Use Type	Site PLER (lb/ac/year)	Phosphorus Load Draining to BMP (lb/year)	Treatment Efficiency for 1" Storm (%)	Phosphorus Credit (lb/year)
BMP-362	314 Totten Pond Road	Bioretention	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.53	0.84
BMP-363	314 Totten Pond Road	Bioretention	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.53	0.84
BMP-364	314 Totten Pond Road	Infiltration Trench	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.92	1.45
BMP-365	314 Totten Pond Road	Infiltration Trench	0.89	0.27	Urban Public/Institutional	1.78	1.58	0.92	1.45
BMP-368	190 Trapelo Road	Wet Pond	4.11	0.27	Urban Public/Institutional	1.78	7.32	0.53	3.88
BMP-369	70 Putney Lane	Wet Pond	2.09	1.02	Forest	1.52	3.18	0.53	1.68
BMP-370	385 Forest Street	Wet Pond	1.93	0.27	Urban Public/Institutional	1.78	3.44	0.53	1.82
BMP-371	385 Forest Street	Wet Pond	1.93	0.27	Urban Public/Institutional	1.78	3.44	0.53	1.82
BMP-71	138 Beal Road	Wet Pond	1.30	1.02	Participation Recreation	1.52	1.98	0.53	1.05
LS-193	No Address in GIS	Infiltration Trench	0.12	0.27	Participation Recreation	1.52	0.18	0.92	0.17
LS-194	No Address in GIS	Infiltration Trench	0.12	0.27	Participation Recreation	1.52	0.18	0.92	0.17
LS-195	No Address in GIS	Infiltration Trench	0.07	0.27	Participation Recreation	1.52	0.10	0.92	0.10
LS-196	No Address in GIS	Infiltration Trench	0.07	0.27	Participation Recreation	1.52	0.10	0.92	0.10
LS-211	No Address in GIS	Infiltration Trench	0.06	0.27	Participation Recreation	1.52	0.09	0.92	0.08
LS-212	No Address in GIS	Infiltration Trench	0.01	0.27	Multi-Family Residential	2.32	0.03	0.92	0.02
LS-213	No Address in GIS	Infiltration Trench	0.01	0.27	Multi-Family Residential	2.32	0.03	0.92	0.02
LS-214	No Address in GIS	Infiltration Trench	0.01	0.27	Multi-Family Residential	2.32	0.03	0.92	0.02
LS-215	No Address in GIS	Infiltration Trench	0.01	0.27	Multi-Family Residential	2.32	0.03	0.92	0.02
LS-216	No Address in GIS	Infiltration Trench	0.01	0.27	Multi-Family Residential	2.32	0.03	0.92	0.02

Total Credit (lb/year) 70.70

Appendix F - 1: Proposed Structural BMP

Monsignor McCabe Playground

City of Waltham Phosphorus Control Plan

Structural BMP Conceptual Design Packet

for

Monsignor McCabe Playground

A subsurface infiltration system is proposed at the Monsignor McCabe Playground located north of Candace Avenue between Mayall Road and Charlotte Road. Monsignor McCabe Playground is a multi-use park with baseball fields, tennis courts, a basketball court, a playground, and a spray park. The public property is located west of the James Fitzgerald Elementary School. The project area is shown in Figure 1.

The subsurface infiltration system would be in the outfield of the northern baseball field and would divert stormwater from an existing drain manhole located in Charlotte Road. A diversion structure may be needed in the manhole for stormwater to preferentially flow to the infiltration chambers.

The tributary area upstream of the diversion manhole is approximately 23.45 acres. A map of the drainage area is provided in Figure 2. The surface of the drainage area is 39% impervious. The land use of the drainage area is a mix of high-density residential and commercial.

The conceptual design proposes installing a new pretreatment structure off Charlotte Road upstream of the underground infiltration chambers. The new pretreatment structure is located off the road and between two sidewalks, which should improve ease of access for maintenance vehicles.

The final design should consider the following elements that are not incorporated into the conceptual design:

- Establish an isolator row in the infiltration chambers to improve ease of maintenance.
- Install a manhole where the pipe enters the infiltration chambers to provide access for cleaning out the isolator row. The manhole should be located in a place accessible to maintenance vehicles which may require moving the chambers to another location in the field.
- Install a hydraulic relief line that diverts flow to an existing storm drain when the water surface reaches the top of the chambers.

According to NRCS soil data, the hydrologic soil group in the project area is unknown. Geotechnical investigations are required to determine the suitability of the soil for infiltration and the depth to the high groundwater level. At a minimum, the soil infiltration rate must be at least 0.17 in/hr and the depth from the bottom of the infiltration chamber to the high groundwater level should be at least two feet. The infiltration chambers should be designed to completely infiltrate within 72 hours.

The annual phosphorus load exported from the drainage area was estimated using the methodology provided in Appendix F, Attachment 3 of the 2016 MS4 Permit. The annual phosphorus load is estimated to be 22.30 lb/yr (see Tables 2 to 4).

The conceptual design maximizes the number of underground infiltration chambers that could fit in the field. The infiltration chambers are capable of storing the stormwater runoff volume for storms up to 1.0-inch in depth (see Tables 2 to 6).

Brown AND Caldwell

The treatment efficiency of the infiltration chambers was estimated using Table 3-7 of Appendix F, Attachment 3 of the 2016 MS4 Permit. It was assumed that the infiltration rate for the project site is 0.17 in/hr as a conservative estimate. With a design volume equivalent to the 1-inch storm, the treatment efficiency is estimated to be 90%. As a result, it is estimated that the underground infiltration chambers will remove 20.07 lb/yr (see Table 11).

The conceptual design is preliminary in nature. Additional data needs to be collected and analysis performed during preliminary design to finalize design parameters. The location and size of all existing utilities have not been verified. Engineering analysis and geotechnical investigations are required prior to final design and may result in significant changes to the conceptual design. Modeling is also recommended to further evaluate the hydraulics of the proposed system.

A conceptual opinion of probable construction cost, probable annual operational cost, and probable 20-year life cycle costs were prepared for the project. The opinion of probable construction cost is considered a Level 4 estimate as defined by AACE International, and as such, has an expected range (after application of contingency; 30 percent was applied) of -20 percent to +40 percent. The estimated construction cost of the project is $2,010,700 ($1,608,600 to $2,815,000). The estimated annual O&M cost is 2% of the construction cost or $40,300 ($32,300 to $56,500). Over the course of 20 years, the cost of the stormwater BMP is estimated to be $2,816,700 ($2,253,400 to $3,943,400). Based on these costs and the aforementioned annual phosphorus removal rate, it is estimated that over the course of 20 years, the total cost (construction and O&M) of removing each pound of phosphorus will be $7,100 ($5,700 to $10,000). See Tables 12 to 15.

Table 1. Monsignor McCabe Playground Summary	
Drainage Area Characteristics	
Area	23.45 acres
Percent Impervious	39%
Estimated Annual Phosphorus Export Load	22.30 lb/yr
Proposed BMP	
Technology	Underground infiltration chambers
Runoff Volume	1.0-inch storm
Treatment Volume	40,198 CF
Estimated Phosphorus Treatment Efficiency	90%
Estimated Annual Phosphorus Removal	20.07 lb/yr
Cost Estimate[1]	
Total Construction Cost	$2,010,700
Total Construction Cost AACE Class 4 Cost Range (2023 Dollars)[1]	$1,608,600 to $2,815,000
Annual O&M[2]	$40,300
20-Year Life Cycle Cost	$2,816,700
Construction Dollars Per Acre of Drainage Area	$85,800
Construction Dollars Per Annual Pound of Phosphorus Removed	$100,300
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$7,100

Notes:

1. *AACE Class 4 cost estimate. Its expected accuracy range is -20% to +40%. The cost estimate was developed in June 2023.*
2. *Annual O&M was estimated at 2% of the total construction cost.*

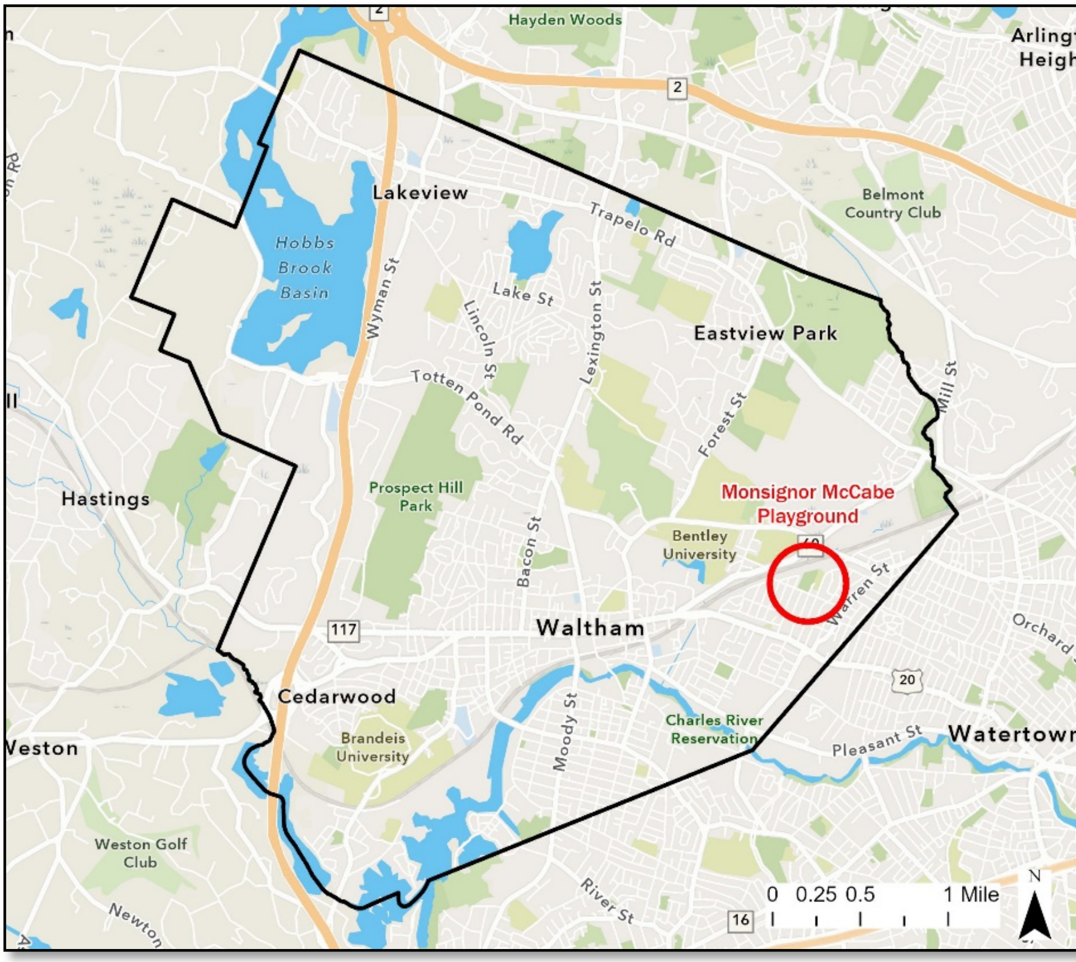

Figure 1. Monsignor McCabe Playground Study Area Map

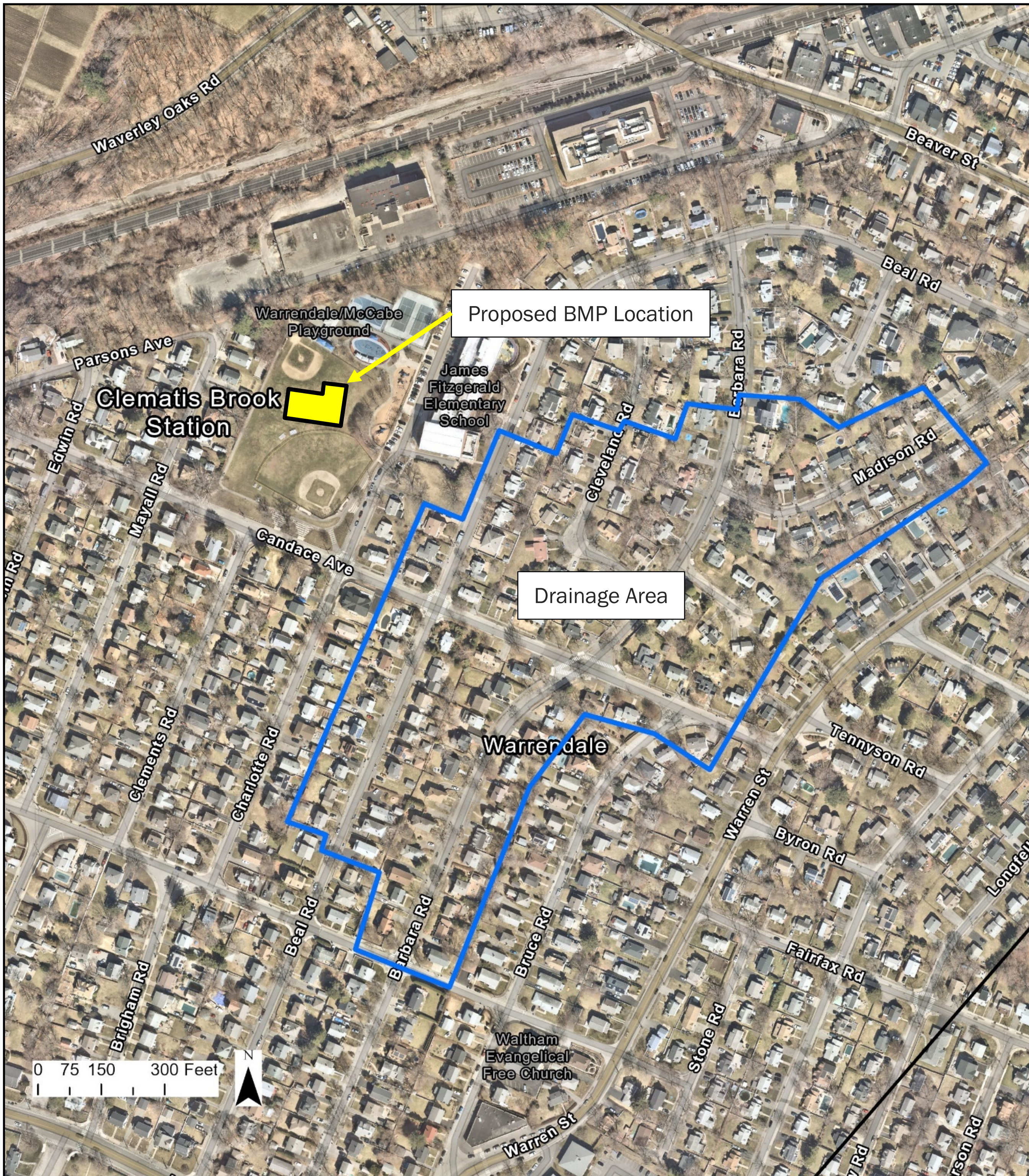

Figure 2. Monsignor McCabe Playground Drainage Area Map

City of Waltham Phosphorus Control Plan Phase 1
McCabe Playground - Stormwater BMP Calculations

Drainage Area Annual Phosphorus Export Load

Table 2. Phosphorus Export Load: Directly Connected Impervious Area			
Land use	Impervious Area (ac)	Phosphorus Export Rate[1] (lb/ac-yr)	Phosphorus Export (lb/yr)
Commercial	0.08	1.78	0.14
High-Density Residential	7.62	2.32	17.69
Total	7.70		17.83

Notes:
1. Phosphorus export rates from 2016 MS4 Permit, Appendix F, Attachment 3, Table 3-1.

Table 3. Phosphorus Export Load: Pervious Areas (and Impervious Areas that are Not Directly Connected)				
Land use	Hydrologic Soil Group	Area (ac)	Phosphorus Export Rate[1] (lb/ac-yr)	Phosphorus Export (lb/yr)
Commercial	B	0.00074	0.17	0.00
	Unknown	0.00	0.36	0.00
	Not Directly Connected	0.00	0.17	0.00
High-Density Residential	B	5.74	0.17	1.00
	Unknown	8.48	0.36	3.03
	Not Directly Connected	1.53	0.28	0.43
Total		15.75		4.47

Notes:
1. Phosphorus export rates from 2016 MS4 Permit, Appendix F, Attachment 3, Table 3-1.

Table 4. Total Annual Phosphorus Export Load		
Area Type	Area (ac)	Phosphorus Export (lb/yr)
Directly Connected Impervious Area	7.70	17.83
Pervious Areas (and Impervious Areas that are Not Directly Connected)	15.75	4.47
Total Annual Phosphorus Export Load[1] =	23.45	22.30

Notes:
1. Total annual phosphorus export load is the sum of the annual phosphorus export load from the directly connected areas and the pervious areas.

Drainage Area Runoff

Table 5. Runoff Estimates for Storms		
Rainfall (in)	Runoff Volume[1]	
	(cf)	(ac-ft)
0.1	3,351	0.08
0.2	7,316	0.17
0.4	14,941	0.34
0.5	19,115	0.44
0.6	23,289	0.53
0.8	31,122	0.71
1	39,570	0.91 <-- Design Volume
1.2	49,557	1.14
1.5	69,475	1.59
2	98,983	2.27

Notes:
1. Runoff volume were calculated according to the procedures contained in 2016 MS4 Permit, Appendix F, Attachment 3.

Table 6. Source Data for Runoff Calculations	
Surface Type	Area (ac)
Impervious	9.23
Pervious Areas	
Hydrologic Soil Group B	5.74
Hydrologic Soil Group Unknown[1]	8.48
Total Pervious Areas	14.22

Notes:
1. Unknown hydrologic soil groups are assumed to have hydrologic properties similar to type C soils.

Subsurface Infiltration System

Table 7. Infiltration System Dimensions	
Approx. Area - Bed Size (sf)	18,543
Approx. Length - Longest Side (ft)	180
Approx. Width - Longest Side (ft)	125

Table 8. Elevations (ft, NAVD88)	
Ground Elev. At Park	59
Top of Chamber	53.1
Bottom of Chamber	50.6
High Groundwater (est.)	48.6

Table 9. Excavation and Material Volumes	
Excavation Volume (cy)	2,404
Stone Volume (cy)	1,525
Stone Porosity	40%
Average Cover Over Chambers (in)	18

Table 10. Infiltration System Information	
Infiltration Device	StormTech SC-740
Height (in)	30
Number of Chambers	517
Number of Rows	26
Stone Above (in)	6
Stone Below (in)	6
Storage Volume per Chamber (CF/chamber)	74.5
Total Installed Storage (cf)	40,198
Est. Infiltration Rate (in/hr)	0.17

Table 11. Infiltration System Treatment	
Total Load to Site (lb/yr)	22.30
Treatment Volume (cf)	40,198
Size Storm Treated (in)	1
Infiltration Rate (in/hr)	0.17
Treatment Efficiency	90%
Phosphorus Removed (lb/yr)	20.07

City of Waltham Phosphorus Control Plan Phase 1
McCabe Playground - Cost Estimate

Table 12. Planning Level Cost Estimate - Monsignor McCabe Playground					
Description	Quantity	Unit Type	Unit Cost	Base[2]	Notes
Road replacement	502	SF	$15.00	$7,530	
Asphalt walking path replacement	797	SF	$9.00	$7,173	
Misc. baseball field improvements	1	LS	$5,000.00	$5,000	
Medium pretreatment device	1	EA	$50,000.00	$50,000	
Sod	28,913	SF	$1.30	$37,587	
StormTech SC-740 infiltration chambers (includes delivery to site, excavation, installation, materials)	40,198	CF	$15.00	$602,970	Quote from ADS 6/28/23
24" RCP	160	LF	$150.00	$24,000	
Fencing replacement	1	LS	$5,000.00	$5,000	
Total				$739,260	

Table 13. Total Cost Estimate				
Line Item	Cost	Percentage	Value	Notes
1	Base construction		$739,260	
2	Erosion and sediment control	5%	$36,963	5% of Item 1
3	Mobilization/demobilization	10%	$73,926	10% of Item 1
	Subtotal		$850,149	
4	Contingency	30%	$255,045	30% of Items 1-3
	Subtotal		$1,105,194	
5	Survey, geotech, permitting	5%	$55,260	5% of Items 1-5
6	Construction services	0%	$0	0% of Items 1-5
Total Construction Cost			$2,010,700	Sum of Items 1-6
AACE Class 4 Cost Estimate Range (-20% to +40%)[3]			$1,608,600 to $2,815,000	

COST ESTIMATE NOTES:
1. All costs in 2023 dollars.
2. Includes labor and materials.
3. This estimate of probable construction cost is considered a Class 4 estimate as defined by AACE International and as such has an expected range (after application of contingency, 30% used) of -20% to +40%. This estimate assumes a competitive bid situation and is an estimate of fair market value, and is not an estimate of the anticipated low bid. Brown and Caldwell has no control over the cost of labor and materials, the contractor's method of bidding, market conditions, or the time of bidding. Brown and Caldwell cannot and does not guarantee that actual construction costs will not vary from this estimate.

Table 14. 20-Year Life-Cycle Cost	
Total Construction Cost	$2,010,700
Annual O&M	$40,300
20-Year Life Cycle Cost	$2,816,700

Table 15. Cost-Effectiveness	
Construction Dollars Per Acre of Drainage Area	$85,800
Construction Dollars Per Annual Pound of Phosphorus Removed	$100,300
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$7,100

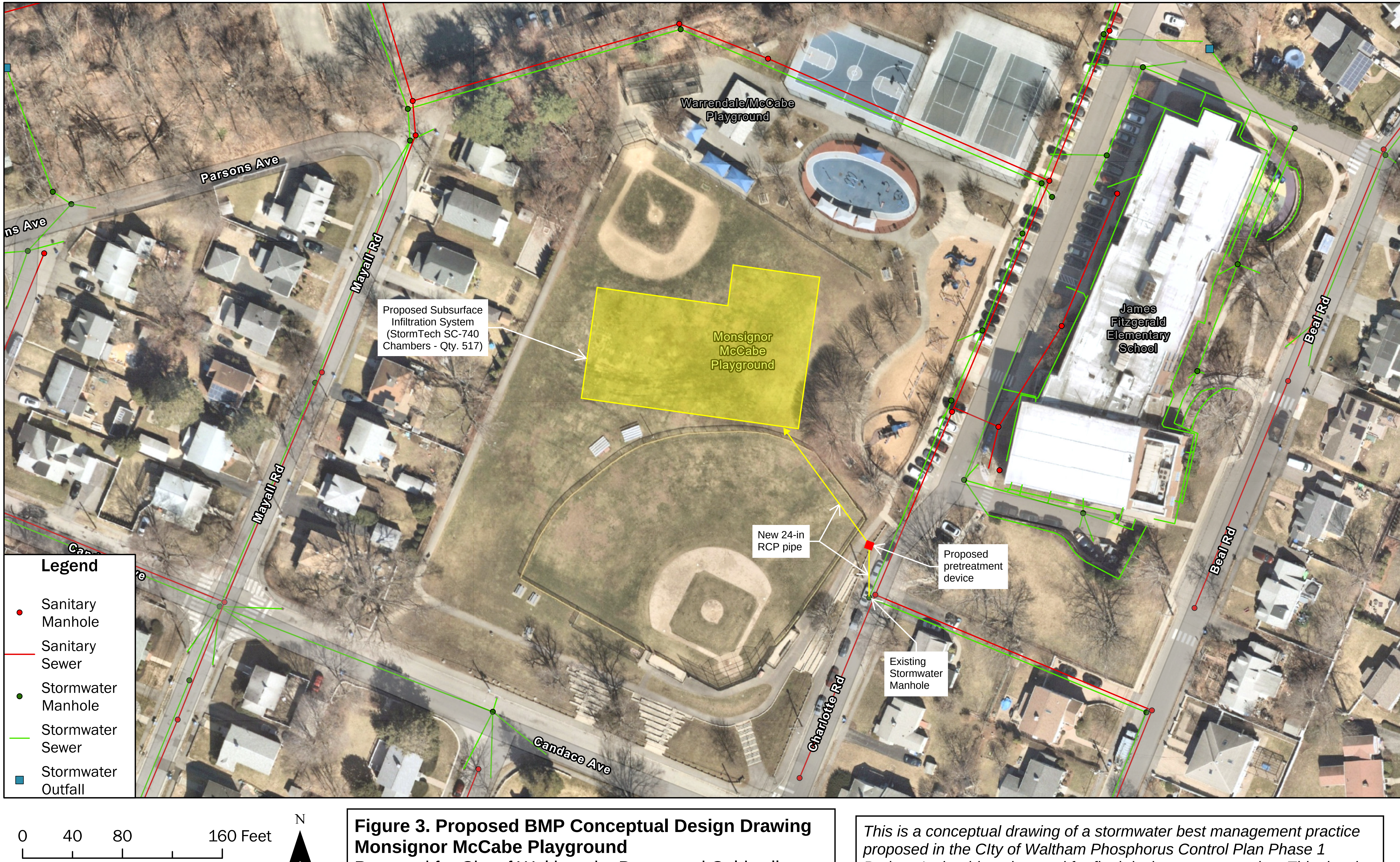

Figure 3. Proposed BMP Conceptual Design Drawing Monsignor McCabe Playground
Prepared for City of Waltham by Brown and Caldwell
June 2023

This is a conceptual drawing of a stormwater best management practice proposed in the CIty of Waltham Phosphorus Control Plan Phase 1 Project. It should not be used for final design or construction. This drawing is subject to the limitations in the Phosphorus Control Plan.

Appendix F - 2: Proposed Structural BMP

Bobby Connors Playground

City of Waltham Phosphorus Control Plan

Structural BMP Conceptual Design Packet

for

Bobby Connors Playground

A subsurface infiltration system is proposed at the public property Bobby Connors Playground located south of Sunnyside Street between Morton Street and South Street. Bobby Connors Playground is a multi-use park with a small baseball/softball field, basketball court, playground, spray park. The project area is shown in Figure 1.

The subsurface infiltration system would be in the open field area and would divert stormwater from an existing drain manhole located in Sunnyside Street. A weir would increase the water surface elevation in the manhole so that stormwater can flow by gravity to the subsurface infiltration system.

The tributary area upstream of the manhole is approximately 16.34 acres. A map of the drainage area is provided in Figure 2. The surface of the drainage area is 38% impervious. The land use of the drainage area is a mix of high-density residential, medium-density residential, forest, and open land.

The conceptual design proposes installing a new pretreatment structure off Sunnyside Street upstream of the underground infiltration chambers. The new pretreatment structure is located next to the sidewalk inside the park fence with a gate, which should improve ease of access for maintenance vehicles.

A manhole is proposed where the pipe enters the chambers. The manhole will provide an access point for cleaning the isolator row of the infiltration chambers. A relief pipe is proposed that connects the manhole next to the infiltration chambers to the storm drain in South Street. The purpose of the relief pipe is to prevent surcharging of the chambers. The invert of the upstream end of the relief pipe should be approximately the same elevation as the top of chambers, that way if the water surface reaches the top of the chambers, excess water can drain to the stormwater pipe in South Street, helping to ensure that the water surface does not climb above the top of the chambers.

According to NRCS soil data, the hydrologic soil group in the project area is a mix of hydrologic soil group A and unknown. Geotechnical investigations are required to determine the suitability of the soil for infiltration and the depth to the high groundwater level. At a minimum, the soil infiltration rate must be at least 0.17 in/hr and the depth from the bottom of the infiltration chamber to the high groundwater level should be at least two feet. The infiltration chambers should be designed to completely infiltrate within 72 hours.

The annual phosphorus load exported from the drainage area was estimated using the methodology provided in Appendix F, Attachment 3 of the 2016 MS4 Permit. The annual phosphorus load is estimated to be 14.34 lb/yr (see Tables 2 to 4).

The conceptual design maximizes the number of underground infiltration chambers that could fit in the field. The infiltration chambers are capable of storing the stormwater runoff volume for storms up to 1.0-inch in depth (see Tables 2 to 6).

The treatment efficiency of the infiltration chambers was estimated using Table 3-7 of Appendix F, Attachment 3 of the 2016 MS4 Permit. It was assumed that the infiltration rate for the project site is 0.17 in/hr as a conservative estimate. With a design volume equivalent to the 1-inch storm, the treatment efficiency is estimated to be 90%. As a result, it is estimated that the underground infiltration chambers will remove 12.91 lb/yr (see Table 11).

The conceptual design is preliminary in nature. Additional data needs to be collected and analysis performed during preliminary design to finalize design parameters. The location and size of all existing utilities have not been verified. Engineering analysis and geotechnical investigations are required prior to final design and may result in significant changes to the conceptual design. Modeling is also recommended to further evaluate the hydraulics of the proposed system.

A conceptual opinion of probable construction cost, probable annual operational cost, and probable 20-year life cycle costs were prepared for the project. The opinion of probable construction cost is considered a Level 4 estimate as defined by AACE International, and as such, has an expected range (after application of contingency; 30 percent was applied) of -20 percent to +40 percent. The estimated construction cost of the project is $1,550,500 ($1,244,400 to $2,177,700). The estimated annual O&M cost is 2% of the construction cost or $31,200 ($25,000 to $43,700). Over the course of 20 years, the cost of the stormwater BMP is estimated to be $2,179,500 ($1,743,600 to $3,051,300). Based on these costs and the aforementioned annual phosphorus removal rate, it is estimated that over the course of 20 years, the total cost (construction and O&M) of removing each pound of phosphorus will be $8,500 ($6,800 to $11,900). See Tables 12 to 15.

Table 1. Bobby Connors Playground Summary	
Drainage Area Characteristics	
Area	16.34 acres
Percent Impervious	38%
Estimated Annual Phosphorus Export Load	14.34 lb/yr
Proposed BMP	
Technology	Underground infiltration chambers
Runoff Volume	1.0-inch storm
Treatment Volume	28,821 CF
Estimated Phosphorus Treatment Efficiency	90%
Estimated Annual Phosphorus Removal	12.91 lb/yr
Cost Estimate[1]	
Total Construction Cost	$1,555,500
Total Construction Cost AACE Class 4 Cost Range (2023 Dollars)[1]	$1,244,400 to $2,177,700
Annual O&M[2]	$31,200
20-Year Life Cycle Cost	$2,179,500
Construction Dollars Per Acre of Drainage Area	$95,200
Construction Dollars Per Annual Pound of Phosphorus Removed	$120,600
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$8,500

Notes:

1. *AACE Class 4 cost estimate. Its expected accuracy range is -20% to +40%. The cost estimate was developed in June 2023.*
2. *Annual O&M was estimated at 2% of the total construction cost.*

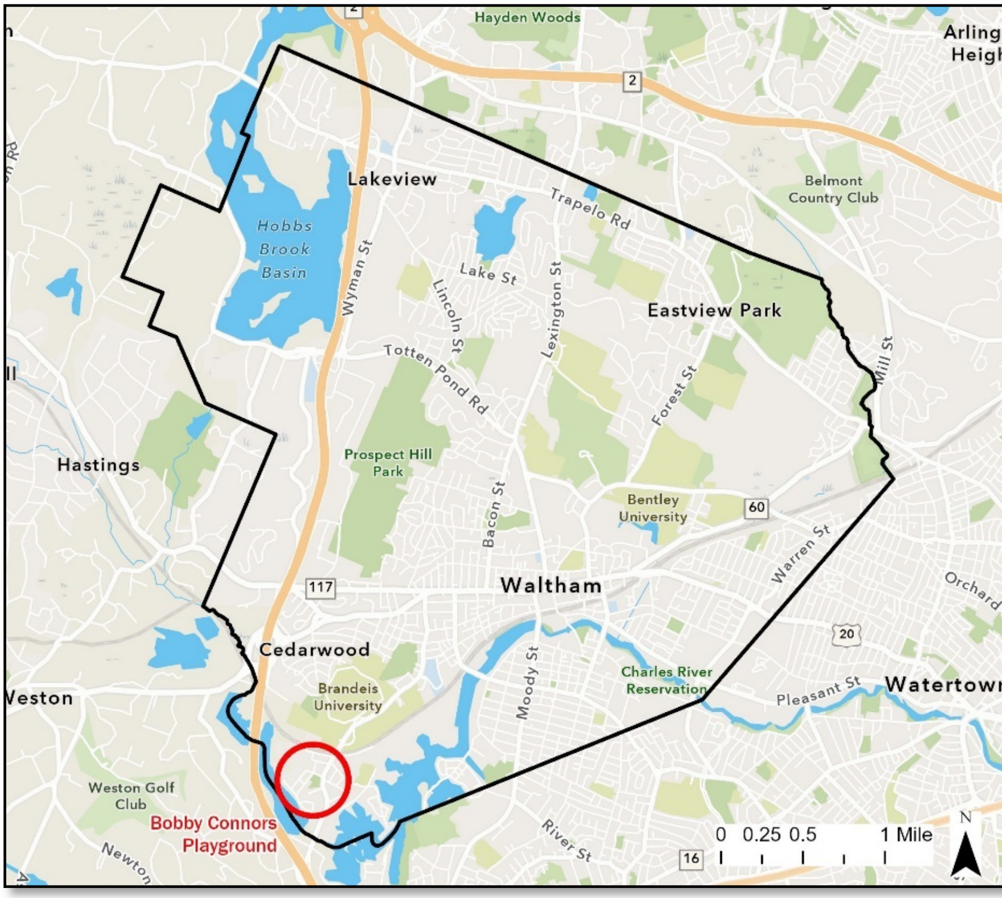

Figure 1. Bobby Connors Playground Study Area Map

Figure 2. Bobby Connors Playground Drainage Area Map

City of Waltham Phosphorus Control Plan Phase 1
Bobby Connors Playground - Stormwater BMP Calculations

Drainage Area Annual Phosphorus Export Load

Table 2. Phosphorus Export Load: Directly Connected Impervious Area

Land use	Impervious Area (ac)	Phosphorus Export Rate[1] (lb/ac-yr)	Phosphorus Export (lb/yr)
High-Density Residential	3.95	2.32	9.17
Medium-Density Residential	0.55	1.96	1.07
Forest	0.11	1.52	0.17
Open Land	0.17	1.52	0.25
Total	4.77		10.66

Notes:
1. Phosphorus export rates from 2016 MS4 Permit, Appendix F, Attachment 3, Table 3-1.

Table 3. Phosphorus Export Load: Pervious Areas (and Impervious Areas that are Not Directly Connected)

Land use	Hydrologic Soil Group	Area (ac)	Phosphorus Export Rate[1] (lb/ac-yr)	Phosphorus Export (lb/yr)
High-Density Residential	A	0.90	0.04	0.04
	C/D	1.24	0.45	0.56
	Unknown	5.53	0.36	1.98
	Not Directly Connected	0.81	0.34	0.27
Medium-Density Residential	A	0.00	0.04	0.00
	C/D	0.07	0.45	0.03
	Unknown	0.97	0.36	0.35
	Not Directly Connected	0.28	0.36	0.10
Forest	A	0.13	0.11	0.01
	C/D	0.44	0.21	0.09
	Unknown	0.20	0.19	0.04
	Not Directly Connected	0.24	0.19	0.04
Open Land	A	0.28	0.04	0.01
	C/D	0.00	0.45	0.00
	Unknown	0.34	0.36	0.12
	Not Directly Connected	0.13	0.22	0.03
Total		11.56		3.68

Notes:
1. Phosphorus export rates from 2016 MS4 Permit, Appendix F, Attachment 3, Table 3-1.

Table 4. Total Annual Phosphorus Export Load

Area Type	Area (ac)	Phosphorus Export (lb/yr)
Directly Connected Impervious Area	4.77	10.66
Pervious Areas (and Impervious Areas that are Not Directly Connected)	11.56	3.68
Total Annual Phosphorus Export Load[1] =	16.34	14.34

Notes:
1. Total annual phosphorus export load is the sum of the annual phosphorus export load from the directly connected areas and the pervious areas.

Drainage Area Runoff

Table 5. Runoff Estimates for Storms

Rainfall (in)	Runoff Volume[1] (cf)	Runoff Volume[1] (ac-ft)	
0.1	2,263	0.05	
0.2	5,164	0.12	
0.4	10,647	0.24	
0.5	13,548	0.31	
0.6	16,496	0.38	
0.8	22,027	0.51	
1	28,196	0.65	<-- Design Volume
1.2	35,961	0.83	
1.5	51,877	1.19	
2	74,329	1.71	

Notes:
1. Runoff volume were calculated according to the procedures contained in 2016 MS4 Permit, Appendix F, Attachment 3.

Table 6. Source Data for Runoff Calculations

Surface Type	Area (ac)
Impervious	6.23
Pervious Areas	
Hydrologic Soil Group A	1.31
Hydrologic Soil Group C/D	1.75
Hydrologic Soil Group Unknown[1]	7.04
Total Pervious Areas	10.11

Notes:
1. Unknown hydrologic soil groups are assumed to have hydrologic properties similar to type C soils.

Subsurface Infiltration System

Table 7. Infiltration System Dimensions

Approx. Area - Bed Size (sf)	13,407
Approx. Length - Longest Side (ft)	140
Approx. Width - Longest Side (ft)	100

Table 8. Elevations (ft, NAVD88)

Ground Elev. At Park	79
Top of Chamber	73.5
Bottom of Chamber	71
High Groundwater (est.)	69

Table 9. Excavation and Material Volumes

Excavation Volume (cy)	1,738
Stone Volume (cy)	1,118
Stone Porosity	40%
Average Cover Over Chambers (in)	18

Table 10. Infiltration System Information

Infiltration Device	StormTech SC-740
Height (in)	30
Number of Chambers	365
Number of Rows	29
Stone Above (in)	6
Stone Below (in)	6
Storage Volume per Chamber (CF/chamber)	74.5
Total Installed Storage (cf)	28,821
Est. Infiltration Rate (in/hr)	0.17

Table 11. Infiltration System Treatment

Total Load to Site (lb/yr)	14.34
Treatment Volume (cf)	28,821
Size Storm Treated (in)	1
Infiltration Rate (in/hr)	0.17
Treatment Efficiency	90%
Phosphorus Removed (lb/yr)	12.91

City of Waltham Phosphorus Control Plan Phase 1
Bobby Connors Playground - Cost Estimate

Table 12. Planning Level Cost Estimate - Bobby Connors Playground

Description	Quantity	Unit Type	Unit Cost	Base[2]	Notes
Road replacement	636	SF	$15.00	$9,540	
Sidewalk replacement	443	SF	$9.00	$3,987	
Asphalt walking path replacement	938	SF	$9.00	$8,442	
Medium pretreatment device	1	EA	$50,000.00	$50,000	
Sod	19,686	SF	$1.30	$25,592	
StormTech SC-740 infiltration chambers (includes delivery to site, excavation, installation, materials)	28,822	CF	$15.00	$432,330	Quote from ADS 6/28/23
24" RCP	180	LF	$150.00	$27,000	
4' Diameter Manhole	2	EA	$7,500.00	$15,000	
Total				$571,891	

Table 13. Total Cost Estimate

Line Item	Cost	Percentage	Value	Notes
1	Base construction		$571,891	
2	Erosion and sediment control	5%	$28,595	5% of Item 1
3	Mobilization/demobilization	10%	$57,189	10% of Item 1
	Subtotal		$657,674	
4	Contingency	30%	$197,302	30% of Items 1-3
	Subtotal		$854,977	
5	Survey, geotech, permitting	5%	$42,749	5% of Items 1-5
6	Construction services	0%	$0	0% of Items 1-5
Total Construction Cost			$1,555,500	Sum of Items 1-6
AACE Class 4 Cost Estimate Range (-20% to +40%)[3]			$1,244,400 to $2,177,700	

COST ESTIMATE NOTES:

1. All costs in 2023 dollars.

2. Includes labor and materials.

3. This estimate of probable construction cost is considered a Class 4 estimate as defined by AACE International and as such has an expected range (after application of contingency, 30% used) of -20% to +40%. This estimate assumes a competitive bid situation and is an estimate of fair market value, and is not an estimate of the anticipated low bid. Brown and Caldwell has no control over the cost of labor and materials, the contractor's method of bidding, market conditions, or the time of bidding. Brown and Caldwell cannot and does not guarantee that actual construction costs will not vary from this estimate.

Table 14. 20-Year Life-Cycle Cost

Total Construction Cost	$1,555,500
Annual O&M	$31,200
20-Year Life Cycle Cost	$2,179,500

Table 15. Cost-Effectiveness

Construction Dollars Per Acre of Drainage Area	$95,200
Construction Dollars Per Annual Pound of Phosphorus Removed	$120,600
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$8,500

Figure 3. Proposed BMP Conceptual Design Drawing
Bobby Connors Playground
Prepared for City of Waltham by Brown and Caldwell
June 2023

This is a conceptual drawing of a stormwater best management practice proposed in the CIty of Waltham Phosphorus Control Plan Phase 1 Project. It should not be used for final design or construction. This drawing is subject to the limitations in the Phosphorus Control Plan.

Appendix F - 3: Proposed Structural BMP

Beaver Brook Reservation

City of Waltham Phosphorus Control Plan

Structural BMP Conceptual Design Packet

for

Beaver Brook Reservation

An off-line surface infiltration basin with a diversion structure is proposed at the Beaver Brook Reservation located between Trapelo Road and Metropolitan Parkway. Beaver Brook Reservation is a publicly owned property managed by the Massachusetts Department of Conservation and Recreation (DCR). The 0.6-acre off-line system would be located in the field adjacent to an existing stream channel. The tributary area upstream of the manhole is approximately 88.93 acres. The site discharges downstream to an existing wetland east of Metropolitan Parkway (also part of Beaver Brook Reservation).

A flow diversion structure will be installed within the existing channel downstream of the culvert outlet and will be used to hydraulically control the volume of runoff being treated. The diversion structure will route the treatment runoff into the surface infiltration basin for percolation into the surrounding soil. Excess water from larger storm events will bypass the diversion structure and be conveyed downstream in the existing channel. The purpose of the diversion structure will be to retain the first flush of stormwater runoff to promote water quality improvement by removing phosphorus and other contaminants. It will also be used to reduce local flooding impacts.

The riprap-lined sediment forebay is proposed to capture excess sediment and debris prior to treatment and slow velocities of incoming stormwater. A grass-lined channel is proposed downstream of the forebay to convey flow to the surface infiltration basin.

According to NRCS soil data, hydrologic soil groups B and D exist at the site. Geotechnical investigations are required to determine the suitability of the soil for infiltration and the depth to the high groundwater level. At a minimum, the soil infiltration rate must be at least 0.17 in/hr and the depth from the bottom of the infiltration basin to the high groundwater level should be at least two feet. The infiltration basin should be designed to completely infiltrate within 72 hours. The use of highly permeable engineered soil media to optimize infiltration should be considered during final design. Additionally, a backup underdrain system is proposed to drain water by gravity back to the stream and outlet via headwall. The pipe sizing and discharge location of the underdrain system should be further evaluated during detailed design.

Constructing the infiltration basin using a 4:1 side slope in this location would result in the following design parameters:

- Excavation volume: 133,786 cf (3.07 ac-ft)
- Maximum water surface elevation in basin: 181.1 ft
- Maximum water depth in basin: 3.9 ft
- Bottom of basin depth: 117 ft
- Storage volume: 1.42 ac-ft

The annual phosphorus load exported from the drainage area was estimated using the methodology provided in Appendix F, Attachment 3 of the 2016 MS4 Permit. The annual phosphorus load is estimated to be 78.25 lb/yr (see Tables 2 to 4).

The treatment efficiency of the infiltration basin was estimated using Table 3-7 of Appendix F, Attachment 3 of the 2016 MS4 Permit. It was assumed that the infiltration rate for the project site is 1.02 in/hr. With a design volume equivalent to the 0.4-inch storm, the treatment efficiency is estimated to be 81%. As a result, it is estimated that the underground infiltration chambers will remove 63.38 lb/yr (see Table 8).

The conceptual design is preliminary in nature. Additional data needs to be collected and analysis performed during preliminary design to finalize design parameters. The location and size of all existing utilities have not been verified. Engineering analysis and geotechnical investigations are required prior to final design and may result in significant changes to the conceptual design. Modeling is also recommended to further evaluate the hydraulics of the proposed system, such as to determine if a berm would be needed to hydraulically separate the stream channel and infiltration basin. The design team will coordinate closely with DCR during the design process.

A conceptual opinion of probable construction cost, probable annual operational cost, and probable 20-year life cycle costs were prepared for the project. The opinion of probable construction cost is considered a Level 4 estimate as defined by AACE International, and as such, has an expected range (after application of contingency; 30 percent was applied) of -20 percent to +40 percent. The estimated construction cost of the project is $1,995,400 ($1,596,400 to $2,793,600). The estimated annual O&M cost is 2% of the construction cost or $40,000 ($32,000 to $46,000). Over the course of 20 years, the cost of the stormwater BMP is estimated to be $2,795,400 ($2,236,400 to $3,913,600). Based on these costs and the aforementioned annual phosphorus removal rate, it is estimated that over the course of 20 years, the total cost (construction and O&M) of removing each pound of phosphorus will be $2,300 ($1,900 to $3,300). See Tables 9 to 12.

Table 1. Beaver Brook Reservation Summary	
Drainage Area Characteristics	
Area	88.93 acres
Percent Impervious	38%
Estimated Annual Phosphorus Export Load	78.25 lb/yr
Proposed BMP	
Technology	Surface infiltration basin
Runoff Volume	0.4-inch storm
Treatment Volume	61,856 CF (1.42 ac-ft)
Infiltration Rate	1.02 in/hr (Type A/B soils)
Estimated Phosphorus Treatment Efficiency	81%
Estimated Annual Phosphorus Removal	63.38 lb/yr
Cost Estimate[1]	
Total Construction Cost	$1,995,400
Total Construction Cost AACE Class 4 Cost Range (2023 Dollars)[1]	$1,596,400 to $2,793,600
Annual O&M[2]	$40,000
20-Year Life Cycle Cost	$2,795,400
Construction Dollars Per Acre of Drainage Area	$75,100
Construction Dollars Per Annual Pound of Phosphorus Removed	$31,500
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$2,300

Notes:

1. *AACE Class 4 cost estimate. Its expected accuracy range is -20% to +40%. The cost estimate was developed in June 2023.*
2. *Annual O&M was estimated at 2% of the total construction cost.*

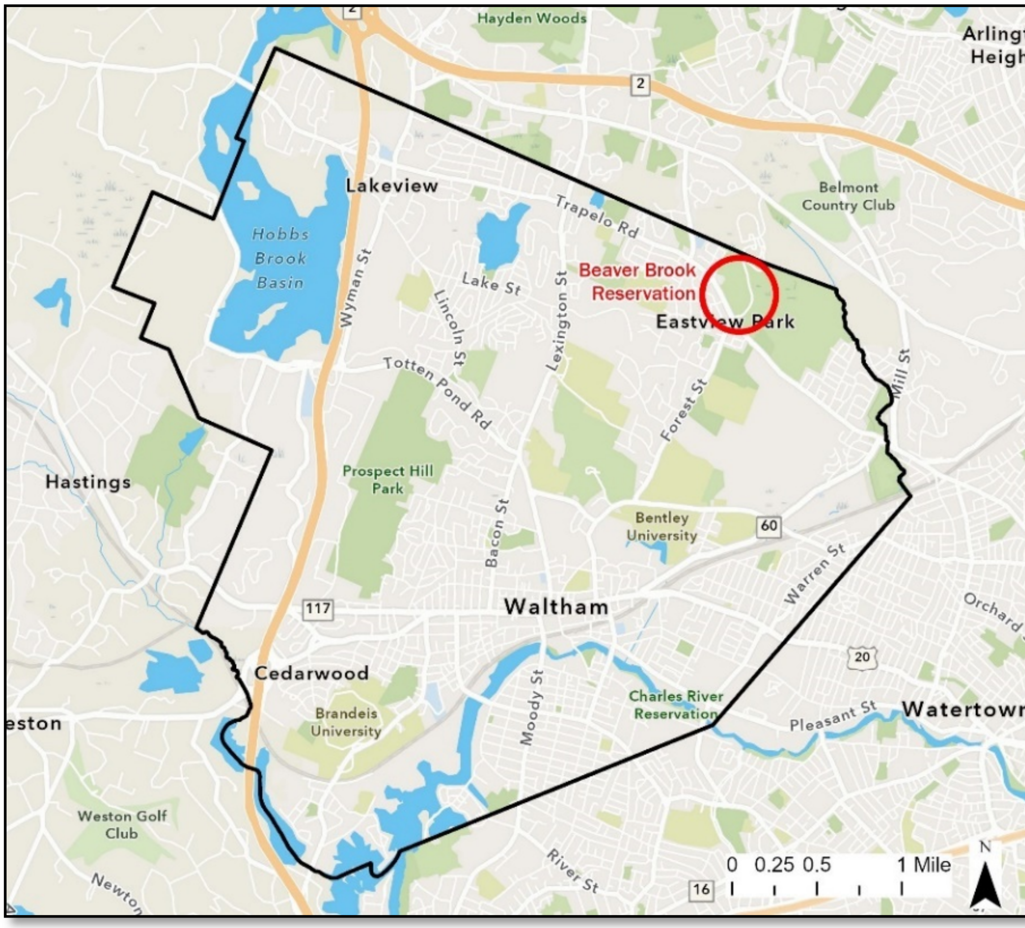

Figure 1. Beaver Brook Reservation Study Area Map

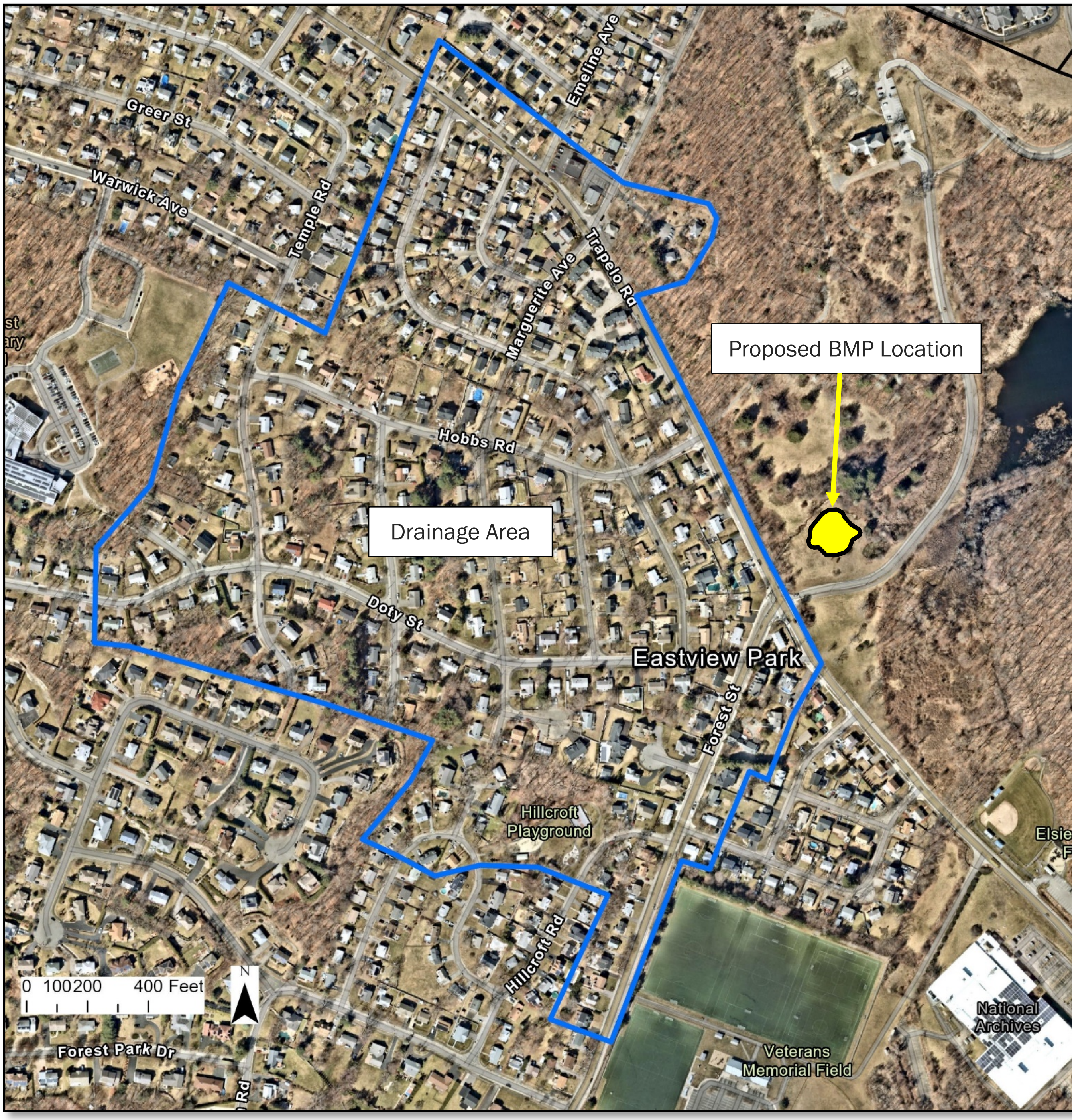

Figure 2. Beaver Brook Reservation Drainage Area Map

City of Waltham Phosphorus Control Plan Phase 1
Beaver Brook Reservation - Stormwater BMP Calculations

Drainage Area Annual Phosphorus Export Load

Table 2. Phosphorus Export Load: Directly Connected Impervious Area

Land use	Impervious Area (ac)	Phosphorus Export Rate[1] (lb/ac-yr)	Phosphorus Export (lb/yr)
Commercial	0.23	1.78	0.41
High-Density Residential	23.00	2.32	53.35
Medium-Density Residential	2.61	1.96	5.12
Forest	0.04	1.52	0.06
Open Land	0.30	1.52	0.45
Agriculture	0.40	1.52	0.61
Total	26.58		60.01

Notes:
1. Phosphorus export rates from 2016 MS4 Permit, Appendix F, Attachment 3, Table 3-1.

Table 3. Phosphorus Export Load: Pervious Areas (and Impervious Areas that are Not Directly Connected)

Land use	Hydrologic Soil Group	Area (ac)	Phosphorus Export Rate[1] (lb/ac-yr)	Phosphorus Export (lb/yr)
Commercial	B	0.14	0.17	0.02
	C	0.00	0.36	0.00
	Unknown	0.01	0.36	0.00
	Not Directly Connected	0.02	0.19	0.00
High-Density Residential	B	11.08	0.17	1.93
	C	0.17	0.36	0.06
	Unknown	28.63	0.36	10.25
	Not Directly Connected	4.40	0.31	1.35
Medium-Density Residential	B	3.01	0.17	0.52
	C	1.08	0.36	0.39
	Unknown	6.19	0.36	2.22
	Not Directly Connected	2.06	0.30	0.63
Forest	B	3.95	0.14	0.56
	C	0.41	0.19	0.08
	Unknown	0.61	0.19	0.11
	Not Directly Connected	0.43	0.15	0.06
Open Land	B	0.01	0.17	0.00
	C	0.00	0.36	0.00
	Unknown	0.09	0.36	0.03
	Not Directly Connected	0.04	0.33	0.01
Agriculture	B	0.01	0.29	0.00
	C	0.00	0.60	0.00
	Unknown	0.00	0.60	0.00
	Not Directly Connected	0.01	0.29	0.00
Total		62.35		18.24

Notes:
1. Phosphorus export rates from 2016 MS4 Permit, Appendix F, Attachment 3, Table 3-1.

Table 4. Total Annual Phosphorus Export Load

Area Type	Area (ac)	Phosphorus Export (lb/yr)
Directly Connected Impervious Area	26.58	60.01
Pervious Areas (and Impervious Areas that are Not Directly Connected)	62.35	18.24
Total Annual Phosphorus Export Load[1] =	88.93	78.25

Notes:
1. Total annual phosphorus export load is the sum of the annual phosphorus export load from the directly connected areas and the pervious areas.

Drainage Area Runoff

Table 5. Runoff Estimates for Storms

Rainfall (in)	Runoff Volume[1]	
	(cf)	(ac-ft)
0.1	12,173	0.28
0.2	26,986	0.62
0.4	55,322	1.27 <-- Design Volume
0.5	70,855	1.63
0.6	86,329	1.98
0.8	115,386	2.65
1	147,023	3.38
1.2	185,048	4.25
1.5	263,152	6.04
2	376,947	8.65

Notes:
1. Runoff volume were calculated according to the procedures contained in 2016 MS4 Permit, Appendix F, Attachment 3.

Table 6. Source Data for Runoff Calculations

Surface Type	Area (ac)
Impervious	33.5
Pervious Areas	
Hydrologic Soil Group B	18.2
Hydrologic Soil Group C	1.7
Hydrologic Soil Group Unknown[1]	35.5
Total Pervious Areas	55.4

Notes:
1. Unknown hydrologic soil groups are assumed to have hydrologic properties similar to type C soils.

Surface Infiltration Basin

Table 7. Infiltration System Dimensions

Basin Area (ac)	0.60
Excavation Volume (cf)	133,786
Max. Water Surface Elev. In Basin (ft)	181.1
Max. Water Depth in Basin (ft)	3.9
Basin Bottom Elev. (ft)	177.2
Basin Side Slope	4:1
Storage Volume (ac-ft)	1.42

Table 8. Infiltration System Treatment

Total Load to Site (lb/yr)	78.25
Treatment Volume (ac-ft)	1
Size Storm Treated (in)	0.4
Infiltration Rate (in/hr)	1.02
Treatment Efficiency	81%
Phosphorus Removed (lb/yr)	63.38

City of Waltham Phosphorus Control Plan Phase 1
Beaver Brook Reservation - Cost Estimate

Table 9. Planning Level Cost Estimate - Beaver Brook Reservation

Description	Quantity	Unit Type	Unit Cost	Base[2]	Notes
Diversion structure	1	EA	$20,000.00	$20,000	
Excavation (4:1 slope to elevation 177 ft)	4,976	CY	$75.00	$373,175	
Engineered soil media	2,451	CY	$75.00	$183,861	2.5 ft depth - basin and grass channel
Underdrain (12" perforated PVC)	200	LF	$56.00	$11,200	
Culvert outlet headwall	1	EA	$3,000.00	$3,000	
Reseeding	28,115	SF	$2.05	$57,636	Basin, grass channel, entrance road
Riprap	12	CY	$66.92	$793	20' L x 16' W x 1' depth - forebay
Construction entrance road	1	LS	$84,000.00	$84,000	
Total				$733,665	

Table 10. Total Cost Estimate

Line Item	Cost	Percentage	Value	Notes
1	Base construction		$733,665	
2	Erosion and sediment control	5%	$36,683	5% of Item 1
3	Mobilization/demobilization	10%	$73,366	10% of Item 1
	Subtotal		$843,715	
4	Contingency	30%	$253,114	30% of Items 1-3
	Subtotal		$1,096,829	
5	Survey, geotech, permitting	5%	$54,841	5% of Items 1-5
6	Construction services	0%	$0	0% of Items 1-5
Total Construction Cost			$1,995,400	Sum of Items 1-6
AACE Class 4 Cost Estimate Range (-20% to +40%)[3]			$1,596,400 to $2,793,600	

COST ESTIMATE NOTES:

1. All costs in 2023 dollars.

2. Includes labor and materials.

3. This estimate of probable construction cost is considered a Class 4 estimate as defined by AACE International and as such has an expected range (after application of contingency, 30% used) of -20% to +40%. This estimate assumes a competitive bid situation and is an estimate of fair market value, and is not an estimate of the anticipated low bid. Brown and Caldwell has no control over the cost of labor and materials, the contractor’s method of bidding, market conditions, or the time of bidding. Brown and Caldwell cannot and does not guarantee that actual construction costs will not vary from this estimate.

Table 11. 20-Year Life-Cycle Cost

Total Construction Cost	$1,995,400
Annual O&M	$40,000
20-Year Life Cycle Cost	$2,795,400

Table 12. Cost-Effectiveness

Construction Dollars Per Acre of Drainage Area	$75,100
Construction Dollars Per Annual Pound of Phosphorus Removed	$31,500
20-Year Life Cycle Cost Per Pound of Phosphorus Removed	$2,300

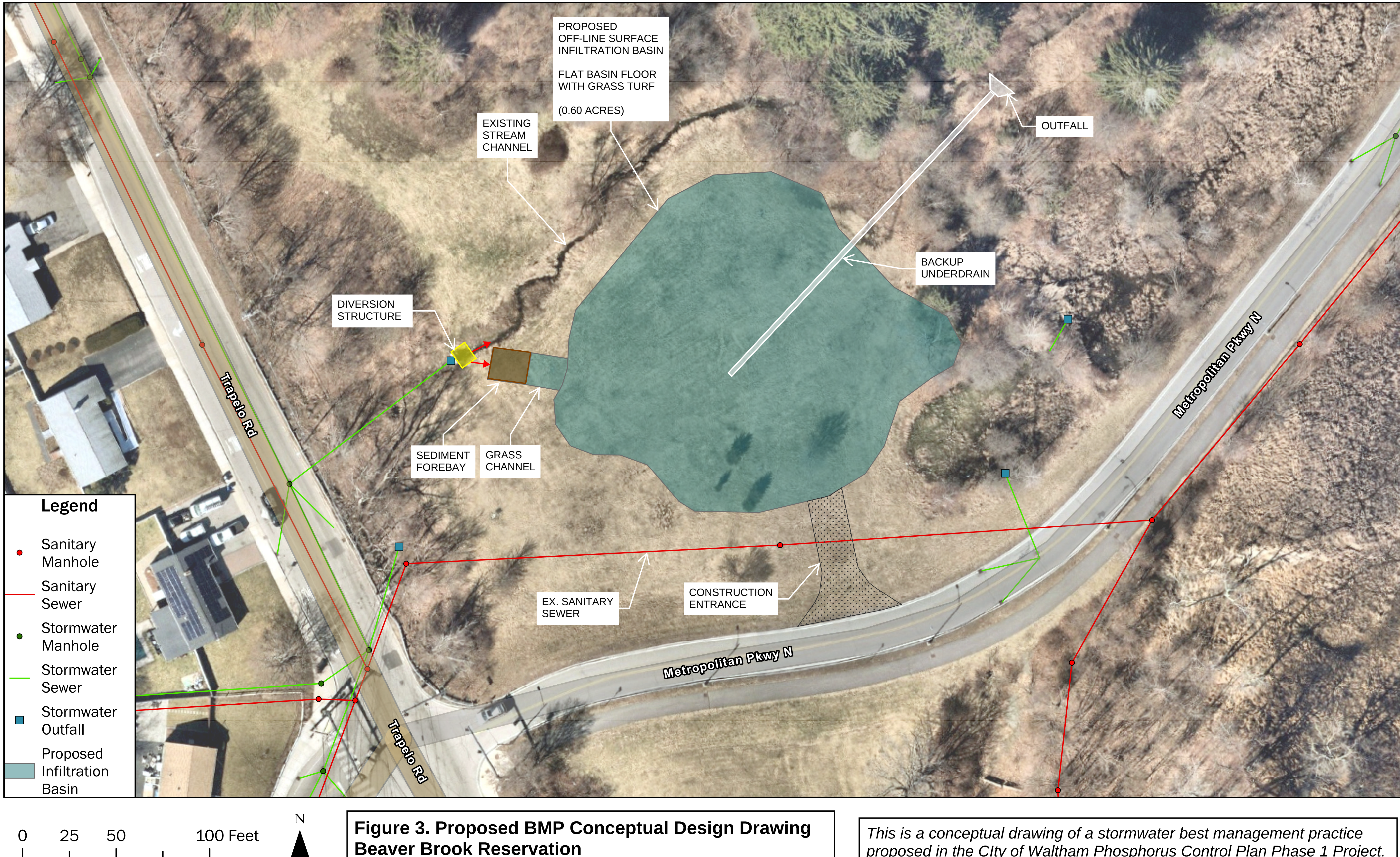

Figure 3. Proposed BMP Conceptual Design Drawing
Beaver Brook Reservation
Prepared for City of Waltham by Brown and Caldwell
June 2023

This is a conceptual drawing of a stormwater best management practice proposed in the CIty of Waltham Phosphorus Control Plan Phase 1 Project. It should not be used for final design or construction. This drawing is subject to the limitations in the Phosphorus Control Plan.

Appendix G: Phosphorus Removal in the Cambridge Reservoir

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Suite 403
Andover, MA 01810

T: 978.794.0336

Technical Memorandum

Prepared for: City of Waltham, MA

Project Title: Waltham Phosphorus Control Plan – Phase 1

Project No.: 158735

Technical Memorandum

Subject: Cambridge Reservoir Phosphorus Treatment Study

Date: May 6, 2023

To: Bob Winn, City of Waltham, MA

From: Matt Davis, Brown and Caldwell

Copy to: Scott Simpson, Fiona Worsfold, and Stephanie Alimena, Brown and Caldwell

Prepared by: Scott Simpson, PE

Fiona Worsfold, EIT

Stephanie Alimena, PE

Reviewed by: Matt Davis, PE

Limitations:

Section 1: Introduction

Stormwater discharges from the City of Waltham's (*City*) municipal separate storm sewer system (*MS4*) are regulated by the 2016 Massachusetts Small General MS4 Permit (*Permit*). Accordingly, the City is subject to Appendix F of the Permit which enforces the Charles River Phosphorus TMDL, which requires the communities within the Charles River watershed reduce the phosphorus loads in their stormwater discharges to the Charles River. The MS4 Permit requires that the City develop a three-phase Phosphorus Control Plan (PCP) to meet the reduction requirements.

The City is currently developing Phase 1 of its PCP. As part of this effort, the City is evaluating the phosphorus reductions being achieved through non-structural and structural BMPs. During this process, the City has identified the Hobbs Brook and Stony Brook Reservoirs as waterbodies that may be removing phosphorus from the stormwater they receive, in essence, functioning like a wet pond BMP[1]. Understanding the treatment capabilities of these reservoirs is important for the City as approximately 30 percent of its land area falls within the catchment of these reservoirs.

The City engaged Brown and Caldwell (BC) to evaluate the phosphorus treatment capabilities of the Hobbs Brook and Stony Brook Reservoirs. The study goals of the study were as follows:

- Estimate the average annual phosphorus load discharged from the Stony Brook Reservoir[2] through a field sampling program and estimate the portion of the load that originated from the City.
- Estimate the average annual phosphorus load in the City's stormwater discharged to the reservoirs using the data and methodologies that EPA used to estimate the baseline phosphorus loads in the Permit.
- Compare the phosphorus loads into and out of the reservoirs and estimate their phosphorus treatment efficiency.

This Technical Memorandum (TM) documents the methodologies, data and conclusions of the study.

Section 2: Catchment Area

The location of the Hobbs Brook and Stony Brook Reservoirs are shown in Figure 1. The figure also shows the combined catchment boundary of the two reservoirs and the City's jurisdictional boundary.

The Hobbs Brook Reservoir discharges to Stony Brook which flows into the Stony Brook Reservoir. Waters discharged from the Stony Brook Reservoir flow through a short stream segment before discharging to the Charles River. Both the Hobbs Brook and Stony Brook Reservoirs have dams that control the discharge of flows.

Table 1 provides a summary of the reservoir catchment area inside and outside of the City's jurisdictional boundary. The total area of the City is 2,491 acres with 30 percent of the City falling within the reservoir catchment area.

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[1] The reservoirs also serve as a water supply for the City of Cambridge. The phosphorus in waters diverted to the Cambridge water supply system do not directly enter the Charles River.

[2] The two reservoirs are in series with the Stony Brook being the most downstream reservoir. Estimating the load at the downstream of the Stony Brook Reservoir provides a measure of the total load being discharged to the Charles River.

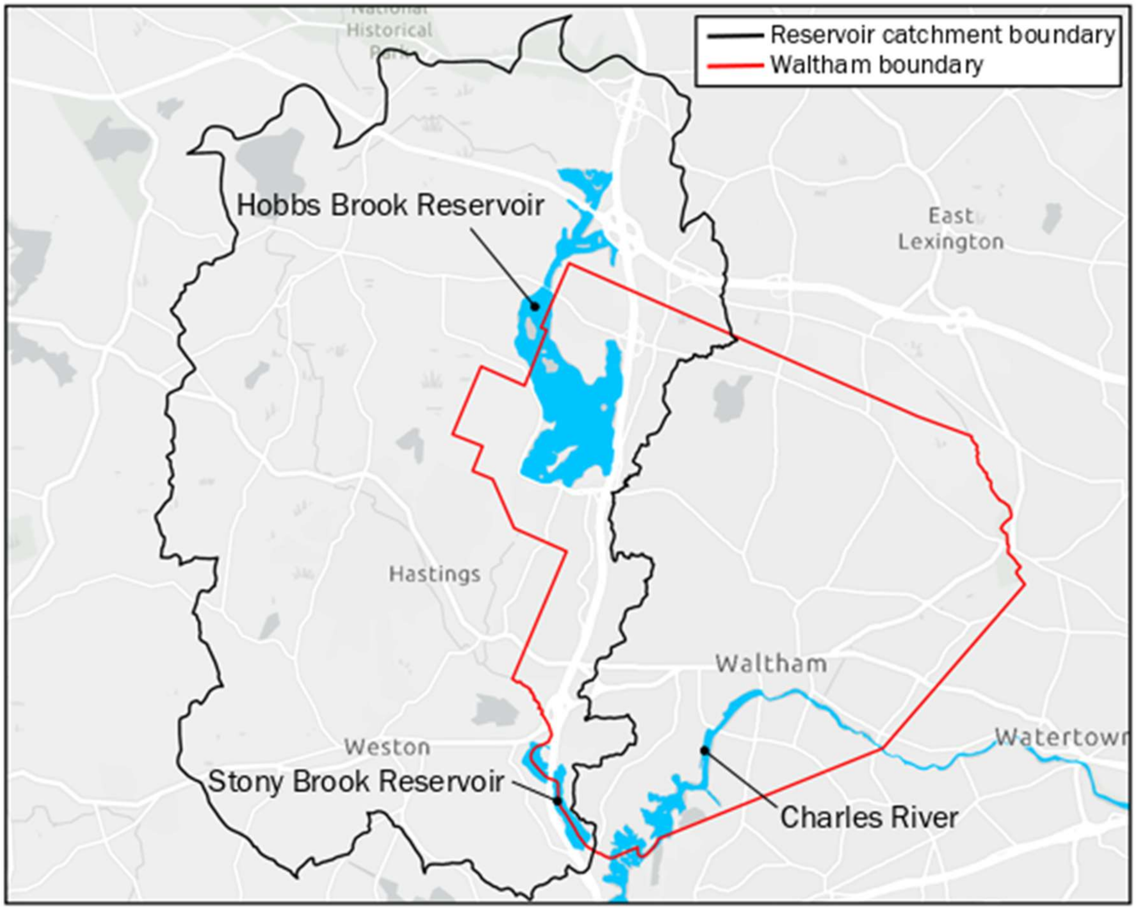

Figure 1. Cambridge Reservoirs

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Table 1. Summary of Reservoir Catchment Area in Waltham

Catchment Subarea	Area (ac)		
	Impervious	Pervious	Total
Waltham	747	1,744	2,491
Outside of Waltham	1,393	11,242	12,635
Total	2,140	12,986	15,126

Section 3: Field Program Overview

A field data collection program was developed to gather the measurements needed to estimate the annual phosphorus load discharged from the Stony Brook Reservoir dam. Data was collected during the three-month period from September through November 2022.

The following data was collected during the monitoring period:

- Phosphorus concentrations - Weekly phosphorus samples were collected downstream of the Stony Brook Reservoir dam at the location shown in Figure 2.

  The weekly phosphorus samples were collected regardless of wet or dry weather conditions. It would have been ideal to collect just wet weather samples since the PCP targets phosphorus loads in stormwater, but due to the time of travel, hydraulic residence time and mixing in the reservoir it was not possible to collect water samples composed primarily of stormwater runoff. It is expected that the discharge from the reservoir is typically a well-mixed blend of waters that were supplied during both dry and wet weather conditions. As a result, it is expected that phosphorus concentrations are not very sensitive to current weather conditions, except for rare, extreme events.
- Stony Brook Reservoir discharge flow rates –USGS operates a monitoring station (#01104480) downstream of the Stony Brook Reservoir where the phosphorus samples were collected. The monitoring station continuously measures the flow rates discharged from the reservoir. The data was downloaded from the USGS website.
- Rainfall – The study relied on rainfall data collected from the aforementioned Stony Brook Reservoir USGS monitoring station and a rain gauge on the roof of the City's Department of Public Works building.

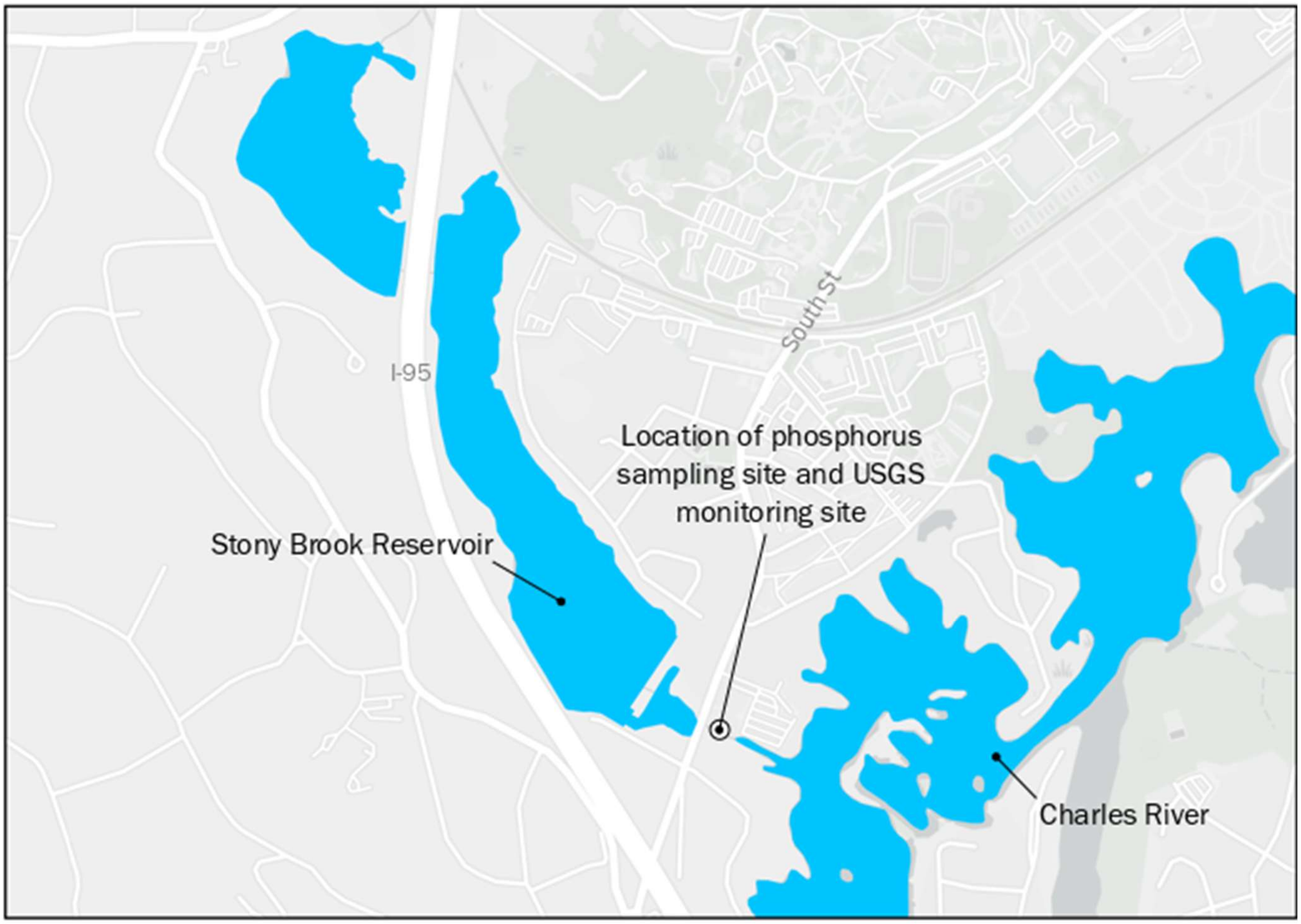

Figure 1. Phosphorus Sample Collection Site

Section 4: Data Summary

This section summarizes the data collected during the course of the study.

4.1 Precipitation

The cumulative rainfall measured by the DPW rain gauge and the USGS monitoring station during the monitoring period is shown in Figure 3. In total, the DRP rain gauge measured 10.18 in and the USGS monitoring station measured 10.05 in.

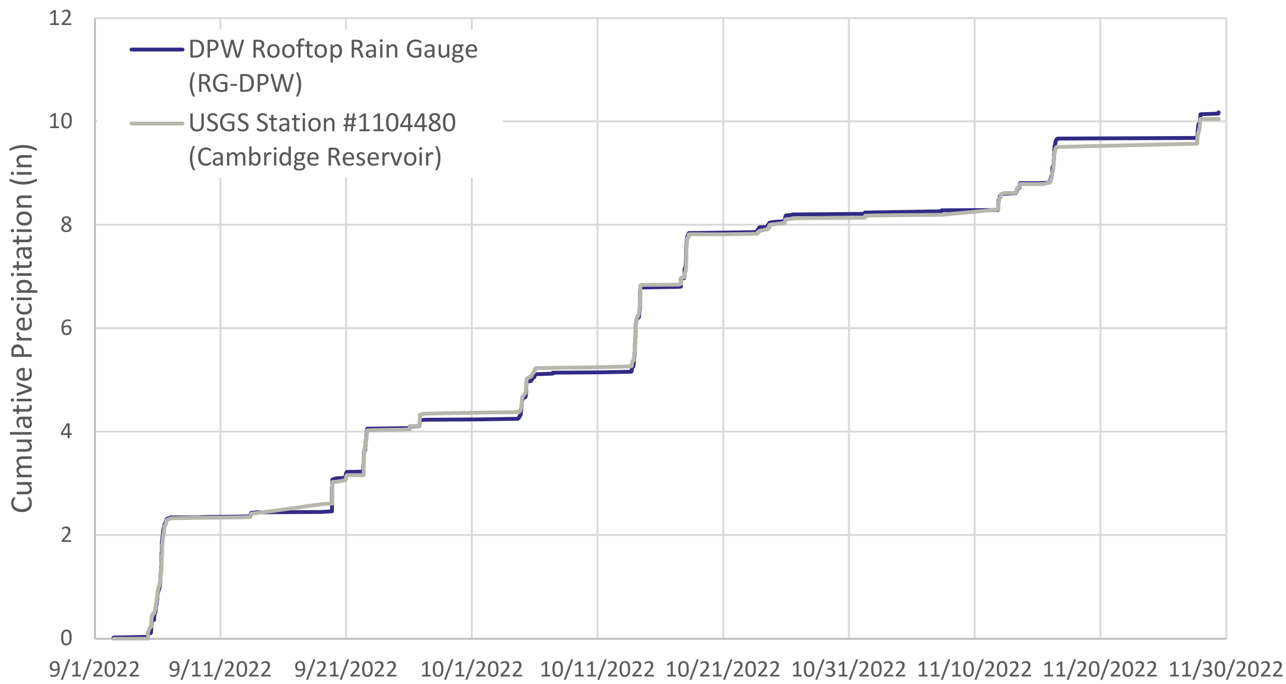

Figure 3. Cumulative Precipitation during the Monitoring Period

The summer preceding the monitoring period was one of the driest on record and was declared a critical drought by the State's Drought Monitor. Precipitation returned to historical norms in early September at the start of the monitoring period.

Over the monitoring period, the data from the two rain gauges were in good agreement, with a difference in the total cumulative precipitation of less than 1.3%.

4.2 Flow Rates

The flow rates from the Stony Brook Reservoir were obtained from USGS monitoring station #01104480 and are shown in Figure 4.

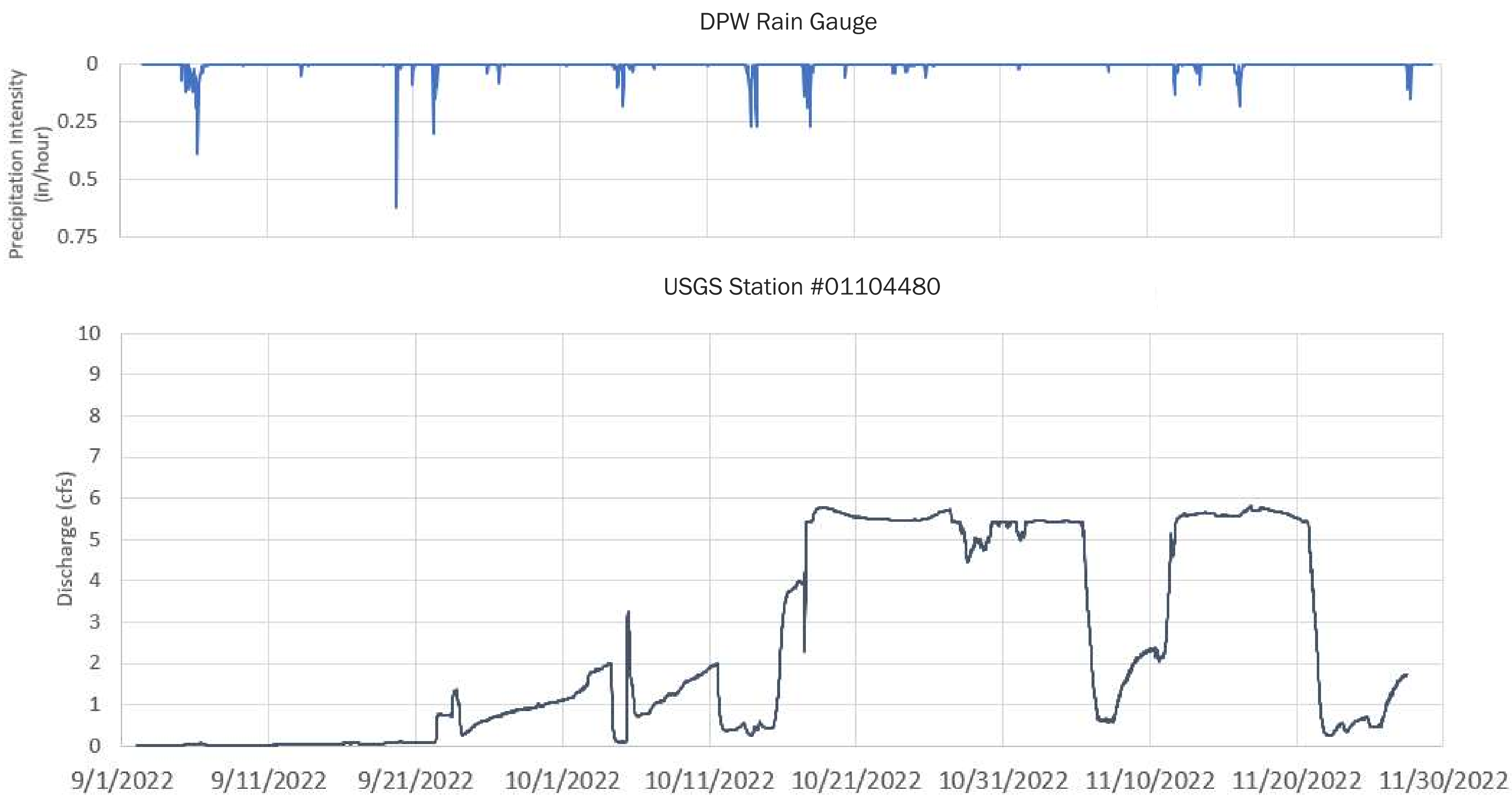

Figure 4. Flows Discharged from the Stony Brook Reservoir during the Monitoring Period

Due to the drought conditions during the summer, the flows discharged from the Stony Brook Reservoir were low during September, but flows gradually increased during the monitoring period as rainfall returned to normal levels. It should be noted that even though the flows increased during the monitoring period, discharge during October and November were still significantly lower than the same period in 2021.

4.3 Phosphorus Sampling

Ten total phosphorus samples were collected downstream of the Stony Brook Reservoir during the monitoring period. Four of the samples were below detection limits of 0.01 mg/L. The average total phosphorus concentration of the samples was 0.024 mg/L[3]. The phosphorus concentrations are shown in Figure 5. As discussed previously, the samples were collected irrespective of weather conditions. Samples were collected during both wet and dry weather conditions.

[3] The concentration of the samples below the detection limit was assumed to be the detection limit value.

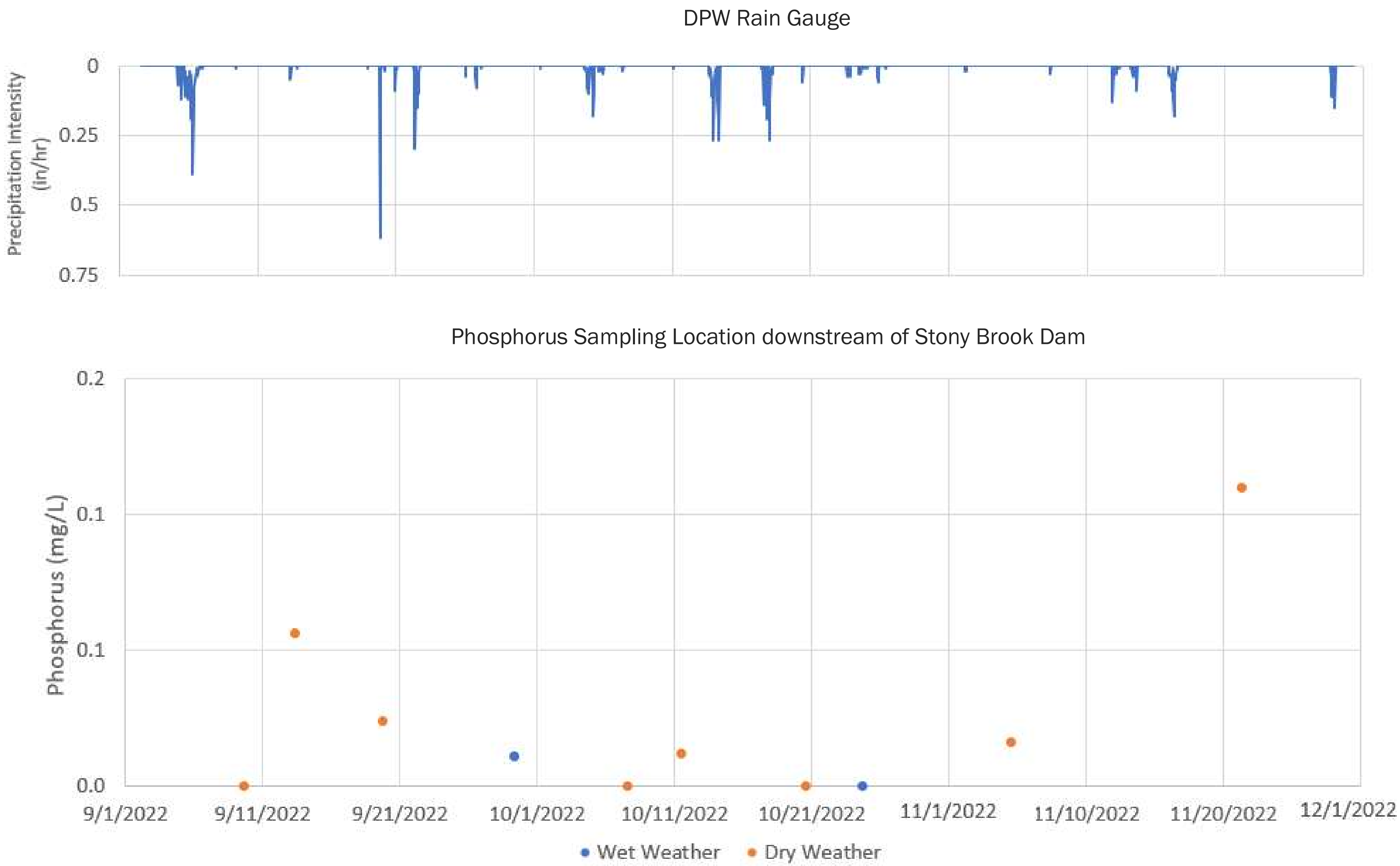

Figure 5. Phosphorus Concentrations during the Monitoring Period

4.4 Instantaneous Phosphorus Loading Rates

Instantaneous phosphorus loading rates were calculated from the measured phosphorus concentrations and the flow rates at the time of sampling. The relationship between the flow rates and the instantaneous phosphorus loading rates is shown in Figure 6.

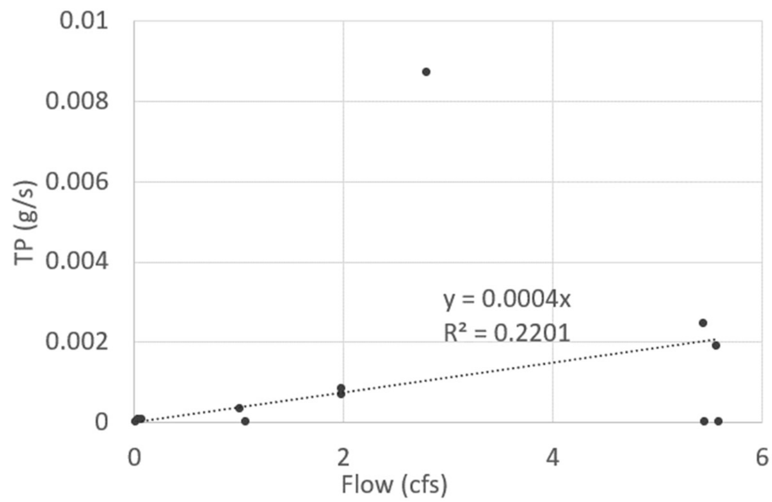

Figure 6. Flow Rates vs Phosphorus Loading Rates

A linear curve was fit to the data. This curve will be used in the next section to estimate instantaneous phosphorus loading rates based on flow rates.

Section 5: Estimating the Phosphorus Load Discharged by the Stony Brook Reservoir

This section uses the field data presented in the previous section to estimate the phosphorus load discharged from the Stony Brook Reservoir during the monitoring period.

A continuous record of instantaneous phosphorus loads discharged from the Stony Brook Reservoir was estimated for the monitoring period by using the measured flow rates (see Figure 4) and the fitted curve in Figure 6 that correlates flow rate to instantaneous phosphorus loading rates. The estimated instantaneous phosphorus loads are shown in Figure 7 alongside the measured instantaneous phosphorus loads corresponding with phosphorus sampling events. In general, the estimated values match the measured values fairly well. There is one measured value that was significantly higher than the estimated value, but the other measured values were either close to the estimated value or lower.

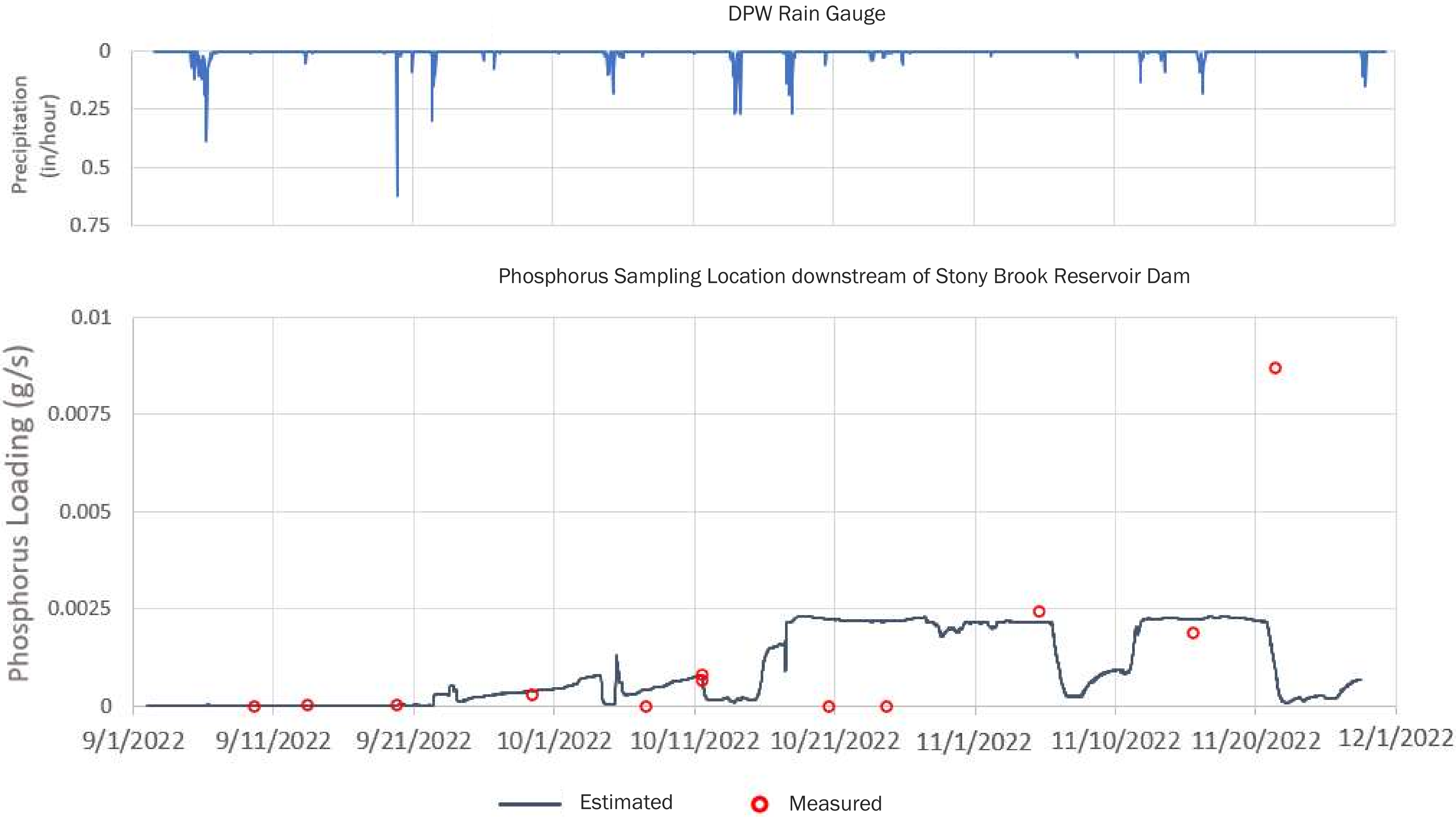

Figure 7. Instantaneous Phosphorus Loads during the Monitoring Period

Using the estimated instantaneous phosphorus loading rates in Figure 9, the total phosphorus load discharged from the Stony Brook Reservoir during the monitoring period was estimated to be 66 lb. As will be discussed in the next section, it is estimated that the City generates about 30 percent of the stormwater phosphorus load entering the reservoirs. This percentage was multiplied by the 66 lb of phosphorus discharged from the Stony Brook Reservoir during the monitoring period to estimate that 20 lb originated from the City.

The estimated loads during the study period were extrapolated to average annual values. The study period lasted 87 days. The average daily load discharged from the Stony Brook Reservoir during the study period was 0.76 lb/d (66 lb / 87 days). To estimate the average annual phosphorus load, the daily load was then multiplied by 365 days, yielding a value of 277 lb/yr, with 30 percent of this total, 84 lb/yr, originating from the City. For such a large catchment area, these phosphorus loads are surprisingly low. It is speculated that the low loads may be due to the drought conditions during the summer of 2022 that preceded the monitoring period. For example, the Stony Brook Reservoir did not discharge for roughly the first month of the monitoring period. The higher residence times may have resulted in increased phosphorus removal through sedimentation and biological uptake. It is important to note, however, that even when the Reservoir did releasing flow in October, the phosphorus levels remained low.

Since the rainfall conditions preceding the monitoring period were unusually dry, an analysis was performed to estimate the phosphorus loads discharged from the Stony Brook Reservoir under rainfall conditions closer to historical norms. The analysis was performed using 5 years of flow data (June 2018 – June 2023) from the USGS station downstream of the Stony Brook Reservoir dam and an assumed average annual total phosphorus concentration of 0.03 mg/L, which is a conservative value given the mean concentration of 0.024 mg/L measured during the monitoring program[4]. The results are presented in table 6.

Table 6. 5-Year Estimate of Total Phosphorus Loads from Stony Brook Reservoir

Timeframe	Total Rainfall (in/yr)	Estimated Annual Phosphorus Load Discharged from the Stony Brook Reservoir	
		Portion Originating from Waltham[1]	Total[2]
June 2018 - June 2019	31.1	596	1,986
June 2019 - June 2020	28.7	351	1,169
June 2020 - June 2021	25.1	258	859
June 2021 - June 2022	32.4	652	2,172
June 2022 - June 2023	23.6	285	949
Average	28.2	428	1,427

Notes:

1. *Estimated by multiplying the total load by 30 percent which is the estimated percentage of the City's stormwater phosphorus load in the catchment (see Table 7).*
2. *Estimated from (1) measured flows discharged from the Stony Brook Reservoir at the USGS monitoring station and (2) an assumed average phosphorus concentration of 0.03 mg/L.*

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[4] Other historical total phosphorus data is available at this site. The Table 6 of *Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts* (Charles River Watershed, May 2011) provides the total phosphorus concentrations measured downstream of the Stony Brook Reservoir dam during the TMDL study. Five samples were analyzed. The total phosphorus concentrations ranged from 0.022 – 0.036 mg/L with a mean concentration of 0.027 mg/L. This mean value is slightly higher than the mean value of 0.024 mg/L measured by this study.

The average annual phosphorus load from the Stony Brook Reservoir that is attributable to Waltham, based on the 5-year analysis, is 428 lb/year. These results are significantly higher than the annual loads estimated from the field data (84 lb/yr). To be conservative, the results from the 5-year analysis will be used to estimate the phosphorus removed by the reservoirs in Section 7[5].

Section 6: Estimating Annual Stormwater Phosphorus Loads into the Reservoirs using EPA Methodology

The average annual phosphorus load discharged from the Stony Brook Reservoir was discussed in the previous section. In order to develop an understanding of the phosphorus treatment capabilities of the reservoirs, it is necessary to also estimate the average annual phosphorus load that enters the reservoirs. By comparing these two values, it is possible to estimate the phosphorus removal effectiveness of the reservoirs. This section provides an estimate of the phosphorus loads from stormwater runoff entering the reservoirs. It should be noted that the loads discussed in this section are from stormwater whereas the loads discussed in the previous section are total loads and include phosphorus from other sources. This will be addressed in the next section when the loads into and out of the reservoirs are discussed.

The EPA estimated baseline phosphorus loads for the Charles River communities. The values are provided in Attachment 3 of Appendix F of the Permit. The EPA provided a description of the methodology they used to calculate the baseline phosphorus loads in the Draft Memorandum dated 1/14/2014 from Mark Voorhees (EPA) to the Permit File for Draft Small Massachusetts MS4 Permit. EPA used land use, impervious cover and soils GIS data corresponding to 2005 conditions to perform the calculations.

Using the same methodologies and data sources used by EPA, the study calculated the average annual phosphorus loads in stormwater runoff in the catchment area (see Figure 1). The results are provided in Table 7. The average annual loads are provided for both the portion of the catchment in and outside of Waltham. In performing these calculations, the catchment was subdivided in two along the Waltham boundary and the phosphorus loads were calculated separately for each area. The City's estimated average annual phosphorus load of 1,448 lb/yr generated within the Hobbs Brook and Stony Brook Reservoir catchments is approximately 23 percent of the City's overall baseline phosphorus load of 6,382 lb/yr.

Table 7. Estimating Average Annual Stormwater Phosphorus Loads in Hobbs Brook and Stony Brook Reservoir Catchments

Catchment Subarea	Catchment Area (ac)	Average Annual Phosphorus Load[1] (lb/yr)
Waltham	2,491	1,448
Outside of Waltham	12,986	3,420
Total	15,126	4,868

Notes:

1. *Calculated using the methodologies and data EPA used to calculate baseline phosphorus loads for the 2016 MS4 Permit.*

[5] Higher loads discharged from the Stony Brook Reservoir means that the reservoirs are removing less phosphorus which leads to a more conservative estimate of the phosphorus treatment capabilities of the reservoirs.

Section 7: Results

The estimated average annual phosphorus load discharged from the Stony Brook Reservoir was discussed in Section 5. The estimated average annual phosphorus load in stormwater runoff flowing into the reservoirs was discussed in Section 6. In this section, these values will be compared and the phosphorus removal effectiveness of the reservoirs will be discussed.

Table 7 summarizes the average annual phosphorus loads discussed in the previous sections. The study estimated that the City's stormwater runoff contributes an average annual phosphorus load 1,448 lb/yr to the reservoirs. The study also estimated that 428 lb/yr of the average annual phosphorus load discharged from the Stony Brook Reservoir is attributable to sources in the City.

Table 7. Estimating Average Annual Stormwater Phosphorus Loads in Reservoir Catchment

Catchment Subarea	Average Annual Phosphorus Load (lb/yr)	
	Stormwater Runoff into Reservoirs[1]	Discharged from Stony Brook Reservoir
Waltham	1,448	428
Outside of Waltham	3,420	999
Total	4,868	1,427[2]

Notes:

1. *Estimated using same data and methodologies used by EPA to calculate the baseline phosphorus loads in the Massachusetts 2016 MS4 General Permit.*
2. *Estimated value based on 5-years of flow data measured at the USGS station downstream of the Stony Brook Reservoir and an assumed average total phosphorus concentration of 0.03 mg/L. It was assumed that 30 percent of this load originated in Waltham with the remainder originating outside of Waltham. This percentage was estimated based on the distribution of the phosphorus loads from stormwater runoff into the reservoirs in preceding column.*

It is important to note that the table is comparing different *types* of phosphorus loads. The phosphorus load into the reservoirs is from stormwater only, whereas the phosphorus load out of the Stony Brook Reservoir is comprised of phosphorus from stormwater runoff as well as 'other sources'. If it is assumed for a moment that these 'other sources' are negligible, then the phosphorus loads can be directly compared and it would be reasonable to conclude that the reservoirs are removing approximately 1,020 lb/yr of phosphorus on average (70 percent reduction) from stormwater originating in Waltham. However, it is likely that the 'other sources' are not negligible. As an example, let's assume that only half of the load discharged from the Stony Brook Reservoir originates from stormwater runoff. In this case, the City's phosphorus load from stormwater going into the reservoir is 1,448 lb/yr and 214 lb/yr of this load comes out which means that the reduction taking place in the reservoirs is 1,234 lb/yr (85 percent reduction). This value is more than the reduction value of 1,020 lb/yr that was estimated under the assumption that all of the discharged load was derived from stormwater. These scenarios serve to illustrate that the reservoirs are likely removing at least 1,020 lb/yr of phosphorus on average from the City's stormwater. Indeed, they are likely removing more but how much more depends on the amount of phosphorus in the catchment that comes from non-stormwater sources.

There are several additional factors that may impact these conclusions. First, the phosphorus samples were collected in the fall. Phosphorus concentrations in stormwater runoff and waterways are typically elevated at this time of year due to an abundance of leaf litter. If this were the case, the study may be overestimating the phosphorus loads being discharged from the Stony Brook Reservoir. Secondly, the estimated average annual phosphorus load from the Stony Brook Reservoir is based upon the assumption of an average total phosphorus concentration of 0.03 mg/L, which was higher than the average total concentration of 0.024 mg/L measured during the study. If the actual average annual total phosphorus concentration is lower than 0.03 mg/L, the study may be overestimating the phosphorus load out of the Stony Brook Reservoir. In both of these cases, overestimating the phosphorus loads out of the Stony Brook Reservoir would lead to an underestimation of the amount of phosphorus removed by the reservoirs.

7.1 Conclusions

The study strongly suggests that the average annual phosphorus loads discharged from the Stony Brook Reservoir are significantly lower than the estimated phosphorus loads in stormwater runoff entering the reservoirs. On average, it is estimated that reservoirs are removing at least 1,020 lb/yr of phosphorus from the City's stormwater runoff. This is not surprising given the diversion of waters from the reservoir to the City of Cambridge water supply system and the treatment potential of reservoirs with such sizable volumes.

While the results are encouraging, further study over a longer period is recommended to further confirm and define the conclusions. It is recommended that the City develop and implement a water quality monitoring plan for a full year of study to refine the estimates of the annual phosphorus loads reductions in the reservoirs.

Appendix H: StormTech Isolator Row O&M Manual

Isolator® Row
O&M Manual

ADS StormTech™

The Isolator® Row

Introduction

An important component of any Stormwater Pollution Prevention Plan is inspection and maintenance. The StormTech Isolator Row is a technique to inexpensively enhance Total Suspended Solids (TSS) and Total Phosphorus (TP) removal with easy access for inspection and maintenance.

The Isolator Row

The Isolator Row is a row of StormTech chambers, either SC-160, SC-310, SC-310-3, SC-740, DC-780, MC-3500 or MC-7200 models, that is surrounded with filter fabric and connected to a closely located manhole for easy access. The fabric-wrapped chambers provide for sediment settling and filtration as stormwater rises in the Isolator Row and passes through the filter fabric. The open bottom chambers and perforated sidewalls (SC-310, SC- 310-3 and SC-740 models) allow stormwater to flow both vertically and horizontally out of the chambers. Sediments are captured in the Isolator Row protecting the adjacent stone and chambers storage areas from sediment accumulation.

ADS geotextile fabric is placed between the stone and the Isolator Row chambers. The woven geotextile provides a media for stormwater filtration, a durable surface for maintenance, prevents scour of the underlying stone and remains intact during high pressure jetting. A non-woven fabric is placed over the chambers to provide a filter media for flows passing through the chamber's sidewall. The non-woven fabric is not required over the SC-160, DC-780, MC-3500 or MC-7200 models as these chambers do not have perforated side walls.

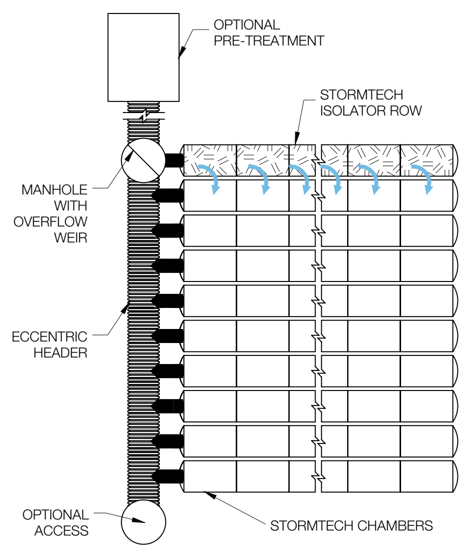
The Isolator Row is designed to capture the "first flush" runoff and offers the versatility to be sized on a volume basis or a flow-rate basis. An upstream manhole provides access to the Isolator Row and includes a high/low concept such that stormwater flow rates or volumes that exceed the capacity of the Isolator Row bypass through a manifold to the other chambers. This is achieved with an elevated bypass manifold or a high-flow weir. This creates a differential between the Isolator Row row of chambers and the manifold to the rest of the system, thus allowing for settlement time in the Isolator Row. After Stormwater flows through the Isolator Row and into the rest of the chamber system it is either exfiltrated into the soils below or passed at a controlled rate through an outlet manifold and outlet control structure.

The Isolator Row may be part of a treatment train system. The treatment train design and pretreatment device selection by the design engineer is often driven by regulatory requirements. Whether pretreatment is used or not, StormTech recommend using the Isolator Row to minimize maintenance requirements and maintenance costs.

Note: *See the StormTech Design Manual for detailed information on designing inlets for a StormTech system, including the Isolator Row.*

Looking down the Isolator Row from the manhole opening, woven geotextile Fabric is shown between the chamber and stone base.

StormTech Isolator Row with Overflow Spillway (*not to scale*)



Isolator Row Inspection/Maintenance

Inspection

The frequency of inspection and maintenance varies by location. A routine inspection schedule needs to be established for each individual location based upon site specific variables. The type of land use (i.e. industrial, commercial, residential), anticipated pollutant load, percent imperviousness, climate, etc. all play a critical role in determining the **actual frequency of inspection and maintenance practices.**

At a minimum, StormTech recommends annual inspections. Initially, the Isolator Row should be inspected every 6 months for the first year of operation. For subsequent years, the inspection should be adjusted based upon previous observation of sediment deposition.

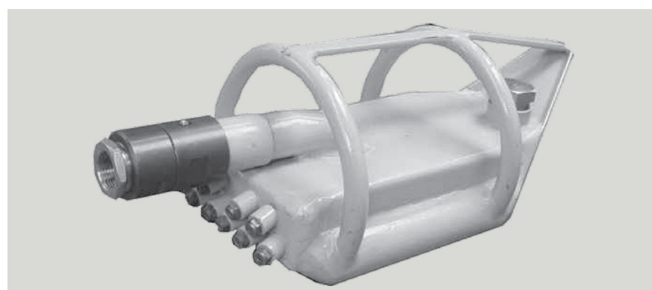
The Isolator Row incorporates a combination of standard manhole(s) and strategically located inspection ports (as needed). The inspection ports allow for easy access to the system from the surface, eliminating the need to perform a confined space entry for inspection purposes.

If upon visual inspection it is found that sediment has accumulated, a stadia rod should be inserted to determine the depth of sediment. When the average depth of sediment exceeds 3 inches throughout the length of the Isolator Row, clean-out should be performed.

Maintenance

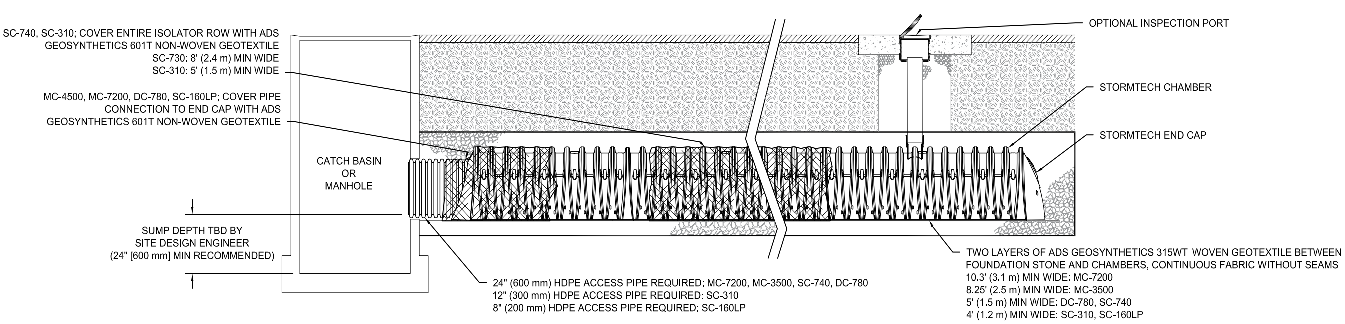
The Isolator Row was designed to reduce the cost of periodic maintenance. By "isolating" sediments to just one row, costs are dramatically reduced by eliminating the need to clean out each row of the entire storage bed. If inspection indicates the potential need for maintenance, access is provided via a manhole(s) located on the end(s) of the row for cleanout. If entry into the manhole is required, please follow local and OSHA rules for a confined space entries.

Maintenance is accomplished with the JetVac process. The JetVac process utilizes a high pressure water nozzle to propel itself down the Isolator Row while scouring and suspending sediments. As the nozzle is retrieved, the captured pollutants are flushed back into the manhole for vacuuming. Most sewer and pipe maintenance companies have vacuum/JetVac combination vehicles. Selection of an appropriate JetVac nozzle will improve maintenance efficiency. Fixed nozzles designed for culverts or large diameter pipe cleaning are preferable. Rear facing jets with an effective spread of at least 45" are best. JetVac reels can vary in length. For ease of maintenance, ADS recommends Isolator Row lengths up to 200" (61 m). **The JetVac process shall only be performed on StormTech Isolator Rows that have AASHTO class 1 woven geotextile (as specified by StormTech) over their angular base stone.**



StormTech Isolator Row (not to scale)

Note: *Non-woven fabric is only required over the inlet pipe connection into the end cap for SC-160LP, DC-780, MC-3500 and MC-7200 chamber models and is not required over the entire Isolator Row.*



Isolator Row Step By Step Maintenance Procedures

Step 1

Inspect Isolator Row for sediment.

A) Inspection ports (if present)
   i. Remove lid from floor box frame
   ii. Remove cap from inspection riser
   iii. Using a flashlight and stadia rod,measure depth of sediment and record results on maintenance log.
   iv. If sediment is at or above 3 inch depth, proceed to Step 2. If not, proceed to Step 3.

B) All Isolator Row
   i. Remove cover from manhole at upstream end of Isolator Row
   ii. Using a flashlight, inspect down Isolator Row through outlet pipe
      1. Mirrors on poles or cameras may be used to avoid a confined space entry
      2. Follow OSHA regulations for confined space entry if entering manhole
   iii. If sediment is at or above the lower row of sidewall holes (approximately 3 inches), proceed to Step 2. If not, proceed to Step 3.

Step 2

Clean out Isolator Row using the JetVac process.

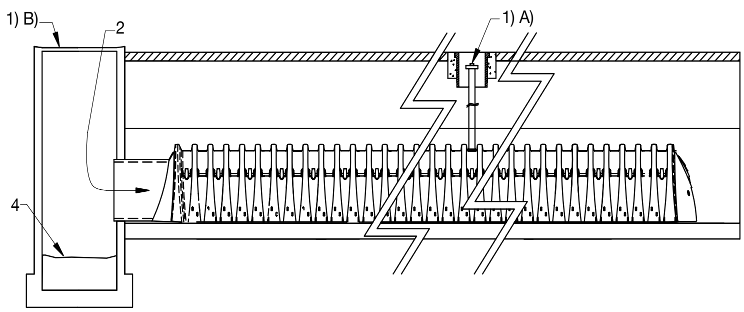
A) A fixed floor cleaning nozzle with rear facing nozzle spread of 45 inches or more is preferable
B) Apply multiple passes of JetVac until backflush water is clean
C) Vacuum manhole sump as required

Step 3

Replace all caps, lids and covers, record observations and actions.

Step 4

Inspect & clean catch basins and manholes upstream of the StormTech system.



Sample Maintenance Log

Date	Stadia Rod Readings		Sedi-ment Depth (1)–(2)	Observations/Actions	Inspector
	Fixed point to chamber bottom (1)	Fixed point to top of sediment (2)			
3/15/11	6.3 ft	none		New installation. Fixed point is CI frame at grade	DJM
9/24/11		6.2	0.1 ft	Some grit felt	SM
6/20/13		5.8	0.5 ft	Mucky feel, debris visible in manhole and in Isolator Row, maintenance due	NV
7/7/13	6.3 ft		0	System jetted and vacuumed	DJM

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