CRYSTAL LAKE MANAGEMENT PLAN

City of Newton
1000 Commonwealth Avenue
Newton Centre, MA 02459

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1. INTRODUCTION

Crystal Lake is located in the City of Newton, Massachusetts, south of Newton Center and north of Boylston Street, as shown in Figure 1-1, the site locus. The lake is surrounded by private residential properties and is a popular recreation area with two small parks, a town beach, and a bath house.

In recent years, Crystal Lake has experienced summer blooms of cyanobacteria. Such blooms are linked to increases in the concentration of the key nutrient phosphorus, to lowered ratios of the nutrient nitrogen to phosphorus, and increases in temperature. Although phosphorus aids with plant growth, too much phosphorus can lead to excessive algal and weed growth, reduced dissolved oxygen, and changing pH levels, and can cause depleted oxygen levels, fish kills, and harmful lake conditions. Long-term inputs of phosphorus from the Crystal Lake watershed can create a nutrient buildup in lake sediments that has the potential to release over time and mix back into the whole water column, creating algae blooms.

The City of Newton desires to reverse this trend and maintain water quality to support the intended uses of Crystal Lake. In order to assist the City of Newton with implementing best management practices to accomplish this goal, a comprehensive lake management assessment was conducted, including both internal and external management evaluations. This report summarizes the evaluation of Crystal Lake and its watershed, and a recommended nutrient management strategy to address both external nutrient loading (watershed) and internal nutrient recycling for Crystal Lake.

This evaluation was conducted to complement previous studies of Crystal Lake and is specifically an evaluation of available phosphorus in lake sediments with the intent of identifying internal nutrient management that can complement ongoing watershed-based nutrient control. Complementary to internal load management, continued actions by the City of Newton, Crystal Lake Conservancy, and the Friends of Crystal Lake to improve watershed conditions and reduce the potential for watershed-based stormwater nutrient loading will be necessary to minimize the potential for future algal blooms.

The report evaluates the phosphorus reduction potential of targeted internal and external management actions and discusses implementation, including costs, operations, maintenance, and permits. The benefits and challenges were considered when developing the recommended strategy to manage current nutrient loads and advance efficient and sound long-term conservation and restoration of Crystal Lake.

In addition to the primary concern of lake clarity and public safety, there are also several regulatory obligations under the Clean Water Act that the City of Newton strives to maintain compliance with. This report will be used by the City to maintain its compliance with the Massachusetts Municipal Separate Storm Sewer System General Permit (MS4 Permit), which regulates stormwater discharges into waters of the US. The MS4 Permit requires the City to engage in specific management actions to reduce potential stormwater pollution, including nutrients, from reaching waterbodies like Crystal Lake. This Crystal Lake Management Plan presents the information and calculations that are required under the MS4 Permit and will act as a model for a City-wide nutrient control plan to be developed for the Charles River, which is an impaired waterbody and where Crystal Lake ultimately discharges. Therefore, implementation of the recommended nutrient control management practices will improve lake conditions and will also be credited towards the City's required phosphorus load reduction under the MS4 Permit requirements.

2. INTERNAL LAKE NUTRIENT MANAGEMENT

2.1 Introduction

Woodard & Curran contracted with Dr. Ken Wagner of Water Resources Services, Inc. to conduct the evaluation of existing water quality data for Crystal Lake, conduct sampling and analysis of Crystal Lake bottom sediments, obtain supplementary in-lake chemistry data, and to develop recommendations associated with internal nutrient management. Dr. Wagner's Nutrient Loading Analysis and Management Review for Crystal Lake, Newton, Massachusetts is included as Appendix A of this report. The following provides a brief summary of Appendix A.

2.2 Background

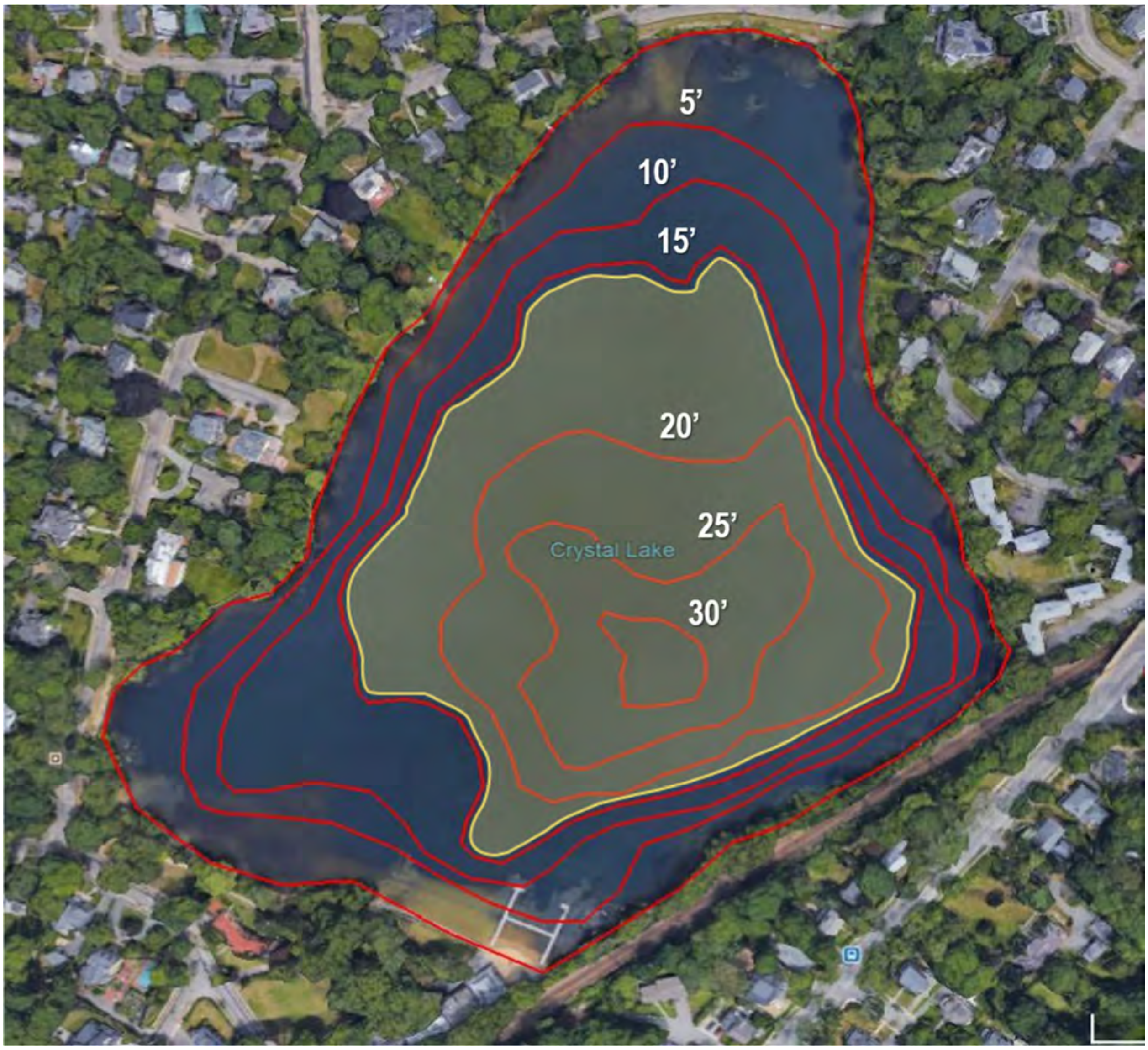
Crystal Lake in Newton Massachusetts is a natural waterbody that covers 27.5 acres to a maximum depth just over 30 feet and receives runoff from a 55-acre watershed that is primarily residential land. The City maintains a popular swimming area and beach with an adjacent park at the lake, which is also a visual amenity in the neighborhood, supports fishing and non-motorized boating, and provides habitat for aquatic organisms.

Analysis of existing data, and a limited but focused study in 2019, have revealed low oxygen in water deeper than about 16 feet during summer, leading to internal recycling of phosphorus through release from bottom sediments. The phosphorus load from sediment release occurs mainly in summer and lowers the nitrogen to phosphorus ratio at a time when warmer temperatures also favor cyanobacteria. This nutrient release from sediment is referred to as the internal load or sediment load in this report. The phosphorus released from sediment under low oxygen conditions over a period of 2-3 months is adequate to support algae blooms but is not evenly distributed in the water column. However, light penetrates deep enough in Crystal Lake to allow cyanobacteria to grow at greater depth. After enough growth and phosphorus storage, cells develop gas pockets that cause them to float upward to get more light, and this results in the observed blooms. Phosphorus near the surface is inadequate to support the bloom for more than a week or two, so clearer water may return, but it is also possible for different cyanobacteria to grow and rise in succession, maintaining undesirable conditions for more of the summer.

Given the observed low oxygen levels in Crystal Lake in the summer, the available phosphorus content of the organic sediment within Crystal Lake is therefore very important, was a focus of this study, and is discussed in more detail in Appendix A. Samples were collected from five stations in Crystal Lake and test results indicate only moderate amounts of iron-bound phosphorus but elevated levels of biogenic phosphorus, which is the most easily released form of organic phosphorus. The lack of iron to bind that biogenic phosphorus as it is released will aid its movement into the water column and make it more available to algae for uptake and growth. Concentrations for all tested features are not very variable over space, suggesting that the organic sediment can be treated as a consistent factor over space in the lake. Wherever oxygen drops below about 2 mg/L there is an increased risk of phosphorus becoming available to support algae growth.

Dr. Wagner utilized phosphorus content in the sediments to estimate available phosphorus under low oxygen summer conditions. Within the upper 10 cm (4 inches) of organic sediment in every square meter at depths where low oxygen occurs, there are about 7.8 g (0.02 lbs) of potentially available phosphorus waiting to be released from each square meter of sediment below a depth of about 5 m (>16.5 feet). Typically, it is assumed that 7% of the iron-bound phosphorus and 2% of the biogenic phosphorus are released, about 0.19 g/m^2 would be released over the area exposed to low oxygen, and as shown in Figure 1. Using the 5 m contour as the contributing area with low oxygen, an internal load of 7 kg (15.4 lbs) is projected as available during the summer. At the 6 m contour, more indicative of 2019, the internal load would be about 5.2 kg/yr (11.5 lbs/yr) An internal load of between 5 and 7 kg/yr (11.5-15.4 lb/yr) is suggested as typical for Crystal Lake under current conditions.

Figure 1: Crystal Lake Bathymetry and Approximate Nutrient Inactivation Control Area (in yellow)



(Contours in feet, adapted from Beals and Thomas survey as augmented by 2019 measurements by WRS Inc.)

As discussed in further detail in the Section 3 and in Attachment A the internal load is all associated with summer, while the watershed load is more evenly distributed throughout the year. As a result, the internal load is the single largest source during the summer and is likely to be the difference between algae blooms or lower productivity in any year.

Based on our evaluation of existing and new stormwater runoff data and the development and evaluation of several watershed pollutant loading modeling scenarios, the lake watershed generates substantial nutrient and organic loads from various sources that either deposit nutrients on impervious surfaces that can be transported to the lake during runoff events or that directly enter the lake during precipitation. Elevated concentrations of phosphorus have been detected in stormwater runoff, particularly in early fall during leaf litter deposition, that enters via seven stormwater discharges. Additional stormwater enters the lake via overland flow (direct drainage areas without piping). Watershed and subwatershed areas are shown in Figure 3.1.

The portion of the annual phosphorus load attributable to stormwater is large enough to be a concern for lake water quality over time, but individual storms are not likely to add enough nutrients to drastically increase the phosphorus load in the short-term. This is largely a function of ratio of watershed size to lake size. With a detention time of about two years, nutrients entering Crystal Lake via stormwater will accumulate in the sediment where recycling is likely. Thus, stormwater runoff has been and will continue to be a major contributor to the internal load of phosphorus over an extended period of time.

Other sources of phosphorus to any lake include direct precipitation, inputs from wildlife, and groundwater, but in our evaluation, these sources are minor; runoff from the watershed and internal loading supply more than 86% of the phosphorus in the lake. The watershed load (53%) is larger than the internal load (34%) but the internal load occurs almost entirely in summer and is a greater contributor to cyanobacteria blooms. Based on existing data, the resultant average concentration of total phosphorus in Crystal Lake is 17-20 µg/L, with <10 µg/L as a very desirable concentration and >20-25 µg/L as a threshold that will support frequent algae blooms. Variation in the weather, leading to variable inputs from the watershed and variable exposure of the bottom to low oxygen, will lead to variation in lake condition that will be unacceptable some of the time, primarily in mid- to late summer, as evidenced by the algae bloom in late summer of 2019.

2.3 Internal Nutrient Load Recommendations

Based on our evaluation, a reduction in the internal phosphorus load that will result in an average concentration of about 13 µg/L could be achieved by dredging, oxygenation, or phosphorus inactivation, with inactivation being the least expensive and most rapid means of gaining improvement. Further discussion of the pros and cons these management options are included in Appendix A.

Under nutrient inactivation, our preferred recommendation, the probability of an algae bloom would be <2% and water clarity is predicted to average at least 10 feet, providing acceptable conditions in the lake. A nutrient inactivation treatment with aluminum could be accomplished in one application period but spreading the treatment out over three applications with two years between each would adequately control internal loading while stripping phosphorus from the water column multiple times, countering stormwater runoff loads of phosphorus to the lake while watershed management actions are being implemented. Given that nutrient cycling is already occurring within Crystal Lake, nutrient inactivation is the only solution to reducing available nutrients within Crystal Lake to solve current algae blooms, but long-term nutrient management in the watershed will prolong the value of internal nutrient inactivation, as described below.

Complementary to internal load management, continued actions by the City of Newton, Crystal Lake Conservancy, and the Friends of Crystal Lake to improve watershed conditions and reduce the potential for watershed-based stormwater loading will be helpful to minimize the potential for future algal blooms. As in any developed landscape, watershed-based best management practices are not usually able to completely counter internal nutrient loads, particularly when nutrients have accumulated in lake sediments over many years.

Based on our evaluation of watershed-based stormwater loads, achieving a watershed load reduction of at least 20% is a practical goal and would reduce the average in-lake phosphorus concentration from 13 µg/L (after nutrient inactivation) to an average in-lake total phosphorus concentration of 11 µg/L. Under this scenario, the associated probability of algae blooms would then be <1%, cyanobacteria would not be expected, and water clarity would average over 10 feet, all very favorable conditions for Crystal Lake. Continued watershed management will be important to the duration of benefits achieved by internal phosphorus inactivation and can provide additional benefits to the lake, including reduced bacterial concentrations, lowered non-algal turbidity, and minimized organic loading that leads to lower oxygen concentrations.

3. EXTERNAL WATERSHED NUTRIENT MANAGEMENT

The Crystal Lake watershed was evaluated to determine the probable annual external phosphorus load to the lake, as a basis for identifying >20% watershed load reduction. As previously described, external watershed management is important for long-term nutrient, and other stormwater entrained pollutants, as excessive loading of nutrients to the lake will result in further degradation and a need for continuous internal management. The City of Newton and watershed partners are already well underway in regard to reducing the input of stormwater-based pollutants using stormwater treatment control devices (structural) and also through non-structural stormwater management. In this report, non-structural best management practices (BMPs), such as enhanced street sweeping, catch basin cleaning, and organic waste and leaf litter collection, and structural BMPs, such as infiltration and filtration prior to discharge, were evaluated as external watershed management options.

The external watershed nutrient management investigations, conducted in this study, included additional lake outfall sampling, pollutant load calculations, siting and sizing of structural BMP “retrofits”, and preparing a cost-benefit evaluation. Several methods of pollutant load calculations were performed to provide a basis of comparison, including one by Dr. Ken Wagner that is described in Appendix A. It is important to note that each of these loading calculations are only an approximation of reality and will vary based on annual precipitation depth, intensity, land use conditions and other variables. The methods described in this section are generally accepted procedures used by the regulatory agencies or watershed managers to define watershed loads and potential load reductions.

One loading calculation follows the guidelines set forth in the MS4 Permit, which uses phosphorus export rate data defined by the United States Environmental Protection Agency (EPA) Region 1. The other method used is the so-called Simple Method, which uses median event mean concentration (EMC) values for nutrient concentrations in stormwater, annual precipitation depth and a watershed routing factor to obtain annual loading values. For this report, the actual mean concentration of total phosphorus collected through sampling over the past several years were used to replace the median EMC values in the Simple Method equation. Finally, structural BMPs were sited and sized to maximize the treatment effectiveness based on influent stormwater runoff volume. A cost-benefit analysis was performed to analyze which proposed BMPs provide the best pollutant removal at the lowest cost.

3.1 Watershed Description

The watershed draining to Crystal Lake is generally bounded by Beacon Street to the north, the Massachusetts Bay Transportation Authority (MBTA) Green Line to the east, Hyde Street to the southwest, and Walnut Street to the west. The watershed delineation is presented in Figure 3-1. The watershed encompasses 55 acres of mostly residential properties. The lake is approximately 27.5 acres and is classified as a “great lake”, as defined by the state of Massachusetts as a lake or lake that is at least 10 acres in size. Crystal Lake water sources include stormwater runoff and groundwater flow. As discussed in Section 1, the Lake ultimately discharges to the Charles River via a brook that passes below the MBTA Green Line and is routed through the City stormwater drainage system.

Crystal Lake is approximately 141 feet above sea level, and the watershed varies in grade ranging from elevation 177 to the lake surface at 141 feet (NAVD88). Contour data, in addition to stormwater infrastructure, building location, and an approximate Lake watershed line, was provided by the City. As a part of this study, watershed areas and sub-areas were further refined and are shown in Figure 3-1. As with any watershed delineation and land use evaluation, all watershed areas and sub-watershed pervious and impervious areas are approximate.

According to the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey, site soils are comprised of Merrimac-Urban land complex (626B), which is characterized as somewhat excessively drained; Canton-Charlton-Urban land complex (629C), which is characterized as well drained; and Charlton-Urban land-Hollis complex (631C), which is also characterized as well drained. The NRCS Soil Survey classifies 626B and 631C soils as Hydrologic Soil Group (HSG) classification “A/D” and 629C soils as HSG “A”.

A soil infiltration rate of 2.41 inches per hour was used in the analysis based on the well-draining soil conditions presented in the NRCS Soil Survey located in Appendix B; however, onsite soil evaluations should be performed to confirm soil conditions prior to design of structural BMPs.

Land use data and impervious surface data was collected from MassGIS 2005 data layers and is the basis of evaluation of the potential stormwater pollutant load. The watershed consists mostly of high-density residential land, which is classified as housing smaller than ¼ acre lots. Other land use categories within the watershed include commercial, forest, and transportation (highway). The land use areas are presented in Figure 3-2. Land use categories and pervious/impervious drainage areas are important factors when calculating pollutant load, because each category has a different phosphorus load export rate. A multi-family or high -density residential neighborhood produces significantly higher pollutant loads than a forest.

3.2 Lake Outfall Phosphorus Sampling

The City of Newton has performed stormwater quality tests at Crystal Lake outfalls since 2011. Woodard & Curran collected total phosphorus samples in October 2019 to compliment previously acquired data. Samples were taken at three lake outfalls, Outfall #5, #7, and #8. Outfalls chosen for sampling were based on watershed size, since a larger watershed is likely to generate a larger pollutant load. The sub-watersheds draining to these outfalls were the largest within the Crystal Lake watershed. The following table provides mean and median total phosphorus concentration values for both data provided from the City and sample data collected by Woodard & Curran.

Table 3-1: Total Phosphorus Sampling Concentration Summary

Location of Sample	Total Phosphorus (mg/L)					
		Data Provided from the City	Number of Sampling Events	Sample Data Collected by W&C	Number of Sampling Events	Weighted Average of City and W&C Data Sets
Outfall #5	Mean	0.412	12	0.864	4	**0.525**
	Median	0.301		0.831		**0.433**
Outfall #7	Mean	0.368	12	0.560	4	**0.416**
	Median	0.290		0.634		**0.376**
Outfall #8	Mean	0.287	11	0.380	4	**0.310**
	Median	0.236		0.404		**0.278**

Nutrient concentrations in stormwater samples tend to be higher in the fall than in other seasons, because leaf litter contributes to the nutrient loading in urban stormwater. The Wisconsin Department of Natural Resources (DNR) prepared an Interim Municipal Phosphorus Reduction Credit for Leaf Management Programs guidance document located in Appendix G, which is a leaf litter collection credit policy scientifically based on the most recent research. Within this document and related studies, the Wisconsin DNR estimates that on average 43% of the annual phosphorus load is discharged in the fall. Therefore, there can be a significant impact from seasonality on phosphorus sample concentrations. The City samples were collected from May to November, providing a good variety of seasonal concentrations. The four Woodard & Curran samples were collected in October 2019, which could be the cause for these sampled concentrations being higher than the City concentrations. The resulting weighted average total phosphorus concentration of all data sets for the selected outfalls is slightly higher than average urban area phosphorus concentration, which is approximately 0.3 to 0.4 mg/L, but provides a conservative estimate for annual nutrient loading estimates.

3.3 Pollutant Loading Estimates

Pollutant load calculations were completed for three Crystal Lake watershed conditions. These conditions include baseline, existing, and proposed conditions. The baseline condition does not account for existing or proposed stormwater management practices; it only accounts for pollutant loads that are generated within the watershed based on percent of impervious cover and land use data collected in 2005. Existing conditions account for BMPs that have been installed or implemented within the Crystal Lake watershed to date. Finally, proposed conditions include existing BMPs in addition to recommended BMPs that have been evaluated during development of this phosphorus control plan. Although the pollutant of concern that is causing lake closures is phosphorus, total suspended solids and nitrogen loads were also evaluated as these contribute to overall lake health.

The pollutant load calculations estimate a numerical pollutant load generated by the watershed given the different land use categories and account for any reductions of pollutants provided through non-structural and structural BMPs. It is important to note, and further described in Appendix A, that these types of annual loading models often overestimate the nutrient loads that are actually immediately available and measurable in the lake water column as a total phosphorus concentration. A significant percentage of the annual load may be comprised of particulate fractions and solids that will only be measurable within the lake water concentrations once they have dissolved and are in solution.

Pollutant load calculations were developed following the MS4 Permit guidance and by using the Opti-Tool. Opti-Tool is a spreadsheet-based tool developed for the EPA Region 1. The purpose of the tool is to optimize structural stormwater management designs to provide cost-effective pollutant and volume reduction plans. The spreadsheet is based on a Storm Water Management Model (SWMM) software application that uses region specific data such as precipitation, buildup and washoff processes for typical land uses, BMP performance, and cost to provide optimal results. This tool was used to calculate pollutant loading in a streamlined and efficient manner, rather than manually calculating the loads. The tool's optimization capability was not used for this analysis due to site conditions and existing constraints. Instead, identified locations for structural stormwater controls were based on existing site constraints, including probable utility conflicts and the experience of the Woodard & Curran team to minimize retrofit costs and increase retrofit benefit.

Pollutant loads for the entire Crystal Lake watershed are summarized in the following sections. Individual sub-watershed export loads, BMP reduction calculations, and Opti-Tool screenshots for baseline, existing, and proposed conditions are presented in Appendix C, D, and E respectively.

3.3.1 Baseline Condition Pollutant Loading

Table 3-2 below summarizes the baseline pollutant load generated calculated using Opti-Tool. In-depth calculations are presented in Appendix C.

Table 3-2: Baseline Pollutant Load Calculation Summary

Load Type	Pollutant Load (lbs/yr)		
	TP	TN	TSS
Pollutant Load Generated	**50.14**	309.22	10,629.10

3.3.2 Existing Condition Pollutant Loading

Table 3-3 below summarizes the existing pollutant load generated, reduced, and remaining. In-depth calculations are presented in Appendix D.

Table 3-3: Existing Pollutant Load Calculation Summary

Load Type	Pollutant Load (lbs/yr)		
	TP	TN	TSS
Pollutant Load Generated	**50.14**	309.22	10,629.10
Non-Structural BMP Reduction	**-4.00**	NC*	NC*
Structural BMP Reduction	**-0.99**	-6.54	-207.81
Pollutant Load Remaining	**45.15**	302.68	10,421.29

*NC: Not calculated

The MS4 Permit provides phosphorus reduction credit guidance for specific non-structural BMPs including enhanced sweeping, catch basin cleaning, and organic waste and leaf litter collection programs. Guidance on applying credit for these programs is presented in Appendix F of the MS4 Permit. Factors vary depending on the selected non-structural BMP but in general include either the area of impervious roadway surface or the entire drainage area, the phosphorus load export rate based on the land use, and a specified phosphorus reduction factor. The roadway area of impervious surface was delineated with guidance from aerial imagery and topography and assumed a 24-foot roadway pavement width. Reduction credit calculations and equations for existing non-structural BMPs within the Crystal Lake watershed are presented in Appendix D.

The City's Department of Public Works currently implements non-structural BMPs. The City currently performs street sweeping efforts with a mechanical broom weekly on average, cleans catch basins semi-annually, and collects and disposes of organic waste and leaf litter during the weekly sweeping efforts within the Crystal Lake watershed. These non-structural BMP efforts result in total phosphorus reduction credit and are calculated based on guidance within Appendix F of the MS4 Permit. The MS4 Permit does not provide a calculation for total nitrogen and total suspended solids load reduction associated with sweeping, and Opti-Tool does not calculate non-structural benefits. Therefore, these values are denoted as not calculated in the pollutant load summary tables but do provide some level of sediment and nutrient reduction benefit.

During a site visit and with guidance from the City, five locations that have existing structural BMPs were identified. These BMPs include a leaching manhole located on Norwood Avenue, infiltrating roof drains at the Bath House, two leaching catch basins in the Norwood Avenue condo parking lot identified as Lot A, a leaching catch basin in the condo parking lot identified as Lot B, and ADS StormTech infiltrating chambers at the Bath House. Figure 3-1 identifies the locations of existing structural stormwater BMPs, and documentation provided by the City related to the design of these BMPs is presented in Appendix F.

Pollutant removal credit was applied only to existing structural BMPs that are practices included in Appendix F of the MS4 Permit. While the watershed has multiple proprietary filters (Fabco StormBasin Water Quality Filters) installed in catch basins, the MS4 Permit does not currently provide a pollutant removal credit for proprietary BMPs. Therefore, credit was not taken for these catch basin retrofits or for the Stormceptor hydrodynamic separator installed at the Bath House. It is anticipated that these devices do provide some benefit, including trash and sediment control, but for the purposes of this study were not included in the evaluation.

The treated depth of runoff was calculated for each existing structural BMP by following calculation guidance presented in Flow Chart 4: Method to determine the phosphorus load reduction for a BMP with known storage volume when both pervious and impervious drainage areas are present in Appendix F of the MS4 Permit. The practice's physical storage volume was approximated and divided by the drainage area directed to the BMP. Since the watershed has mostly HSG A soils, the total volume of runoff contributed from pervious areas was negligible and the assumption that the site was 100% impervious was acceptable. If the treated depth of runoff was less than 0.1 inch, then no credit was applied for the BMP, because the BMP performance curves presented in the MS4 Permit do not provide removal efficiency data for runoff depths less than 0.1 inch. Finally, any assumptions that were made to estimate the physical storage volume if the BMP size was unknown are presented in the individual sub-watershed pollutant load calculations in Appendix D.

The implemented non-structural BMPs and the existing constructed structural BMPs provide an approximate percent reduction of total phosphorus, total nitrogen, and total suspended solids presented in Table 3-4 below.

Table 3-4: Existing Pollutant Percent Reduction

	Pollutant		
	TP	TN	TSS
Existing Percent Reduction	**10%**	2.1%	2.0%

3.3.3 Proposed Condition Pollutant Loading

Table 3-5 below summarizes the proposed condition pollutant load generated, reduced, and remaining after implementation of additional stormwater controls described in this section. In-depth calculations are presented in Appendix E.

Table 3-5: Proposed Condition Pollutant Load Calculation Summary

Load Type	Pollutant Load (lbs/yr)		
	TP	TN	TSS
Pollutant Load Generated	**50.14**	309.22	10,629.10
Proposed Non-Structural BMP Reduction	**-4.57**	NC*	NC*
Existing Structural BMP Reduction	**-0.99**	6.54	207.81
Proposed Structural BMP Reduction	**-10.56**	86.28	2,616.73
Pollutant Load Remaining	**34.02**	216.40	7,804.56

*NC: Not calculated

The proposed non-structural BMP reduction calculations present the ideal non-structural control practices to maximize phosphorus removal credit. These ideal practices include continuing the City's efforts with current catch basin cleaning and organic waste and leaf litter collection programs in addition to a weekly enhanced sweeping program using a high efficiency regenerative air-vacuum sweeper. Purchasing a regenerative air-vacuum sweeper would require an investment in new sweeper technology, as this is not currently the sweeper used in the City. The cost-benefit analysis presented in Section 3.5 below discusses the investment in and possible benefits of utilizing this sweeper technology versus conventional mechanical broom sweepers.

Appendix F of the MS4 Permit indicates that permittees "may propose alternative methods and/or phosphorus reduction factors for calculating phosphorus load reduction credits for these non-structural practices." As a part of this management plan analysis, Woodard & Curran reviewed the Wisconsin DNR Interim Municipal Phosphorus Reduction Credit for Leaf Management Programs to analyze an alternative method for calculating leaf litter collection credit. The Wisconsin DNR policy is based on published USGS research and credits a 17% total phosphorus annual load reduction for the leaf collection effort in the entire drainage area, compared to the 5% phosphorus reduction credit provided by the MS4 Permit. The Wisconsin DNR reduction percentage is based on water quality data for reduction due to collection efforts and annual phosphorus loading occurring in the fall.

The required conditions to achieve the Wisconsin DNR leaf management program credit reduction are included in Appendix G and would likely require a modification to the City approach for fall leaf litter clean up. Sub-watershed OF-

5 was used to compare the MS4 Permit leaf litter collection reduction credit to Wisconsin DNR. The Wisconsin DNR credit was calculated to be nearly 3.5 times more than the MS4 Permit credit. This calculation is presented in Appendix G. This approach could be applied to other areas within the City that meet the Wisconsin DNR required conditions but at this time this credit policy has not been accepted by EPA and therefore these credits were not applied to the analysis as presented in Table 3-5. It is anticipated and recommended that the City consider enhanced leaf litter collection efforts in the Crystal Lake watershed as a 17% phosphorus load reduction for this watershed would provide substantial benefit to meeting a >20% watershed load reduction target.

In addition to non-structural BMPs, Woodard & Curran identified two locations for proposed structural BMPs and one location for which a structural BMP has been designed but is not yet installed. Sub-watershed size and generation of pollutants was a priority when choosing locations for proposed structural BMPs. For some sub-watersheds, like Outfalls #5 and #7, site constraints and utility conflicts restrict development of cost-effective structural BMP designs. Although both of these outfalls tested high for total phosphorus load, steep slopes and lack of space at the outfalls restricted the use of an end of the pipe structural BMP. Lake Terrace was specifically evaluated as a potential location for a proposed structural BMP to treat Outfall #8 runoff; however, during the Crystal Lake site visit multiple utilities were observed within Lake Terrace. Construction of a subsurface BMP would be complicated and costly due to potential utility conflicts and as such the location at Crystal Street and Lake Avenue was preferred as a retrofit location.

The proposed structural BMP locations include Cronin's Cove and the intersection of Crystal Street and Lake Avenue, and the structural BMP that has been designed but not installed is proposed to be located on Trowbridge Avenue. The locations of the proposed BMPs are shown on Figure 3-3. The proposed locations were identified because they would not require land acquisition, there are no known utility conflicts, and the physical characteristics, such as topography and soils, are considered to be adequate. Additional retrofits are also being considered by the City within the Crystal Lake watershed and particularly at Levingston Cove. Since plans have not been finalized, any stormwater management associated with these retrofits is not included in the proposed conditions pollutant load calculations but would further reduce pollutant loads beyond the values presented in Table 3-5.

The Trowbridge Street location had a Rain Guardian and Focal Point bioretention system designed in July 2017. It is our understanding that this improvement project has not yet been constructed but is planned; therefore, the Trowbridge Street BMP is included in proposed conditions loading calculations. Similar to the existing catch basin retrofits, credit was not taken for the proposed Rain Guardian as this is not an approved BMP per Appendix F of the MS4 Permit. The Focal Point bioretention system has an engineered bioretention soil that is intended to infiltrate stormwater at a high infiltration rate and it has been credited with the standard bioretention system reduction efficiency. The Trowbridge Street drainage improvement design plans are included in Appendix F of this report.

Two new infiltration BMPs are proposed at the identified locations. Infiltration BMPs are very beneficial and effective at removing pollutant loading to the target waterbody, specifically phosphorus. Benefits include increasing groundwater recharge, promoting retention and breakdown of pollutants in the soil, reducing thermal impacts of stormwater runoff, and decreasing peak runoff flow rates. Infiltration BMPs are considered suitable for the Crystal Lake watershed based on understanding that the soils are well draining and that separation to groundwater is achievable. Onsite soil evaluations should be performed to confirm soil conditions prior to design of structural infiltration BMPs.

An infiltration trench was chosen for Cronin's Cove, because this park has a long and narrow stretch of open space. A stone trench would fit in this narrow space and would require minimal excavation and backfill. Infiltration trenches treat stormwater by filtration through clean stone and infiltration into native soils. The proposed stone infiltration trench would treat runoff via overland flow as well as runoff captured with adjacent existing catch basins. The Cronin's Cove infiltration trench would receive runoff from lake outfalls #1 and #2, as identified in Figure 3-3. The infiltration trench size and a standard detail is presented in Figure 3-4.

Infiltration chambers are proposed at the intersection of Crystal Street and Lake Avenue. The portion of Crystal Street identified for this retrofit and shown in Figure 3-5 does not appear to have existing utilities such as sewer, gas, or water which can prevent an underground BMP from being installed and/or greatly increase retrofit costs.

The proposed non-structural BMPs and existing and proposed structural BMPs provide an approximate percent reduction of total phosphorus, total nitrogen, and total suspended solids presented in Table 3-6 below.

Table 3-6: Proposed Condition Pollutant Percent Reduction

	Pollutant		
	TP	TN	TSS
Proposed Percent Reduction	**32.2%**	30.0%	26.6%

It is likely that many other structural retrofitting options may exist within the Crystal Lake watershed, including simply retrofitting catch basins as leaching catch basins during capital renewal projects, but based on our recommendation of internal nutrient management in Section 2, in conjunction with recommended non-structural BMPs and the proposed retrofits identified herein, the following recommendations meet our desired condition of a >20% annual total phosphorus load reduction.

3.4 Simple Method Pollutant Loading

For comparison purposes and to demonstrate conservatism within this study, pollutant load calculations developed using Opti-Tool were compared to load calculations using the Simple Method (Schueler, 1987). These calculations are presented in Appendix E. The Simple Method uses estimates of annual precipitation, site percent impervious cover, and stormwater runoff pollutant concentrations based on land use type. Two calculations were performed for Outfalls #5, #7, and #8 using different pollutant concentrations. One variation used a median EMC value for residential land use of 0.3 mg/L and the other used the mean total phosphorus sampled concentrations presented in Section 3.2. The following table summarizes the calculated pollutant loads based on the respective methods.

Table 3-7: Baseline Pollutant Load Calculation Summary

Method of Calculation	Baseline Pollutant Load (lbs/yr)		
	Outfall #5	Outfall #7	Outfall #8
Opti-Tool	5.97	4.41	16.31
Simple Method using Median EMC Value	7.54	5.48	19.86
Simple Method using Sample Concentrations	13.20	7.60	20.53

The significant difference between the two Simple Method results for Outfalls #5 and #7 is due to the outfall sampled concentrations being approximately one and a half times higher than average EMC value for residential land use. The pollutant loads calculated using the Simple Method with a median EMC value are consistently about 25% higher than Opti-Tool's baseline load calculation for these three outfalls.

3.5 Cost-Benefit

A cost-benefit analysis was performed to estimate the cost per pound of phosphorus removed for both non-structural and structural options based on pollutant removal efficiencies and guidance presented in Appendix F of the MS4 Permit. The City currently implements catch basin cleaning and enhanced organic waste and leaf litter collection programs in accordance with the MS4 Permit. Tables 3-8 and 3-9 below describe estimated costs and cost-benefits for existing and proposed non-structural BMPs and proposed structural BMPs.

Table 3-8: Estimated BMP Cost Summary

Estimated Cost	Non-Structural BMP			Structural BMP	
	Existing Catch Basin Cleaning	Existing Street Sweeping + Organic Waste	Proposed Street Sweeping + Organic Waste	Cronin's Cove Infiltration Trench	OF #8A Infiltration Chambers
Cost Estimate	$5,350	$19,000	$25,650	$172,500	$190,000
Annual Inspection/ Maintenance Cost	-	-	-	$1,000	$1,000
Annual Cost	$5,350	$19,000	$25,650	$9,625	$10,500

Cost estimates for existing and proposed non-structural controls were prepared include equipment, maintenance, labor, and disposal costs. Hourly labor rates, disposal costs, and equipment costs were estimated using information from the City of Newton, the City of Leominster, and the City of Portland, Maine. More specific tracking and analysis of specific implementation, inspection and maintenance costs will improve cost-benefit analysis as recommendations are implemented into the future. Non-structural and structural BMP cost assumptions and calculations are included in Appendix H. The cost estimate for the proposed structural BMPs includes a 20% contingency and a 15% engineering design and permitting add-on. These costs include ancillary drainage costs such as routing drainage pipes to and from the structural BMPs. The annual cost estimate assumes a 20-year average life span for the structural BMPs and includes estimated inspection and maintenance costs as a "life-cycle" cost for comparison with annual non-structural BMPs.

Table 3-9: Estimated Cost-Benefit Summary

Estimated Cost-Benefit	Non-Structural BMP			Structural BMP	
	Existing Catch Basin Cleaning	Existing Street Sweeping + Organic Waste EPA (WI DNR)	Proposed Street Sweeping + Organic Waste EPA (WI DNR)	Cronin's Cove Infiltration Trench	OF #8A Infiltration Chambers
Annual Cost	$5,350	$19,000	$25,650	$9,625	$10,500
Phosphorus Load Removed (lbs/yr)	0.86	3.01 (9.09)	3.58 (9.65)	4.01	6.50
Annual Cost-Benefit ($/lb)	6,220	6,312 (2,090)	7,165 (2,658)	2,401	1,615

As shown in Table 3-9, the infiltration chambers proposed within sub-watershed Outfall #8A have the lowest annual cost per pounds of phosphorus removed. These costs are an approximate estimate and reflect an opinion of probably costs.

Non-structural BMPs tend to have a higher cost-benefit than structural BMPs based on the removal credit assigned by the EPA MS4 Permit. The actual benefit provided by these management options may be higher or lower based on watershed characteristics. Table 3-9 compares the existing and proposed cost-benefit for street sweeping and organic waste collection using the EPA credit policy and the Wisconsin DNR leaf litter collection program credit. This comparison demonstrates that the cost-benefit assigned to non-structural BMPs varies significantly depending on the pollutant removal credit assigned to the management practice.

4. LAKE AND WATERSHED MANAGEMENT RECOMMENDATIONS

Given a primary goal for Crystal Lake of eliminating cyanobacteria blooms, treatment with aluminum to inactivate surficial sediment phosphorus is expected to provide immediate and substantial benefit that could potentially last up to two decades. A dose of between 43 and 67 g/m^2 should be applied to all areas of the lake deeper than 5 m (>16.5 feet). The overall reduction in loading, a shift in loading to late summer or early autumn, and an increase in nitrogen to phosphorus ratios are expected to minimize cyanobacteria during the primary period of human use. Such a treatment could be performed incrementally; it does not have to be done all at once, and the cost of sequential additions may be warranted to provide phosphorus stripping of the water column over a period of 6 years while watershed management actions are being implemented.

An oxygenation system could be considered in place of phosphorus inactivation if so desired, as it provides additional water quality and habitat benefits, but will likely cost more than phosphorus inactivation and is not more likely to prevent algae blooms.

Three additional structural BMPs described in Section 3.3.3 are recommended for installation to control runoff from the watershed. The infiltration BMPs when combined with enhanced non-structural controls, have the potential to reduce phosphorus loading to the lake by approximately 35% compared to existing conditions. The three recommended retrofits would account for a 33% phosphorus pollutant load reduction alone and would help to meet our goal of >20% watershed-based load reduction as described in the Nutrient Loading Analysis and Management Review for Crystal Lake, Newton, Massachusetts included as Appendix A.

Unfortunately, under existing EPA nutrient control credit policy the proposed non-structural BMPs are not as cost effective when compared to the proposed structural BMP retrofits or the internal nutrient inactivation. But as existing catch basin cleaning and street sweeping programs are ongoing and it is apparent that new science on leaf litter collection and street sweeping are likely to realize more actual water quality benefit than EPA's policy, it is our recommendation to continue to advance the City's sweeping program and consider expanding the leaf litter collection program in the Crystal Lake watershed. It is evident in our calculations in Section 3, that modifications to non-structural BMP credit policy to be consistent with WIDNR guidance would greatly improve implementation cost-benefit and realize potential significant nutrient load reductions. It is our recommendation to advance discussions with EPA regarding sweeping and leaf litter collection credit policy during the City's next phases of phosphorus control planning to realize both water quality and regulatory "credit".

4.1 Nutrient Inactivation

Although a reduction in the internal phosphorus load could be achieved by dredging or oxygenation, a phosphorus inactivation treatment with aluminum would be the least expensive and most rapid means of gaining improvement within Crystal Lake and is necessary to address internal recycling of phosphorus. The life-cycle cost assumes that implementation of nutrient inactivation could potentially last up to two decades and abate approximately 10 lbs/year of internal phosphorus availability. Table 4-1 below summarizes the costs, permit considerations, and additional assessment needs associated with nutrient inactivation.

Table 4-1: Nutrient Inactivation Summary

Estimated Cost	Permit Considerations	Additional Assessment Needs
• Cost Estimate: $50,000 • Annual "Life-cycle" Cost: $5,000 • Cost/Benefit: $250/lb	• Conservation Commission Order of Conditions • License to Apply Chemicals from MADEP	• Public Outreach • Program Management • Monitoring

4.2 Cronin's Cove Infiltration Trench

The Cronin's Cove infiltration trench is presented in Figure 3-4. This narrow stone trench would require minimal excavation and backfill and would fit in the park's narrow space. The proposed stone infiltration trench would receive runoff from lake outfalls #1 and #2, and the cost associated with rerouting the existing drainage system to the proposed structural BMP is included in the provided cost estimate. Additional soil investigations and topographic and utility survey would need to be conducted prior to design of this system.

Table 4-2: Cronin's Cove Infiltration Trench Summary

Estimated Cost	Permit Considerations	Additional Assessment Needs
• Cost Estimate: $172,500 • Annual "Life-cycle" Cost: $9,625 • Cost/Benefit: $2,401/lb	• Conservation Commission Request for Determination of Applicability • Review by Commission of Inspectional Services and City Engineer	• Soil Investigations • Survey

4.3 Outfall #8A Infiltration Chambers

The Outfall #8A infiltration chambers are shown in Figure 3-7. These chambers would be installed at the intersection of Crystal Street and Lake Avenue and would be installed in-line with the existing drainage system. Additional soil investigations and topographic and utility survey would need to be conducted prior to design of this system.

Table 4-3: Outfall #8A Infiltration Chambers Summary

Estimated Cost	Permit Considerations	Additional Assessment Needs
• Cost Estimate: $190,000 • Annual "Life-cycle" Cost: $10,500 • Cost/Benefit: $1,615/year	• Review by Commission of Inspectional Services and City Engineer	• Soil Investigations • Survey

4.4 High Efficiency Regenerative Air-Vacuum Street Sweeping and Organic Waste Collection

A high efficiency regenerative air-vacuum sweeper is credited with the highest phosphorus reduction efficiency factor within Attachment 2 to Appendix F of the MS4 Permit. Therefore, this is the recommended sweeper technology to maximize benefit under the EPA credit policy. The calculated cost benefit includes reduction credits for both the enhanced sweeping program and organic waste and leaf litter collection, since the City's current and proposed street sweeping program meets the requirements for both credit options under EPA policy. It should be noted that the WIDNR leaf litter credit policy differs in some ways (both timing and equipment) from the EPA policy that may further reduce implementation costs under EPA policy. In-depth cost estimate calculations and assumptions related to the regenerative air-vacuum street sweeper and the EPA policy only are presented in Appendix H and summarized in the table below.

Table 4-4: High Efficiency Regenerative Air-Vacuum Summary

Estimated Cost	Permit Considerations	Additional Assessment Needs
• Annual Cost: $25,650 • Annual "Life-cycle" Cost: $7,165 • Increase in Annual Cost: $6,643 • Increase in Removal Credit: 0.57 lb/year	• N/A	• Negotiations with EPA regarding credit and modification to leaf litter collection methodology • Operator Training for new equipment

5. CONCLUSION

In summary, Woodard & Curran has developed this Lake Management Plan to provide the City of Newton with a pragmatic and cost-effective means to address water clarity and maximize safe swimming in Crystal Lake.

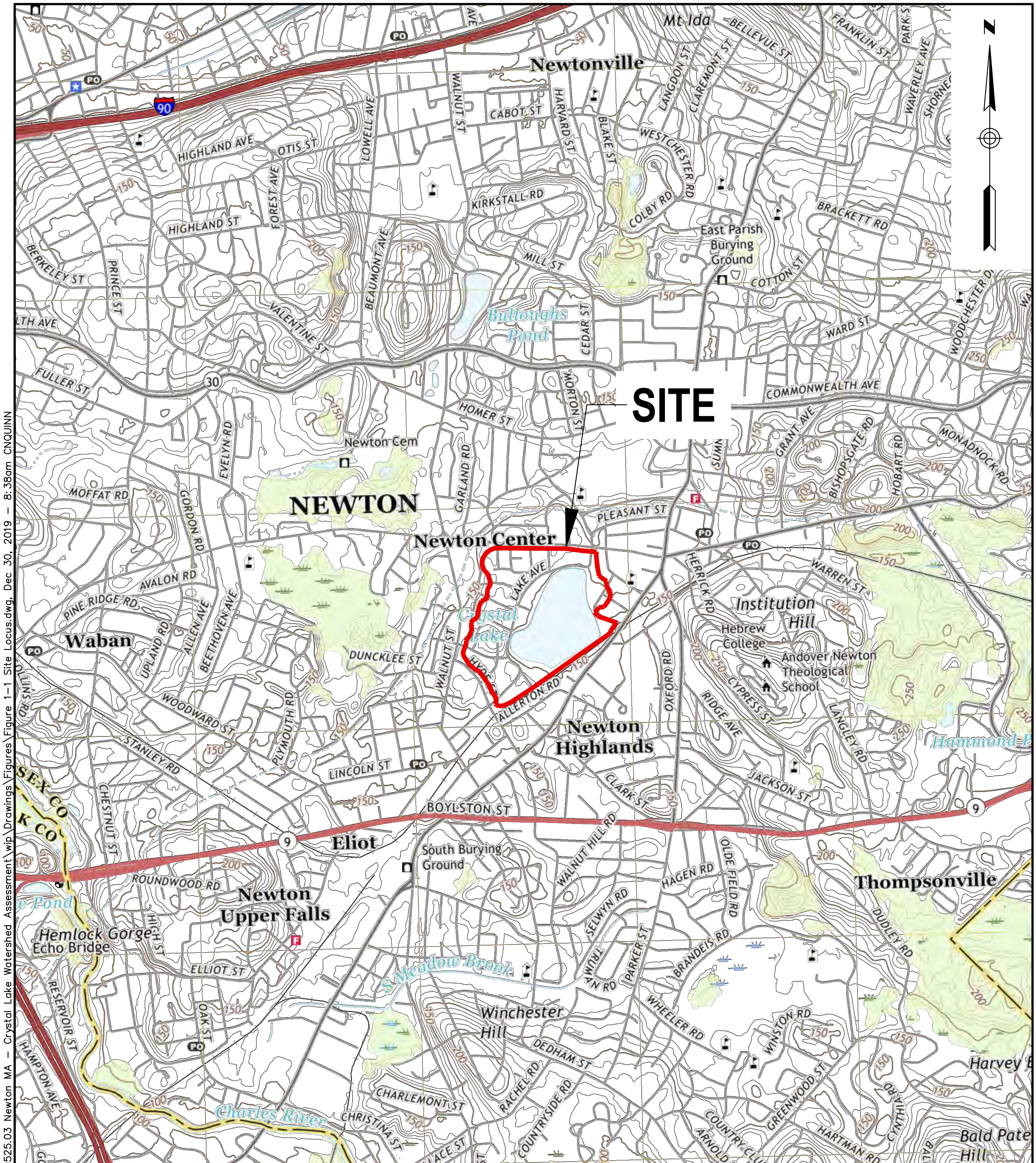
The study conducted the following to supplement previous studies:

- Visual and chemical assessment of lake bottom materials to determine magnitude of phosphorus within existing pond bed material;
- Collection of additional lake water chemistry samples;
- Collection of stormwater runoff samples;
- Assessment of the viability of stormwater control retrofits; and
- Examination of cost-benefit for a variety of both watershed and internal management actions with recommendations.

Crystal Lake will require both internal and external management of nutrients to reduce potential for algae blooms and for long-term lake health and sustainability. Dredging, oxygenation and phosphorus inactivation were internal nutrient management options evaluated. Phosphorus inactivation would be the most viable and cost-effective approach to management of internal nutrient cycling in Crystal Lake.

As noted, an effective phosphorous management program needs to address both internal sources and external sources of nutrients. Several viable structural stormwater controls have been identified for the watershed that would provide long-term nutrient reduction benefit. Additionally, it is recommended that non-structural management actions continue to be implemented by the City with consideration for enhanced efforts to collect and remove leaf litter from the Crystal Lake watershed during fall months.

Figure 1-1: Site Locus



2000' 0 2000' 4000'

BAR SCALE
1" = 2000'
CHECK GRAPHIC SCALE BEFORE USING

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Dedham, Massachusetts 02026
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COMMITMENT & INTEGRITY DRIVE RESULTS

SITE LOCUS

DESIGNED BY: CNQ	CHECKED BY: HCP
DRAWN BY: CNQ	FIGURE 1-1 SITE LOCUS.dwg

CITY OF NEWTON, MA
1000 COMMONWEALTH AVE
NEWTON CENTRE, MA 02459

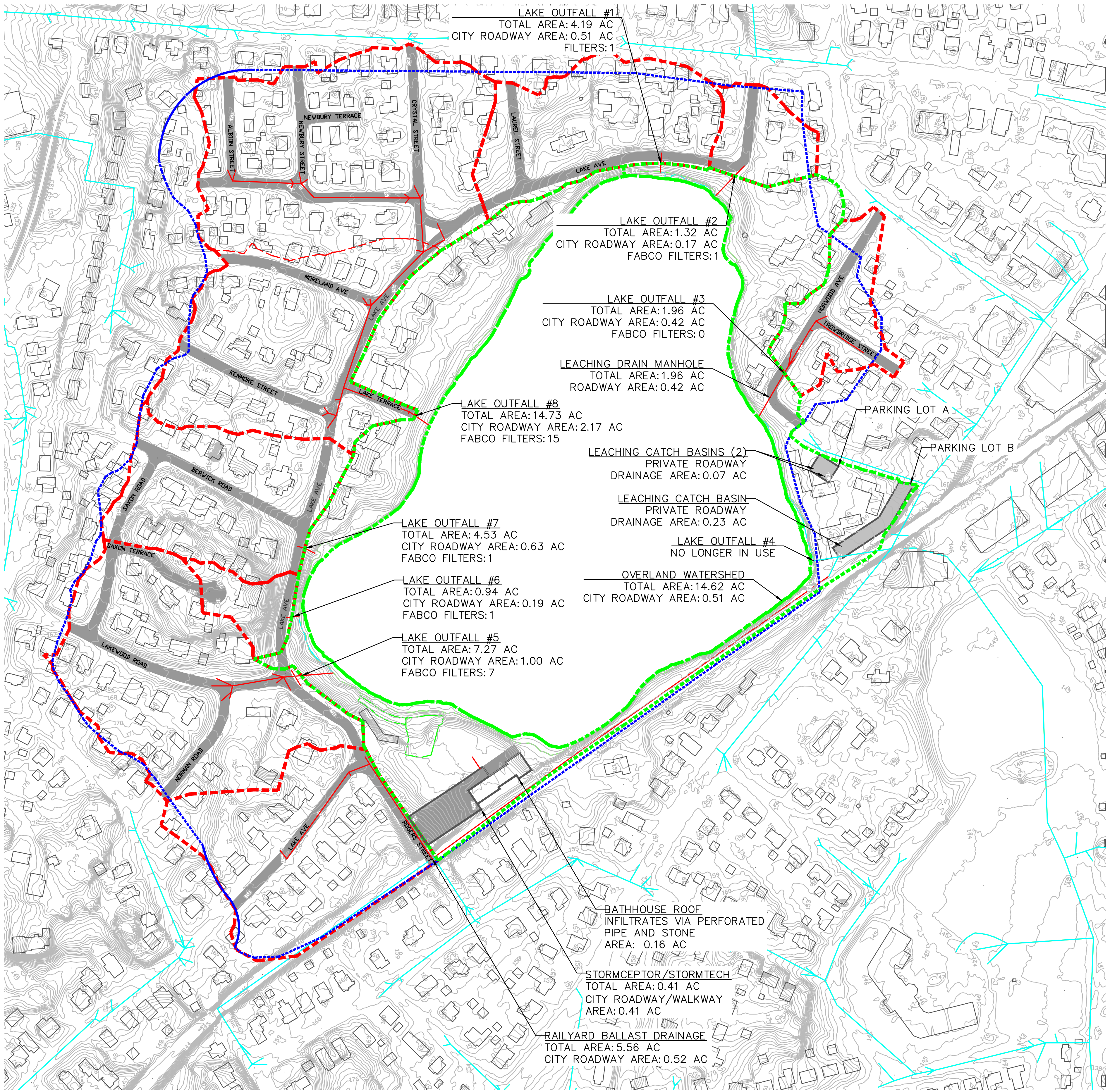
CRYSTAL LAKE MANAGEMENT PLAN

JOB NO: 230525.03
DATE: JANUARY 2020
SCALE: 1" = 2000'

FIGURE 1-1

\\woodardcurran.net\shared\Projects\0230525.03 Newton MA – Crystal Lake Watershed Assessment\wip\Drawings\Figures\Figure 1-1 Site Locus.dwg, Dec 30, 2019 – 8:38am CNQUINN

Figure 3-1: Existing Watershed



CRYSTAL LAKE NEWTON, MA
SUB-WATERSHED FIGURE

LEGEND

- EXISTING CRYSTAL LAKE DRAINAGE SYSTEM
- EXISTING DRAINAGE SYSTEM
- SUB-WATERSHED
- OVERLAND SUB-WATERSHED
- WATERSHED DELINEATION PROVIDED BY CITY
- AREA DRAINING TO EXISTING BMP
- APPROXIMATE CITY ROADWAY LIMIT
- APPROXIMATE PRIVATE ROADWAY LIMIT
- EXISTING BUILDING

300' 0 300' 600'

BAR SCALE
1" = 300'
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EXISTING WATERSHED

DESIGNED BY: CNQ
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CHECKED BY: HCP
FIGURE 3-1 EXISTING WAT*.dwg

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CRYSTAL LAKE MANAGEMENT PLAN

JOB NO: 230525.03
DATE: JANUARY 2020
SCALE: 1" = 300'

FIGURE 3-1

Figure 3-2: Crystal Lake Land Use

Figure 3-2: Crystal Lake Land Use

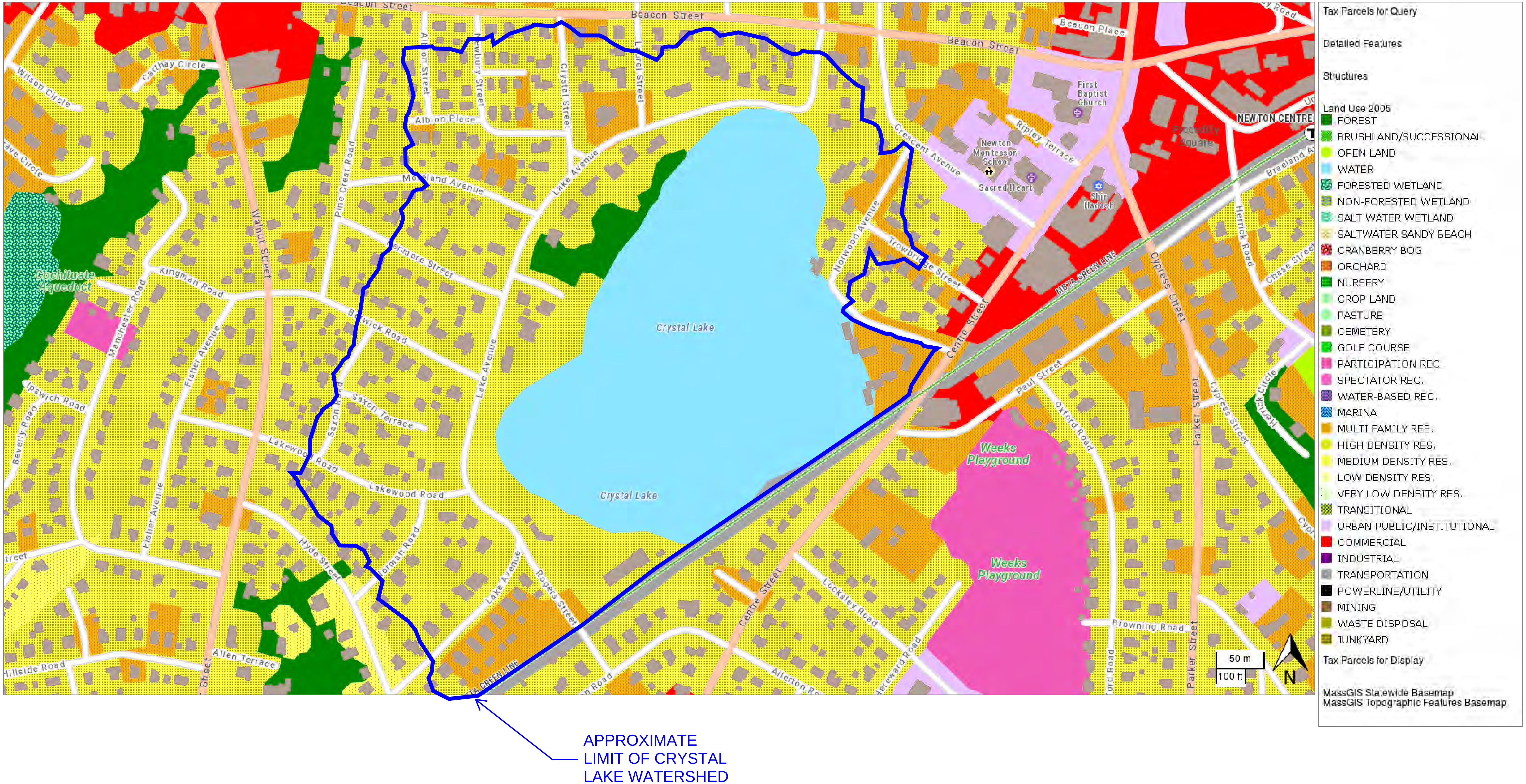
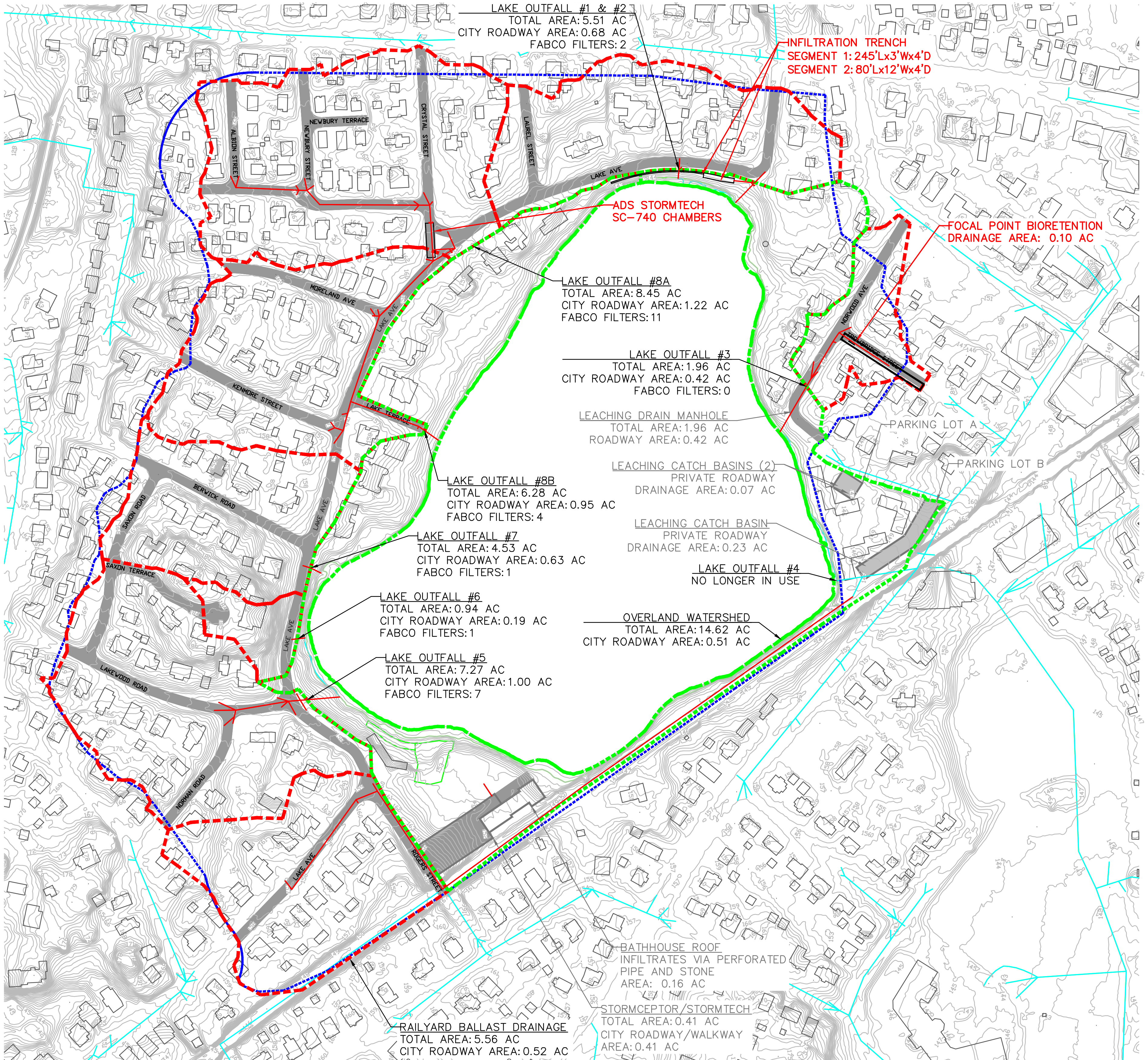


Figure 3-3: Proposed Watershed



CRYSTAL LAKE NEWTON, MA
SUB-WATERSHED FIGURE

LEGEND

- EXISTING CRYSTAL LAKE DRAINAGE SYSTEM
- EXISTING DRAINAGE SYSTEM
- SUB-WATERSHED
- OVERLAND SUB-WATERSHED
- WATERSHED DELINEATION PROVIDED BY CITY
- AREA DRAINING TO EXISTING BMP
- PROPOSED BMP FOOTPRINT
- APPROXIMATE CITY ROADWAY LIMIT
- APPROXIMATE PRIVATE ROADWAY LIMIT
- EXISTING BUILDING

N

300' 0 300' 600'

BAR SCALE
1" = 300'
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PROPOSED WATERSHED

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FIGURE 3-3 PROPOSED WAT*.dwg

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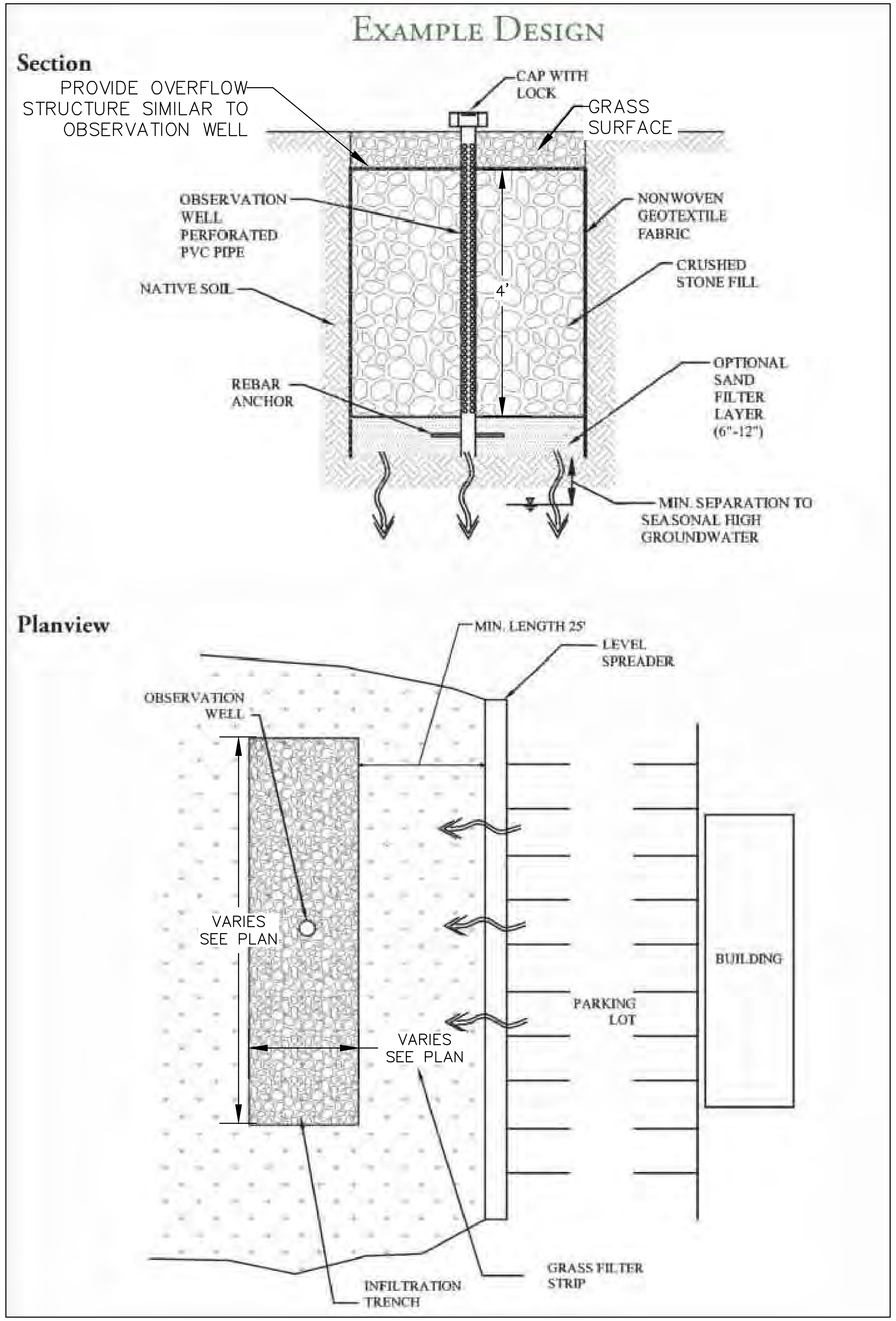
FIGURE 3-3

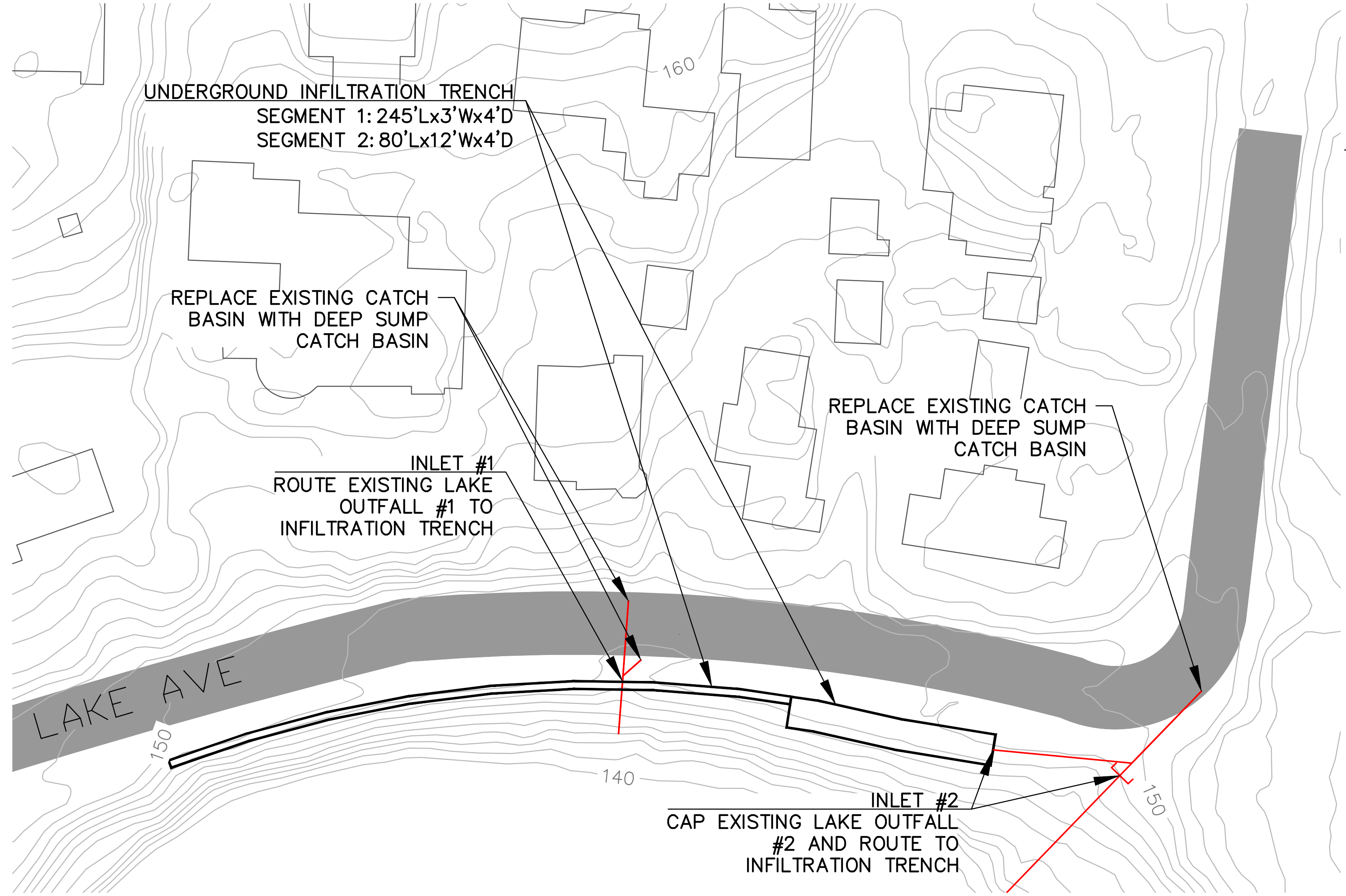
Figure 3-4: Outfall #1 & #2 Infiltration Trench



ADAPTED FROM NEW HAMPSHIRE STORMWATER MANUAL

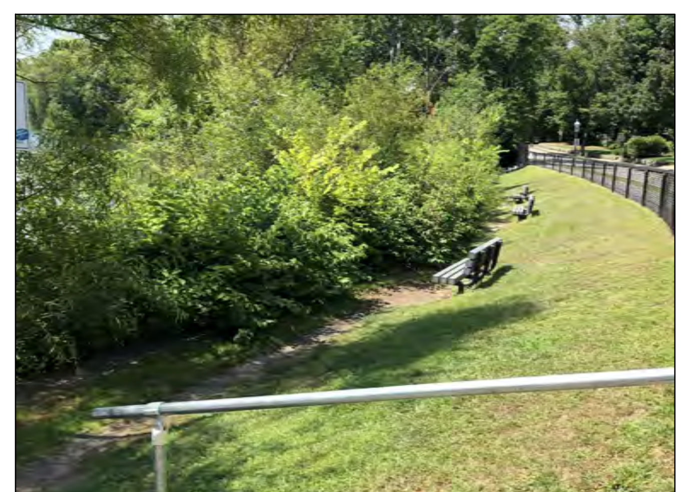
STANDARD INFILTRATION TRENCH DETAIL

SCALE: NOT TO SCALE



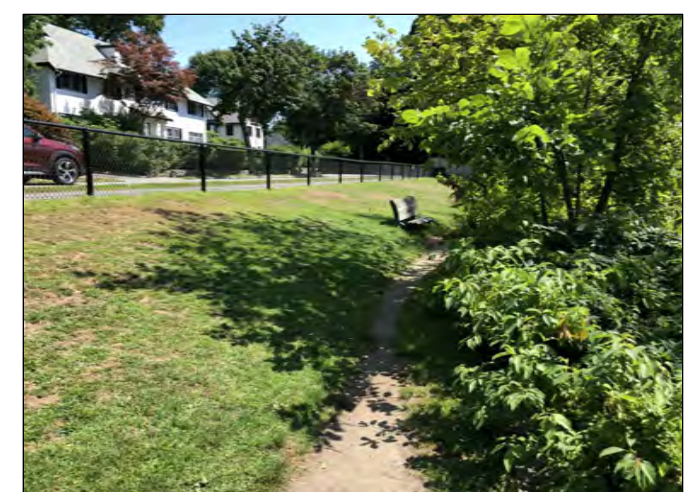
PLAN: LAKE OUTFALL #1 AND #2 INFILTRATION TRENCH

SCALE: 1"=60'



VIEW WEST OF OUTFALL

NOT TO SCALE



VIEW EAST OF OUTFALL

NOT TO SCALE

60' 0 60' 120'

BAR SCALE
1" = 60'
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OUTFALL #1 & #2 INFILTRATION TRENCH

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CHECKED BY: HCP
FIGURE 3-4 INFILTRATION*.dwg

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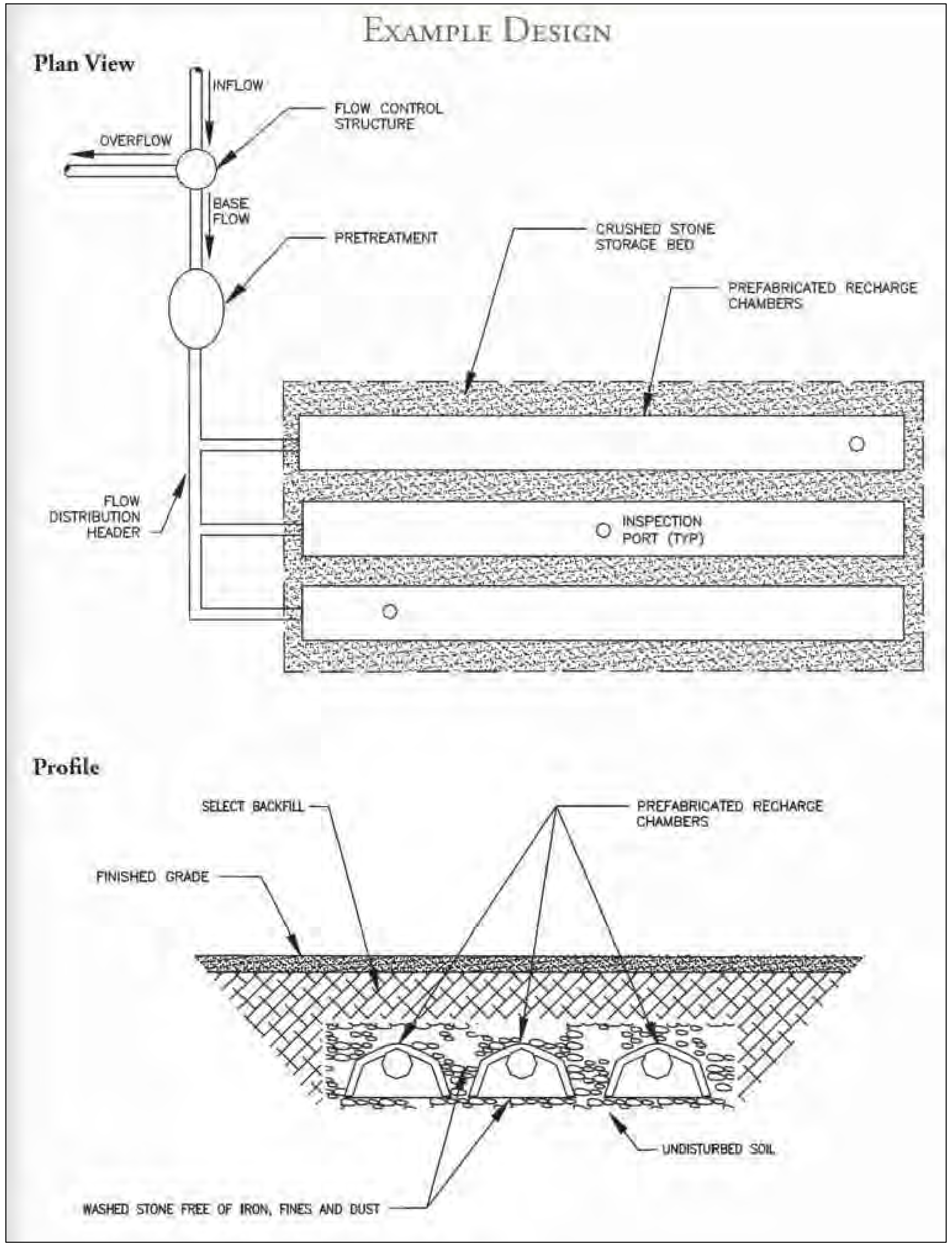
DATE: JANUARY 2020
SCALE: 1" = 60'

FIGURE 3-4

\\woodardcurran.net\shared\Projects\0230525.03 Newton MA - Crystal Lake Watershed Assessment\wip\Drawings\Figures\Figure 3-4 Infiltration Trench.dwg Dec 30, 2019 - 8:41am CNQUINN

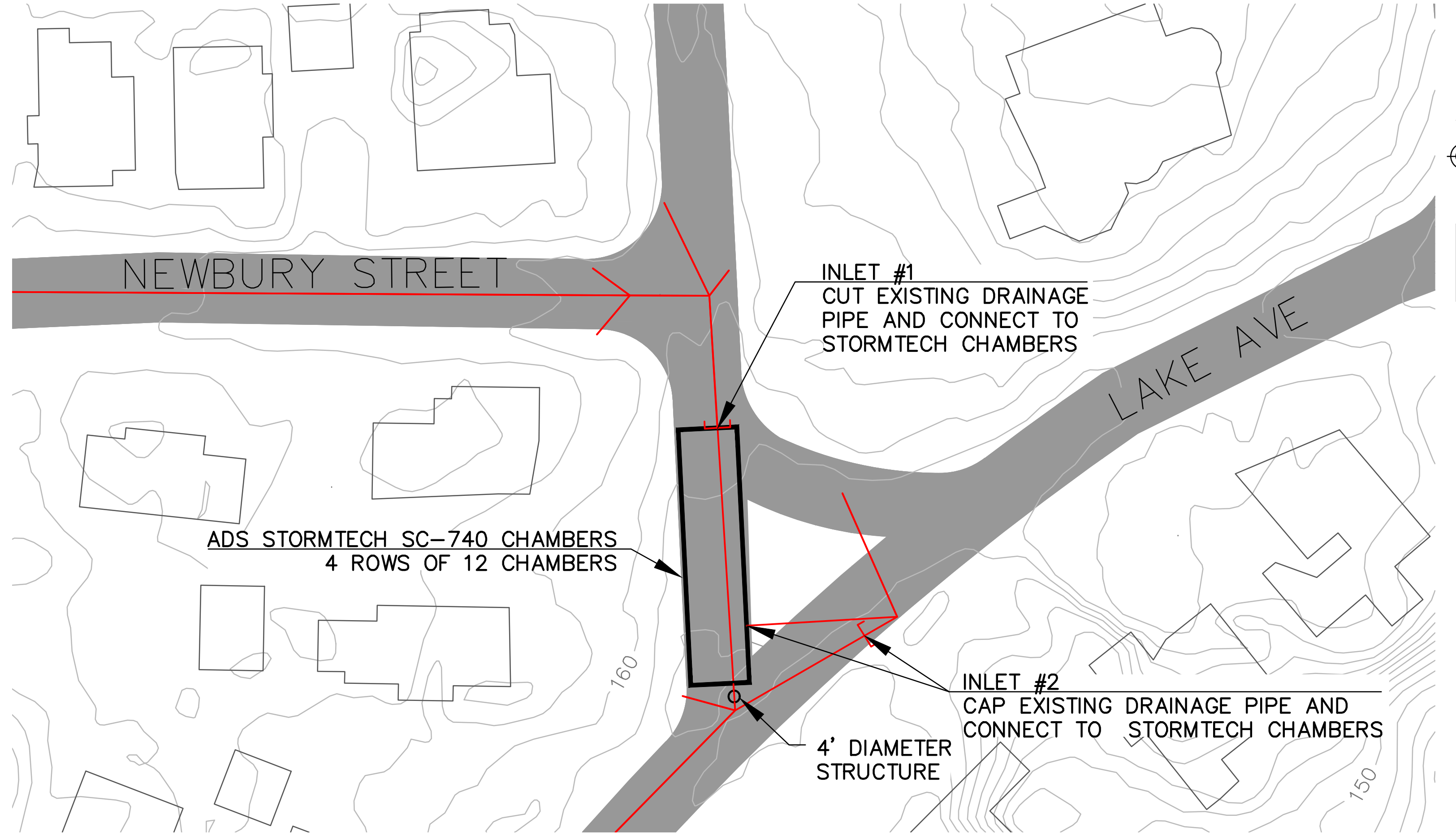
Figure 3-5: Outfall #8A Infiltration Chambers



ADAPTED FROM NEW HAMPSHIRE STORMWATER MANUAL

STANDARD INFILTRATION CHAMBER DETAIL

SCALE: NOT TO SCALE



PLAN: LAKE OUTFALL #8A INFILTRATION CHAMBERS

SCALE: 1"=60'

VIEW OF PROPOSED CHAMBER LOCATION

NOT TO SCALE

60' 0 60' 120'

BAR SCALE
1" = 60'
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OUTFALL #8A
INFILTRATION CHAMBERS

DESIGNED BY: CNQ
DRAWN BY: CNQ
CHECKED BY: HCP
FIGURE 3-5 INFILTRATION*.dwg

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CRYSTAL LAKE MANAGEMENT PLAN

JOB NO: 230525.03
DATE: JANUARY 2020
SCALE: 1" = 60'

FIGURE 3-5

APPENDIX A: NUTRIENT LOADING ANALYSIS AND MANAGEMENT REVIEW FOR CRYSTAL LAKE, NEWTON, MASSACHUSETTS

Nutrient Loading Analysis and Management Review for Crystal Lake, Newton, Massachusetts

Prepared by
Water Resource Services, Inc.

January 17, 2020

Contents

Figures

Tables

Executive Summary

Crystal Lake in Newton Massachusetts is a natural waterbody that covers 27.5 acres to a maximum depth just over 30 feet and receives runoff from a 55-acre watershed that is primarily moderate density residential land. The City maintains a popular swimming area and beach with an adjacent park at the lake, which is also a visual amenity in the neighborhood, supports fishing and non-motorized boating, and provides habitat for aquatic organisms. Historically very clean, it has suffered from summer blooms of cyanobacteria in recent years, but not consistently. Such blooms are linked to increases in the concentration of the key nutrient phosphorus, to lowered ratios of the nutrient nitrogen to phosphorus, and increases in temperature. The City desires to reverse this trend and maintain high clarity to support the intended uses of Crystal Lake. This evaluation was conducted to complement previous studies in the Crystal Lake watershed through the evaluation of available phosphorus in lake sediments and with the intent of identifying internal nutrient management scenarios that can complement ongoing watershed-based nutrient control work in the watershed. This report is intended to complement work being conducted by Woodard & Curran to identify watershed management activities that will reduce stormwater-based nutrient loads.

Analysis of existing data and limited but focused study in 2019 have revealed low oxygen in water deeper than about 16 feet during summer, leading to internal recycling of phosphorus through release from sediment. The phosphorus load from sediment release occurs mainly in summer and lowers the nitrogen to phosphorus ratio at a time when warmer temperatures also favor cyanobacteria. This nutrient release from sediment is referred to as the internal load or sediment load in this report. The phosphorus released from sediment under low oxygen conditions over a period of 2-3 months is adequate to support algae blooms but is not evenly distributed in the water column. However, light penetrates deep enough in Crystal Lake to allow cyanobacteria to grow at greater depth. After enough growth and phosphorus storage, cells develop gas pockets that cause them to float upward to get more light, and this results in the observed blooms. Phosphorus near the surface is inadequate to support the bloom for more than a week or two, so clearer water may return, but it is also possible for different cyanobacteria to grow and rise in succession, maintaining undesirable conditions for more of the summer.

Based on our evaluation of existing and new stormwater runoff data and the development and evaluation of several watershed pollutant loading modeling scenarios, the suburban watershed generates substantial nutrient and organic loads from various sources that deposit nutrients on impervious surfaces that can be transported to the lake during runoff events. Elevated concentrations of phosphorus have been detected in stormwater runoff, particularly in early fall during leaf litter deposition, that enters via seven stormwater discharges and additional stormwater enters the lake via direct drainage area without piping. The portion of the annual phosphorus load attributable to stormwater is large enough to be a concern for lake water quality over time, but individual storms are not likely to add enough nutrients to drastically increase the phosphorus load in the short-term. This is largely a function of the low ratio of watershed area to lake area. With water taking about two years to pass through the lake (referred to as detention time), nutrients entering Crystal Lake via stormwater will accumulate in the sediment where recycling is possible. Thus, stormwater runoff is a major contributor to the internal load of phosphorus over an extended period of time.

Other sources of phosphorus to any lake include direct precipitation, inputs from wildlife, and groundwater, but in our evaluation these sources are minor; runoff from the watershed and internal loading supply more than 86% of the phosphorus in the lake. The watershed load (53%) is larger than the internal load (34%) but the internal load occurs almost entirely in summer and is a greater contributor to cyanobacteria blooms. The resultant average concentration of total phosphorus in Crystal Lake is 17-20 µg/L, with <10 µg/L as a very desirable concentration and >20-25 µg/L as a threshold that will support frequent algae blooms. Variations in the weather, leading to variable inputs from the watershed and variable exposure of the bottom to low oxygen, will lead to a variation in lake condition that will be unacceptable some of the time, primarily in mid- to late summer.

A reduction in the internal phosphorus load that will result in an average concentration of about 13 µg/L could be achieved by dredging, oxygenation, or phosphorus inactivation, with inactivation being the least expensive and most rapid means of gaining improvement. The probability of an algae bloom would be <2% and water clarity is predicted to average at least 10 feet, providing acceptable conditions in the lake.

A phosphorus inactivation treatment with aluminum could be accomplished in one application period but spreading the treatment out over three applications with two years between each would adequately control internal loading while stripping phosphorus from the water column multiple times. The reason to spread the treatment out over several years would be to counter stormwater runoff loads of phosphorus to the lake until watershed management actions have been accomplished, as such actions usually take several years to implement. The cost of the actual inactivation treatment is not expected to exceed $30,000, although public outreach, program management, permitting and monitoring are not included in this estimate and costs for future application are subject to inflation and other uncertainties. Once the prescribed dose has been applied (in one or more applications over time) it is expected that cyanobacteria blooms should be curtailed for at least a decade and possibly two decades in accordance with results from other Massachusetts lakes.

Complementary to internal load management, continued actions by the City, the Crystal Lake Conservancy, the Friends of Crystal Lake and other partners to improve watershed conditions and reduce the potential for watershed-based stormwater loading will be necessary to minimize the potential for future algal blooms. As in any developed suburban and urban landscapes, watershed-based best management practices are not usually able to completely counter internal nutrient loads. Based on our evaluation of watershed-based stormwater loads, achieving a watershed load reduction of 20% is a practical goal and would reduce the average in-lake phosphorus concentration from 13 µg/L, with internal load management as described above, to about 11 µg/L. The associated probability of algae blooms would then be <1%, cyanobacteria would not be expected, and water clarity would average about 12.5 feet, all very favorable conditions for Crystal Lake. The cost of watershed management will vary with the choice of methods and will likely involve ongoing maintenance expense and has been addressed in the Woodard & Curran Crystal Lake Watershed Management Plan. Continued watershed management will be important to the duration of benefits achieved by internal phosphorus inactivation and can provide additional benefits to the lake, including reduced bacterial concentrations, lowered non-algal turbidity, and minimized organic loading that leads to lower oxygen concentrations.

Introduction and Background

Crystal Lake is in Newton, Massachusetts and hosts the Town's swimming facility and an associated park (Figure 1). Crystal Lake is a natural kettlehole pond, formed by stranded glacial ice over 10,000 years ago. Historically known as Wiswall's Pond until the name changed in the late nineteenth century, it covers 27.5 acres of area by recent measurement to a maximum depth slightly more than 30 feet and an average depth of 13.6 feet. The lake has a bowl-like morphometry (Figure 2), leading to a fairly uniform change in area or volume as depth changes (Figures 3 and 4). Volume is about 373 acre-feet at full pool elevation. Residence time for water in the pond averages about two years with overflow via a pipe and the discharge eventually reaching the Charles River.

The watershed covers approximately 55 acres of largely residential land and has a low watershed to lake area ratio of 2 to 1. There are seven active stormwater discharges (and one inactive discharge) that drain areas ranging from <1 to almost 15 acres plus a direct overland drainage area of approximately 20 acres (Figure 5). Historically, the watershed was wetland and forest, with most development occurring in the last half of the nineteenth century. Consequently, the chemistry of Crystal Lake has been influenced by stormwater runoff for more than a century. With a long detention time for water in the lake, most contaminants are likely to settle to the sediment and some, like the important nutrient phosphorus, is recycled during periods of low dissolved oxygen conditions which then cause algae blooms and related water quality problems. The build-up of organic matter creates an oxygen demand that results in low oxygen near the bottom when the lake is thermally stratified in summer, fostering the recycling of phosphorus. This fertilization of the lake is a natural process but has been accelerated by human influence over the last 150 years.

There has been concern over deteriorating conditions in Crystal Lake for about a decade. Cyanobacteria blooms have appeared during summer and have been severe at times, but not consistently. Monitoring has been conducted by the City of Newton and community volunteers, providing some background data for water clarity and oxygen profiles. Some testing of bacteria, phosphorus and nitrogen has been conducted, mainly in the vicinity of stormwater outfalls. Exceedances of bacterial standards for contact recreation were detected but not regularly. Forms of nitrogen were generally found in low concentrations, while phosphorus concentrations were variable and sometimes elevated in association with certain stormwater outlets. These measurements were supplemented by water quality testing by WRS and Woodard & Curran in 2019, including both in-lake and stormwater-based runoff sampling.

Tasks carried out by Woodard & Curran and WRS in 2019 included evaluation of the water column at the deepest point, with assessment of temperature, oxygen, pH, conductivity, turbidity and chlorophyll-a at one-meter intervals and testing for total phosphorus, total Kjeldahl nitrogen, and nitrate + nitrite nitrogen at the top, mid-depth and bottom of the water column on several dates between May and September. Assessment of the extent of organic sediment coverage and testing of the upper 4 inches of that sediment for organic content and phosphorus fractions was conducted. Algae and zooplankton were also sampled and analyzed on several dates. The watershed and stormwater drainage basins were carefully delineated, and the largest discharges were sampled on several dates in the early fall of 2019.

Figure 1: Crystal Lake, Newton, Massachusetts Aerial View

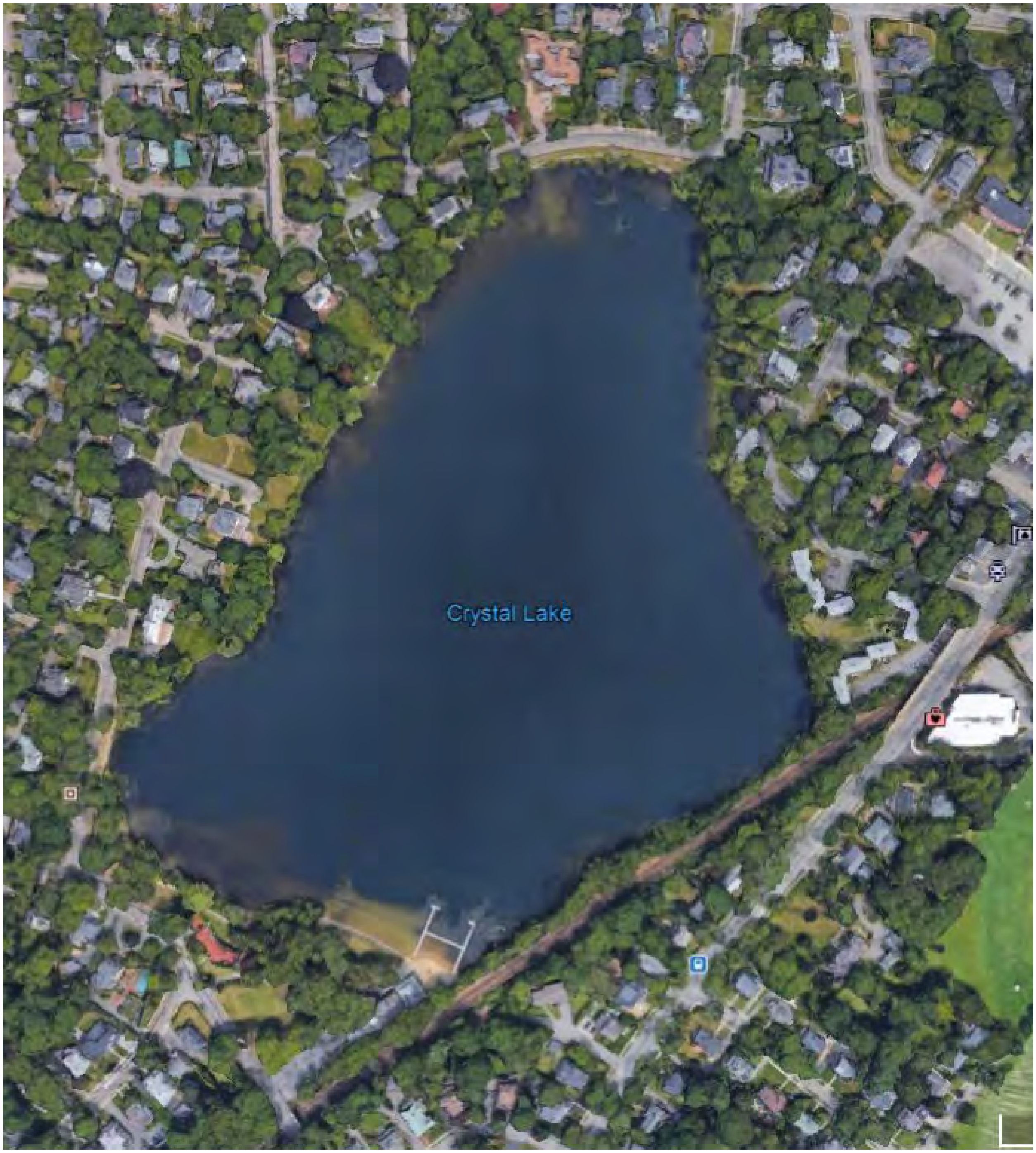
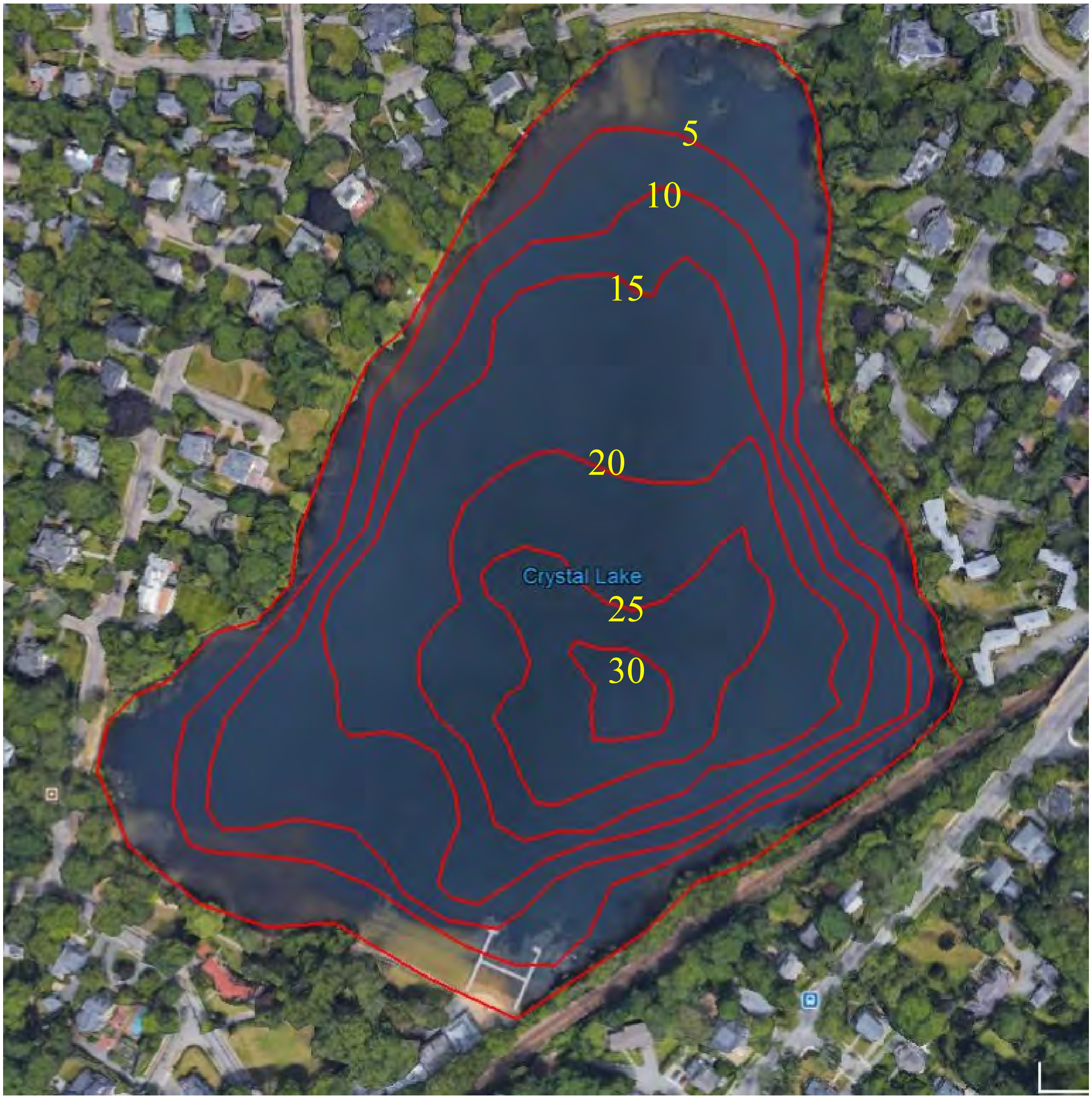


Figure 2: Crystal Lake Bathymetry



(Contours in feet, adapted from Beals and Thomas survey as augmented by 2019 measurements by WRS Inc.)

Figure 3: Relationship Between Depth and Area for Crystal Lake

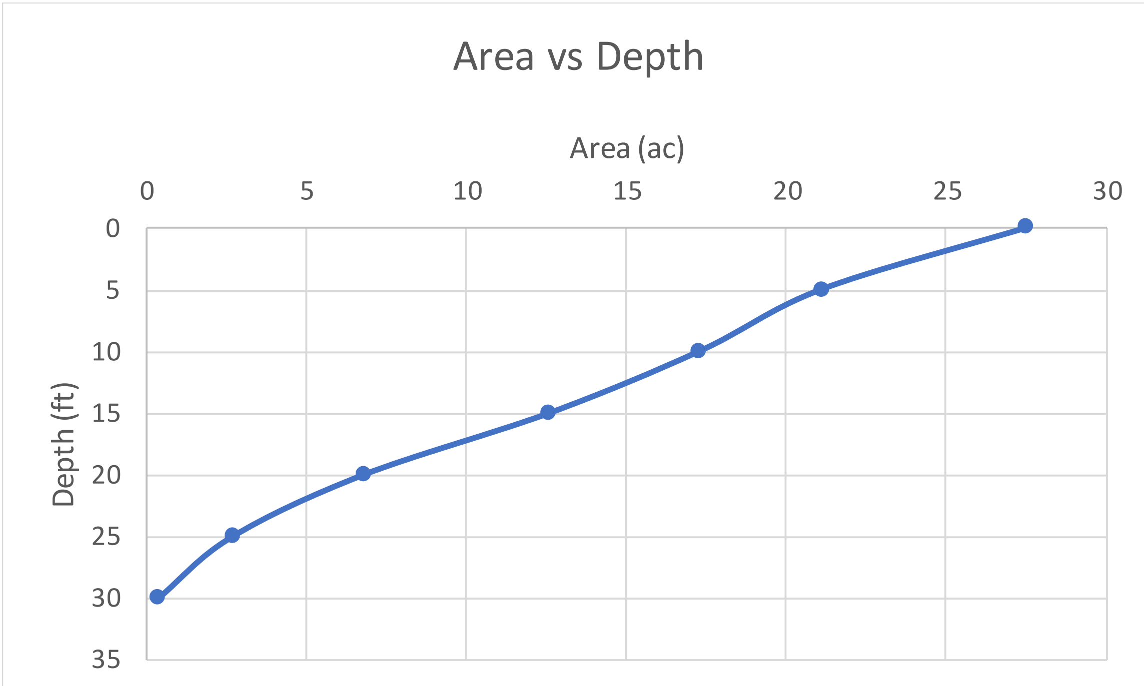


Figure 4: Relationship Between Depth and Area for Crystal Lake

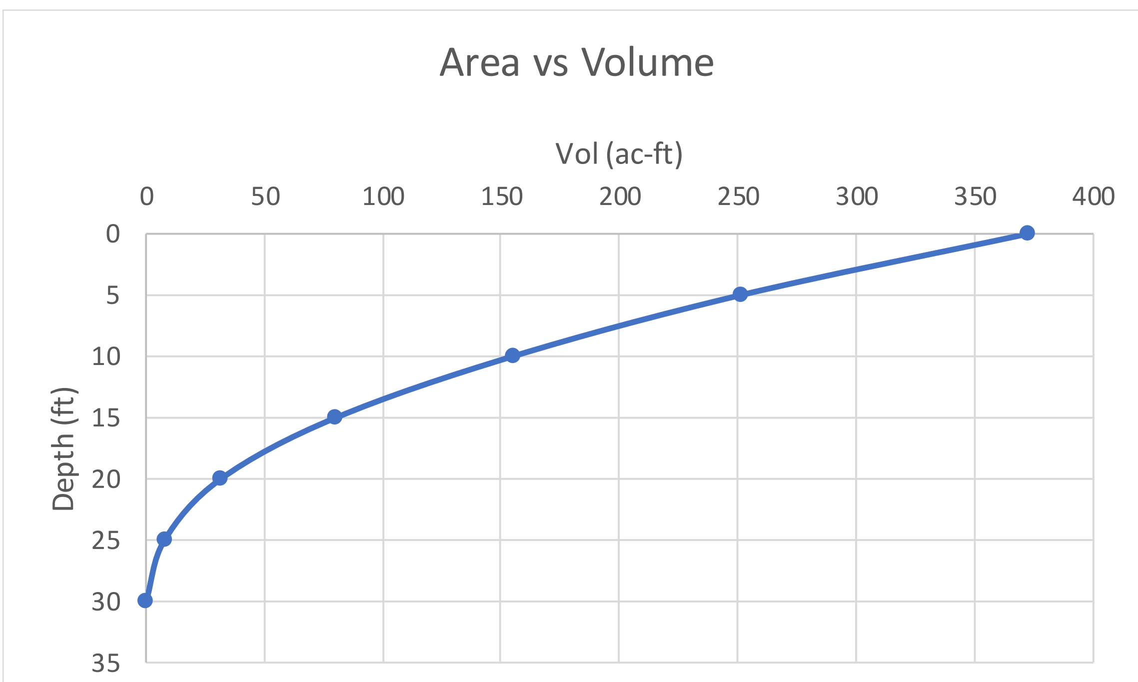
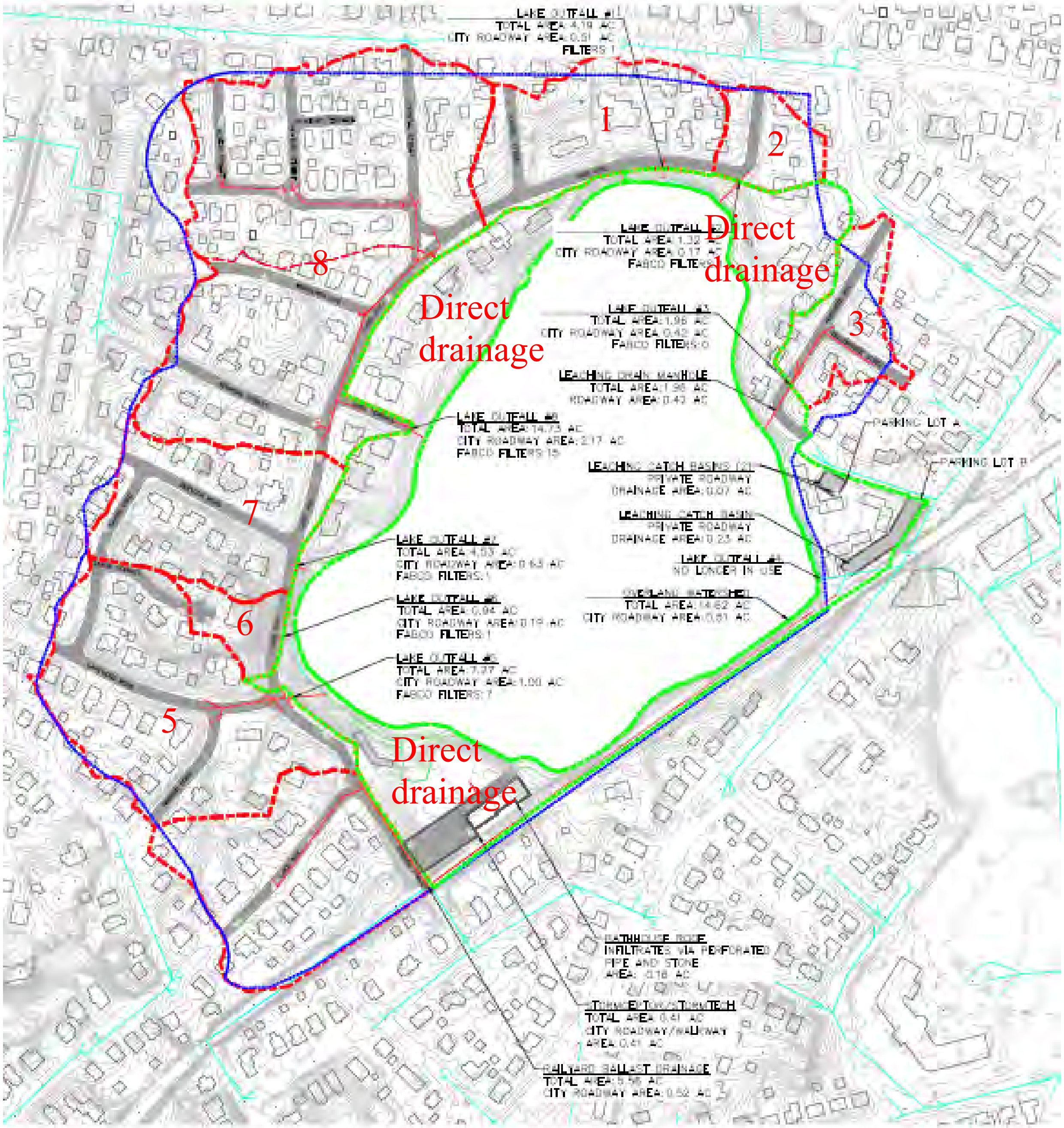


Figure 5: Crystal Lake Watershed and Stormwater Drainage Areas



From existing and new data, an evaluation of both the internal and external load of phosphorus and nitrogen has been conducted. This involves both calculations from actual data and also evaluation of common water quality models supported by sampled data as a check on results. This evaluation allows the condition assessment to be linked to specific causes and supports an analysis of management techniques that can be used to improve and maintain desirable lake conditions.

Condition Assessment

Crystal Lake serves as an active recreational facility for the City of Newton and as an aesthetic amenity in the neighborhood. For both visual and contact recreation purposes, minimizing algae blooms in general and preventing potentially toxic cyanobacteria (blue-green algae) blooms are of great importance. The increase in blooms in recent years is therefore a primary concern. Analysis of samples in 2019 (Table 1) revealed an algal community dominated by flagellated golden algae (chrysophytes) in May, small green algae (chlorophytes) in June, and a mix of cyanobacteria and green algae in August and September. This is a very typical progression for lakes in our region in terms of types of algae, but the magnitude of algae abundance determines any related problems.

None of the biomass estimates from 2019 are especially high, but sampling did not occur at the height of the cyanobacteria bloom that occurred in the last half of August. The presence of problem cyanobacteria was detected in mid-August and the bloom was predicted. Cyanobacteria had subsided by early September, suggesting that these algae rose from deeper water or the sediment-water interface with adequate phosphorus already stored to enable some growth but that phosphorus supplies in shallow surface water were inadequate to sustain the bloom. Results are consistent with nutrient chemistry, as discussed below.

Zooplankton are often an overlooked component of lake ecosystems, forming the link between the algae they eat and the fish that eat them. Abundant, large-bodied zooplankton can filter the water column every few days and keep the concentration of edible algae at a minimum. However, many algae, including most cyanobacteria, many flagellated golden algae, and the small green algae found in Crystal Lake, are less edible. The zooplankton community of Crystal Lake (Table 2) includes mainly large bodies cladocerans, a very desirable group both for consuming algae and feeding fish. The biomass of zooplankton is also desirably high. It appears that the algae community is made up mainly of algae that these zooplankton cannot easily consume. The presence of so many larger bodied zooplankton even in late summer suggests a fish community dominated by larger, predatory fish that keep small fish populations in check. This creates a very desirable fishery, so the indications of the zooplankton community of Crystal Lake are all positive. Unfortunately, when nutrients are abundant, no amount of zooplankton grazing will prevent blooms, as not all algae can be readily consumed.

Oxygen is an important element in healthy aquatic systems. Truly aquatic organisms extract oxygen from the water through gills for survival, plants also need oxygen for metabolism even though they create and release oxygen during photosynthesis, and the presence of oxygen allows accelerated decomposition and related processing of organic matter. Oxygen also allows iron, the most common natural phosphorus binder, to hold phosphorus and make it unavailable to algae. In the absence of oxygen, iron and phosphorus will dissociate and both will move from surficial lake sediments into the water column. Even at the sediment-water interface there can be algae growth if oxygen is low and light penetrates to the bottom; those algae can later float to the surface to form blooms.

Low oxygen has been observed in the deepest area (>20 feet) going back to at least 2010 but, based on available volunteer monitoring data, has never been an issue at <10 feet. The measurements made in 2019 (Table 3), while not necessarily indicative of all years, suggest that low oxygen is found at water depths >16.5 feet (5 meters).

Table 1: Phytoplankton Analysis for Crystal Lake in 2019

	PHYTOPLANKTON DENSITY (CELLS/ML)				PHYTOPLANKTON BIOMASS (UG/L)			
TAXON	Newton Crystal 05/14/19	Newton Crystal 06/27/19	Newton Crystal 08/15/19	Newton Crystal 09/05/19	Newton Crystal 05/14/19	Newton Crystal 06/27/19	Newton Crystal 08/15/19	Newton Crystal 09/05/19
BACILLARIOPHYTA								
Centric Diatoms								
Cyclotella	15	0	0	0	19.2	0.0	0.0	0.0
Araphid Pennate Diatoms								
Asterionella	0	356	0	54	0.0	71.2	0.0	10.7
Biraphid Pennate Diatoms								
Navicula/related taxa	7	0	0	0	3.7	0.0	0.0	0.0
CHLOROPHYTA								
Coccoid/Colonial Chlorophytes								
Ankistrodesmus	89	9	16	7	26.6	4.5	4.8	0.7
Coelastrum	0	0	320	107	0.0	0.0	64.0	21.4
Elakatothrix	0	0	1840	1876	0.0	0.0	184.0	187.6
Kirchneriella	0	0	64	0	0.0	0.0	6.4	0.0
Oocystis	0	0	192	107	0.0	0.0	76.8	42.9
Scenedesmus	0	0	64	27	0.0	0.0	6.4	2.7
Sphaerocystis	0	25276	896	402	0.0	5055.2	179.2	80.4
Filamentous Chlorophytes								
Desmids								
Closterium	0	0	8	0	0.0	0.0	32.0	0.0
Cosmarium	0	0	8	0	0.0	0.0	6.4	0.0
Euastrum	0	0	24	0	0.0	0.0	24.0	0.0
Staurastrum	22	9	16	7	17.8	7.1	12.8	5.4
Staurodesmus	0	0	8	0	0.0	0.0	4.8	0.0
CHRYSOPHYTA								
Flagellated Classic Chrysophytes								
Dinobryon	141	0	0	0	421.8	0.0	0.0	0.0
Mallomonas	15	0	0	0	7.4	0.0	0.0	0.0
Synura	59	0	0	0	47.4	0.0	0.0	0.0
Uroglena	178	0	0	0	17.8	0.0	0.0	0.0
CRYPTOPHYTA								
Cryptomonas	22	0	0	0	4.4	0.0	0.0	0.0
CYANOPHYTA								
Unicellular and Colonial Forms								
Microcystis	0	0	640	1206	0.0	0.0	6.4	12.1
Other Coccoid Bluegreens	0	0	1120	0	0.0	0.0	11.2	0.0
Filamentous Nitrogen Fixers								
Aphanizomenon	0	0	3200	268	0.0	0.0	416.0	34.8
Dolichospermum	0	0	1280	268	0.0	0.0	256.0	53.6
Filamentous Non-Nitrogen Fixers								
EUGLENOPHYTA								
Trachelomonas	15	9	8	34	14.8	8.9	8.0	62.3
DENSITY (CELLS/ML) SUMMARY								
BACILLARIOPHYTA	**22.2**	**356**	**0**	**53.6**	**22.9**	**71.2**	**0.0**	**10.7**
Centric Diatoms	14.8	0	0	0	19.2	0.0	0.0	0.0
Araphid Pennate Diatoms	0	356	0	53.6	0.0	71.2	0.0	10.7
Monoraphid Pennate Diatoms	0	0	0	0	0.0	0.0	0.0	0.0
Biraphid Pennate Diatoms	7.4	0	0	0	3.7	0.0	0.0	0.0
CHLOROPHYTA	**111**	**25293.8**	**3456**	**2532.6**	**44.4**	**5066.8**	**601.6**	**341.0**
Flagellated Chlorophytes	0	0	0	0	0.0	0.0	0.0	0.0
Coccoid/Colonial Chlorophytes	88.8	25284.9	3392	2525.9	26.6	5059.7	521.6	335.7
Filamentous Chlorophytes	0	0	0	0	0.0	0.0	0.0	0.0
Desmids	22.2	8.9	64	6.7	17.8	7.1	80.0	5.4
CHRYSOPHYTA	**392.2**	**0**	**0**	**0**	**494.3**	**0.0**	**0.0**	**0.0**
Flagellated Classic Chrysophytes	392.2	0	0	0	494.3	0.0	0.0	0.0
Non-Motile Classic Chrysophytes	0	0	0	0	0.0	0.0	0.0	0.0
Haptophytes	0	0	0	0	0.0	0.0	0.0	0.0
Tribophytes/Eustigmatophytes	0	0	0	0	0.0	0.0	0.0	0.0
Raphidophytes	0	0	0	0	0.0	0.0	0.0	0.0
CRYPTOPHYTA	**22.2**	**0**	**0**	**0**	**4.4**	**0.0**	**0.0**	**0.0**
CYANOPHYTA	**0**	**0**	**6240**	**1742**	**0.0**	**0.0**	**689.6**	**100.5**
Unicellular and Colonial Forms	0	0	1760	1206	0.0	0.0	17.6	12.1
Filamentous Nitrogen Fixers	0	0	4480	536	0.0	0.0	672.0	88.4
Filamentous Non-Nitrogen Fixers	0	0	0	0	0.0	0.0	0.0	0.0
EUGLENOPHYTA	**14.8**	**8.9**	**8**	**33.5**	**14.8**	**8.9**	**8.0**	**62.3**
PYRRHOPHYTA	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**	**0.0**
TOTAL	**562.4**	**25658.7**	**9704**	**4361.7**	**580.9**	**5146.9**	**1299.2**	**514.6**
CELL DIVERSITY	**0.80**	**0.04**	**0.83**	**0.70**	**0.49**	**0.04**	**0.86**	**0.84**
CELL EVENNESS	**0.80**	**0.05**	**0.68**	**0.65**	**0.49**	**0.06**	**0.70**	**0.77**

Table 2: Zooplankton Analysis for Crystal Lake in 2019

	ZOOPLANKTON DENSITY (#/L)				ZOOPLANKTON BIOMASS (UG/L)		
TAXON	**Newton Crystal 5/14/19**	**Newton Crystal 8/15/19**	**Newton Crystal 9/5/19**	**TAXON**	**Newton Crystal 5/14/19**	**Newton Crystal 8/15/19**	**Newton Crystal 9/5/19**
PROTOZOA				**PROTOZOA**			
Ciliophora	26.0	0.0	0.0	**Ciliophora**	0.5	0.0	0.0
ROTIFERA				**ROTIFERA**			
Conochilus	52.0	0.0	0.0	*Conochilus*	2.1	0.0	0.0
COPEPODA				**COPEPODA**			
Copepoda-Cyclopoida				**Copepoda-Cyclopoida**			
Cyclops	1.3	0.0	0.0	*Cyclops*	3.2	0.0	0.0
Mesocyclops	0.0	0.7	0.0	*Mesocyclops*	0.0	0.8	0.0
Copepoda-Calanoida				**Copepoda-Calanoida**			
Diaptomus	15.0	20.8	15.6	*Diaptomus*	55.3	77.0	57.7
Other Copepoda-Nauplii	2.6	2.0	2.6	**Other Copepoda-Nauplii**	6.9	5.2	6.9
CLADOCERA				**CLADOCERA**			
Bosmina	2.6	0.0	0.0	*Bosmina*	2.5	0.0	0.0
Daphnia ambigua	24.1	5.2	8.5	*Daphnia ambigua*	133.7	29.0	39.1
Daphnia pulex	2.0	1.3	0.7	*Daphnia pulex*	21.6	17.9	3.8
Diaphanosoma	0.7	16.9	13.0	*Diaphanosoma*	1.9	50.4	38.7
SUMMARY STATISTICS				**SUMMARY STATISTICS**			
DENSITY				**BIOMASS**			
PROTOZOA	26.0	0.0	0.0	**PROTOZOA**	0.5	0.0	0.0
ROTIFERA	52.0	0.0	0.0	**ROTIFERA**	2.1	0.0	0.0
COPEPODA	18.9	23.4	18.2	**COPEPODA**	65.4	82.9	64.6
CLADOCERA	29.3	23.4	22.1	**CLADOCERA**	159.9	97.2	81.6
OTHER ZOOPLANKTON	0.0	0.0	0.0	**OTHER ZOOPLANKTON**	0.0	0.0	0.0
TOTAL ZOOPLANKTON	126.1	46.8	40.3	**TOTAL ZOOPLANKTON**	227.8	180.2	146.3
TAXONOMIC RICHNESS							
PROTOZOA	1	0	0				
ROTIFERA	1	0	0				
COPEPODA	3	3	2				
CLADOCERA	4	3	3				
OTHER ZOOPLANKTON	0	0	0				
TOTAL ZOOPLANKTON	9	6	5				
S-W DIVERSITY INDEX	0.68	0.55	0.57				
EVENNESS INDEX	0.71	0.71	0.81				
MEAN LENGTH (mm): ALL FORMS	0.39	0.96	0.92				
MEAN LENGTH: CRUSTACEANS	0.88	0.96	0.92				

Table 3: Field Water Quality Data for Crystal Lake in 2019

Date	Time	Depth	Depth	Temp	DO	DO	Sp. Cond	pH	Turbidity	CHL	Secchi
MM/DD/YY	HH:MM:SS	meters	feet	°C	mg/l	% Sat	µS/cm	Units	NTU	µg/l	m
5/14/19	11:48:54	0.1	0.4	14.0	10.0	98.8	254	7.4	3.3	2.2	6.0
5/14/19	11:48:44	1.0	3.4	14.0	10.0	98.5	254	7.4	3.3	2.3	
5/14/19	11:48:33	2.0	6.6	14.0	10.0	98.3	254	7.3	3.4	2.4	
5/14/19	11:48:16	3.0	9.9	14.0	10.0	98.6	254	7.3	3.4	2.4	
5/14/19	11:47:56	4.0	13.2	14.0	9.9	97.9	254	7.3	3.4	2.3	
5/14/19	11:47:29	5.0	16.4	14.0	8.9	87.8	255	7.3	3.3	2.4	
5/14/19	11:47:03	6.0	19.9	10.9	5.0	45.7	261	7.4	3.5	3.1	
5/14/19	11:46:31	7.0	23.2	9.6	2.7	24.1	262	7.4	3.4	1.7	
5/14/19	11:46:06	8.0	26.5	9.0	1.5	13.4	264	7.5	3.5	1.5	
6/27/19	8:23:47	0.1	0.4	23.9	9.6	115.2	245	7.2	5.7	8.2	2.6
6/27/19	8:23:29	0.6	1.8	23.9	9.6	115.1	245	7.2	5.8	9.1	
6/27/19	8:23:08	1.5	4.9	23.9	9.5	113.7	245	7.1	6.0	10.6	
6/27/19	8:22:47	2.5	8.3	23.9	9.3	112.2	245	7.1	6.2	12.7	
6/27/19	8:22:24	3.5	11.4	23.4	8.8	105.3	245	7.0	6.5	12.8	
6/27/19	8:22:00	4.5	14.9	20.9	7.1	80.7	243	7.0	6.9	19.7	
6/27/19	8:21:35	5.5	18.2	16.4	3.0	31.4	243	7.0	7.4	13.5	
6/27/19	8:21:06	6.5	21.3	13.4	0.6	5.6	246	7.1	8.3	5.4	
6/27/19	8:19:04	7.5	24.8	11.0	0.3	2.9	250	7.5	4.1	4.8	
6/27/19	8:20:02	8.5	28.0	10.2	0.3	3.1	256	7.3	8.4	5.5	
8/15/19	14:53:48	0.3	0.9	26.8	7.7	98.2	247	7.6	6.6	2.3	2.8
8/15/19	14:54:07	1.0	3.2	26.3	7.9	98.7	247	7.6	6.8	2.8	
8/15/19	14:55:00	2.0	6.6	26.0	7.9	99.2	247	7.6	6.9	3.8	
8/15/19	14:55:37	3.0	9.9	25.8	7.8	97.3	247	7.6	7.0	4.5	
8/15/19	14:56:28	4.0	13.1	25.7	7.6	93.9	248	7.6	6.9	5.5	
8/15/19	14:57:40	5.0	16.5	25.3	6.1	74.7	247	7.5	6.8	5.8	
8/15/19	14:58:23	5.5	18.2	21.4	1.1	12.8	251	7.4	6.5	6.7	
8/15/19	14:59:04	6.0	19.8	18.5	1.1	12.1	251	7.4	6.4	6.7	
8/15/19	14:59:53	7.0	23.0	13.8	0.8	7.5	254	7.3	7.2	27.7	
8/15/19	15:00:38	7.5	24.8	12.7	0.1	1.3	267	7.1	10.0	12.8	
9/5/19	10:13:39	0.1	0.5	24.1	8.1	97.8	247	6.8	5.8	3.9	3.6
9/5/19	10:13:11	1.0	3.4	24.1	8.1	97.4	247	6.7	6.0	5.0	
9/5/19	10:12:41	2.0	6.7	24.1	8.1	97.4	247	6.8	6.2	5.4	
9/5/19	10:12:24	3.0	10.0	24.1	8.1	97.5	247	6.7	6.3	5.5	
9/5/19	10:11:44	4.0	13.2	24.0	7.7	93.2	247	6.7	6.8	5.5	
9/5/19	10:10:26	5.0	16.4	23.9	6.7	80.0	247	6.7	8.0	5.8	
9/5/19	10:09:53	5.6	18.3	22.4	1.2	13.7	250	6.7	8.9	6.1	
9/5/19	10:08:52	6.0	19.8	20.2	0.4	4.4	251	6.7	11.9	6.2	
9/5/19	10:08:06	7.0	23.2	15.0	0.5	4.7	251	6.7	17.2	6.5	
9/5/19	10:07:19	8.1	26.8	11.3	0.3	2.5	319	6.6	18.3	7.0	

This equates to about 9 acres of lake area, almost one third of the total lake area, where phosphorus may be released from internal surficial sediments over the summer. This issue may extend into slightly shallower water where light penetrates to the bottom and oxygen may be low at the sediment-water interface despite higher oxygen in the water column immediately above.

Usually the extent of low oxygen matches the distribution of organic matter deposits on the lake bottom, as it is these deposits that are demanding oxygen for decomposition and causing the low oxygen values. In the shallowest of water, mixing will be sufficient on a daily basis to keep oxygen above 4 mg/L, but in water deeper than 10 feet oxygen can be depressed to values <2 mg/L, below which there can be undesirable water quality and biological effects. Visual examination with an underwater camera rig on May 15, 2019 at 42 points determined that the substrate grades from sand and gravel to muck between 13 and 16 feet of water depth. This suggests that low oxygen would be expected at a depth of 16 feet if mixing is not sufficient to keep bringing oxygen to that depth. The temperature data from 2019 (Table 3) indicates that temperature declines rapidly below a depth of 16.5 feet; mixing will be greatly inhibited below that depth by the thermal gradient. Low oxygen was not observed at <18 feet of water depth but there could be low oxygen in the surficial sediments to depths as shallow as 13 feet based on organic matter distribution, and those sediments could support the growth of algae that later rise into the water column.

The phosphorus content of the organic sediment within Crystal Lake is therefore very important, and samples were collected from five stations in Crystal Lake (Figure 6). Test results (Table 4) indicate only moderate amounts of iron-bound phosphorus but elevated levels of biogenic phosphorus, which is the most easily released form of organic phosphorus. The lack of iron to bind that biogenic phosphorus as it is released will aid its movement into the water column and make it more available to algae for uptake and growth. Concentrations for all tested features are not very variable over space, suggesting that the organic sediment can be treated as a consistent factor over space in the lake. Wherever oxygen drops below about 2 mg/L there is an increased risk of phosphorus becoming available to support algae growth.

Phosphorus in the water column in 2019 was low in May and similar at the surface and maximum depth (Table 5). Thermal stratification was setting in and oxygen was declining in deeper water, but only the deepest point (26.5 feet) exhibited oxygen <2 mg/L. Release from sediment was not yet occurring to any significant degree, and phosphorus throughout the lake was too low to support substantial algae growth. The result was low algae abundance (Table 1) and high water clarity (Table 3), with visibility to 20 feet. This is the level of transparency that could be expected for Crystal Lake if phosphorus concentrations are kept low.

Subsequent sampling in mid-August and early September revealed much more extensive low oxygen and resultant increases in phosphorus in deeper water. There is a gradient from bottom to top in the lake, with surface water total phosphorus values still in the low-moderate range (14 and 11 µg/L in August and September, respectively) but bottom concentrations in the clearly unacceptable zone (79 and 114 µg/L in August and September, respectively). The mid-depth range, corresponding to the boundary between the upper and lower water layers during stratification, exhibited intermediate phosphorus levels closer to surface water values. This suggests a gradient of phosphorus in the lower layer which does not mix as strongly as the upper water layer where wind is a factor; phosphorus will be highest near the bottom from which it is released and grade into lower concentrations as the released phosphorus migrates upward, largely by diffusion.

Figure 6. Sediment Sampling Stations in Crystal Lake in May 2019

Table 4. Sediment Features for Five Locations in Crystal Lake in May 2019

Station	Solids %	TOC %	Total P mg/kg	Loose P mg/kg	Fe-P mg/kg	Biogenic P mg/kg	Al-P mg/kg	Ca-P mg/kg	Organic P mg/kg
241	14.9	12.5	1760	<2	45.3	380	798	349	568
242	13.9	12.7	2057	<2	51.6	455	943	385	678
243	12.2	14.1	2404	<2	79.0	477	1241	368	716
244	12.5	13.1	2319	<2	72.3	529	1163	351	733
245	10.7	15.5	2650	<2	72.6	679	1327	334	917
Average	12.8	13.58	2238	<2	64.2	504	1094	357	722
Std Dev	1.6	1	341	0	14.8	112	219	20	126

Table 5. Laboratory Water Quality at the Deep Station in Crystal Lake in 2019

Date	5/14/2019		8/15/2019			9/5/2019		
Depth	Surface	Bottom	Surface	Middle	Bottom	Surface	Middle	Bottom
Total Phosphorus (ug/L)	<10.6	<10.6	13.8	17	78.6	10.6	14.9	114
Total Kjeldahl Nitrogen (ug/L)	350	687	509	445	996	804	511	2390
Nitrate + Nitrite Nitrogen (ug/L)	<50	<50	<50	<50	54.2	<50	<50	<50

If enough of the phosphorus reaches a lighted zone, algae will grow. While release from sediment undoubtedly began sometime in June, the concentration of phosphorus was apparently not high enough in water with enough light to allow a bloom to develop until sometime in late July or early August. We do not have data to know just when growth got started below the lake surface, but we do know that by the last half of August the algae had accumulated enough phosphorus to stimulate gas vacuole formation that triggers a rise in the water column, forming a bloom. This is a known ecological strategy of cyanobacteria, which grow in deeper water and take up excess phosphorus, then form gas pockets that allow them to rise to the surface. They may be mixed to depths of 10-15 feet by wind but will be in the well-lit upper water column where they can grow until phosphorus supplies are exhausted.

As the surface concentration of phosphorus in Crystal Lake is relatively low, the blooms do not last indefinitely. Phosphorus runs out, the cyanobacteria create resting stages that fall back to the sediment, live cells die off, and the blooms subsides. Typical bloom duration is 1-3 weeks without elevated phosphorus in the upper waters, although additional blooms may form as different species of cyanobacteria grow in deeper water and rise in succession. Also, if the dying algae in the surface water release enough phosphorus, other algae can utilize that phosphorus to grow and form blooms without antecedent growth in deeper water. In 2019 we observed only the one cyanobacteria bloom in the last half of August lasting 1-2 weeks, after which the water cleared to a reasonable extent. However, algae growth was sufficient to lower water clarity as measured by Secchi disk to <10 feet on the June and August sampling dates. The early September clarity was slightly better at almost 12 feet, but clarity was much lower than in May.

The onset of stratification, oxygen loss, and phosphorus release is highly weather dependent and climate change is favoring conditions that promote warmer water on average and greater variability among years. These processes could occur earlier in the year or be more severe; the boundary between water layers could be as shallow as 13 feet, could set up in early May, and phosphorus release increases with duration of low oxygen. If so, more blooms or blooms of longer duration could be expected. If the boundary between water layers forms later and is deeper, there may be insufficient phosphorus via release from sediment to support blooms. This is consistent with the unpredictable pattern of blooms over recent summers. Yet, warmer weather on average is pushing the stratification to start earlier and occur at shallower depths, foreshadowing a likely increase in bloom formation in the future if steps are not taken to control phosphorus availability.

Release from sediment is not the only source of phosphorus to Crystal Lake, however. With any developed watershed, the risk of elevated nutrient levels in stormwater runoff can become a factor. Samples collected from stormwater discharges from the larger stormwater drainage areas in 2019 (Table 6) indicate high concentrations of total phosphorus and a very high percentage in dissolved form (average = 78%). This is likely a function of October sampling, during a period of falling leaves and associated decay. Dissolved phosphorus in stormwater during non-fall times of year often represents <50% of the total phosphorus and the non-dissolved particulate fraction settles out quickly and is not immediately available to support algae growth. With time, the particulate nutrient load becomes part of the internal load, so it is still important, but the immediate impact is less than the total concentrations in our sampling might suggest. Additionally, higher than average concentrations during leaf litter deposition (October-November) would not likely contribute to elevated in-lake concentrations when conditions are most likely to support blooms (mid to late summer). Samples collected in the past for stormwater discharges to Crystal Lake exhibit median total phosphorus concentrations ranging from 0.236 to 0.301 mg/L (236 to 301 µg/L) and mean values of 0.287 to 0.412 mg/L (287 to 412 µg/L). These sample results outside of the leaf deposition period are more in line with expectations for stormwater runoff in urbanized watersheds but still quite high from the perspective of impacts to a lake.

Modeling to evaluate how much water is contributed as runoff will be discussed as part of the loading analysis in subsequent sections, but with an average precipitation of 48 inches per year and assuming 30-40% of the rain landing on the watershed reaches the lake as runoff, that is 59 to 79 acre-feet of water entering as surface flow. The volume of the lake is about 373 acre-feet, so the entire volume of stormwater entering the lake in a year is 16-21% of the lake volume. No single storm is likely to deliver enough water to drastically change the phosphorus concentration, but in a wet year the inputs over a season could be significant with high nutrient concentrations in runoff. The watershed is an ongoing source of nutrients and as discussed previously will need to be managed to maintain desired conditions in Crystal Lake.

Nitrogen is less of a factor than phosphorus in overall algae abundance but plays a very important role in the types of algae present. Many cyanobacteria are able to utilize dissolved nitrogen gas from the water column, a source unavailable to other algae. As a result, low nitrate nitrogen availability favors cyanobacteria; it is not the only factor involved but will promote nitrogen-fixing cyanobacteria over other algae. Nitrate concentrations in Crystal Lake were low on all dates and at all depths sampled in 2019 (Table 5). Total Kjeldahl nitrogen, which includes organically bound nitrogen and ammonium nitrogen, ranges from moderate (300-600 ug/L) to high (>600 ug/L) but reflects nitrogen tied up in organic matter. The one very high value for the deepest point in Crystal Lake in September likely reflects a build-up of ammonium, which is formed by decomposition but cannot be converted to nitrate in the absence of oxygen in deep water. While that ammonium might also be used by algae, it is found mainly in water too deep for light to be available, another prerequisite for most algae growth.

There is a modest rooted plant community in Crystal Lake. Dense rooted plants can also interfere with swimming and boating, but the nature of the peripheral sandy substrate in this kettlehole pond and its substantial depth are not conducive to excessive growths on a large scale. Algae blooms have limited light penetration at times, which will limit plant growth, but there is no evidence that improved water clarity as a function of management will lead to problems with rooted plants.

Table 6: Water Quality in Selected Storm Drainage Systems Discharging to Crystal Lake in 2019

Location ID	Date	Time	Flow Depth (inches)	Flow Velocity	Total Phosphorus (mg/L)	Dissolved Phosphorus (mg/L)	DP as a % of TP	TKN (mg/L)	Ammonium N (mg/L)	Nitrate+ Nitrite N (mg/L)	Turbidity (NTU)	TSS (mg/L)
OF-5	07-Oct-19	9:44 PM	0.25	Slow	0.929	0.845	91.0%	1.42	0.359	0.189	13.9	54
OF-5	07-Oct-19	11:15 PM	0.5	Moderate	0.733	0.638	87.0%	1.08	0.292	0.155	5.52	8.4
OF-5	16-Oct-19	10:17 PM	1.5	Moderate	1.56	1.45	92.9%	1.82	0.276	0.197	10.9	30
OF-5	17-Oct-19	2:02 AM	4	Fast	0.234	0.146	62.4%	2.24	0.25	0.0917	30.8	160
OF-7	07-Oct-19	9:36 PM	0.5	Moderate	0.65	0.602	92.6%	1.15	0.304	0.0731	5.33	112
OF-7	07-Oct-19	11:20 PM	0.5	Moderate	0.617	0.551	89.3%	0.847	0.216	0.128	4.42	8.2
OF-7	16-Oct-19	10:05 PM	1.5	Moderate	0.708	0.607	85.7%	1.65	0.309	0.217	13.2	31.6
OF-7	17-Oct-19	1:57 AM	4	Fast	0.264	0.0935	35.4%	1.71	0.224	0.0708	15.2	52
OF-8	07-Oct-19	10:03 PM	0.5	Moderate	0.529	0.447	84.5%	1.38	0.43	0.306	6.28	8.4
OF-8	07-Oct-19	11:30 PM	0.5	Moderate	0.496	0.44	88.7%	1.25	0.337	0.236	6.63	6.2
OF-8	16-Oct-19	9:54 PM	1	Moderate	0.311	0.168	54.0%	1.61	0.229	0.245	16.4	46.8
OF-8	17-Oct-19	1:51 AM	6	Fast	0.185	0.139	75.1%	0.732	0.155	0.0965	8.54	24
Average					0.601	0.511	0.782	1.407	0.282	0.167	11.43	45.13
Std Dev					0.373	0.381	0.191	0.391	0.065	0.077	7.71	48.73

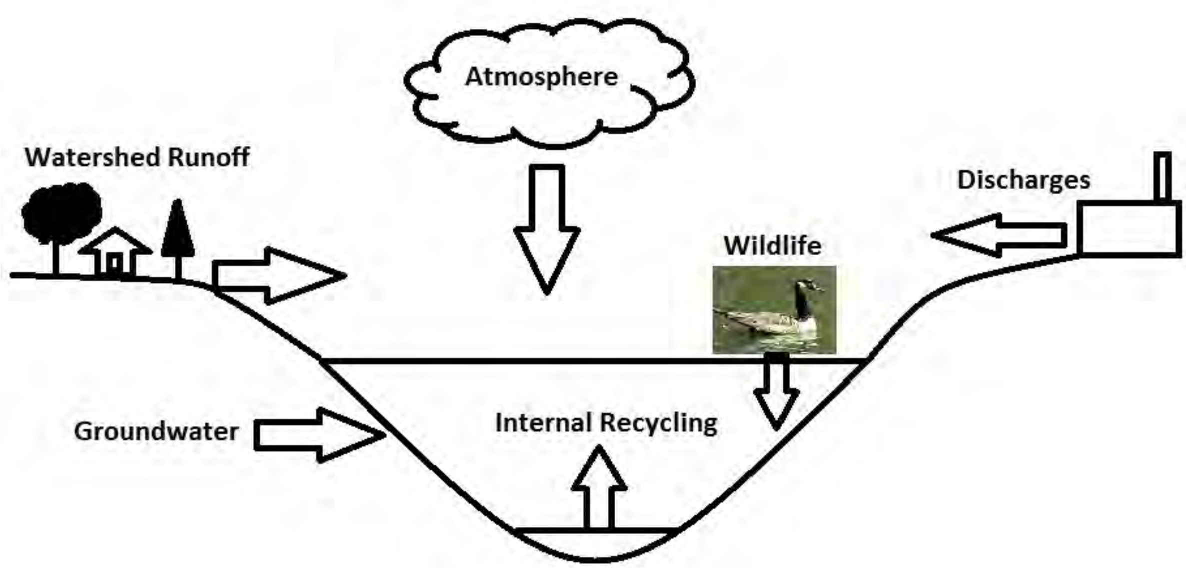
The primary issue facing Crystal Lake is therefore excessive algae growth, particularly summer cyanobacteria blooms, and the primary factors appear to be release of phosphorus from organic sediments under low oxygen concentrations during summer stratification and elevated inputs of phosphorus from the urban watershed in stormwater runoff.

Nutrient Loading Analysis

Elements of a Loading Analysis

For any contaminant of interest, the nutrient (or other pollutant) load to the lake can include up to six source categories (Figure 7):

Figure 7. Contaminant Loading Schematic



1. Atmospheric Deposition – Pollutants landing on the lake surface either with precipitation or as dryfall. This includes only direct inputs; airborne contaminants falling on the land or upstream lakes are processed as other inputs, such as overland flow (runoff). Direct atmospheric inputs constitute a large source only where the lake is large relative to the watershed. The watershed for Crystal Lake is less than twice the area of the lake itself, but the highly developed nature of the watershed is likely to overshadow any atmospheric inputs.
2. Direct Groundwater Seepage – Pollutants entering with groundwater that directly enters the lake. Groundwater that enters a stream or upstream lake is accounted with the flow from that stream or lake and is not part of this element. This can be a major element where the lake is a kettlehole or seepage lake with no tributaries and located in sandy or rocky soils. This element may include wastewater from on-site disposal (septic) systems, which can raise the level of some contaminants substantially and are often split off by modeling efforts as a subset of this element. Crystal Lake's historically excellent water quality and lack of algae blooms was probably a function of substantial groundwater inputs from an undeveloped watershed, but as the land was developed and stormwater drainage systems were installed, runoff undoubtedly became much more important as a source of nutrients than groundwater. The watershed is sewered, so inputs from on-site wastewater disposal systems are not a factor for Crystal Lake water quality.
3. Watershed Runoff (stormwater) – Pollutants entering with surface water flows. These can be direct runoff from the immediate watershed or flows from streams that drain non-contiguous land areas. This also includes flow from upstream lakes to the target lake. This is often the largest loading element in larger or developed watersheds. Crystal Lake has a small watershed, but with nearly all of it altered from its natural condition, there is a threat of substantial pollutant inputs with storms.
4. Discharges – Pollutants entering in any release that is not a natural flow channel, like a stream or lake overflow. This would include wastewater treatment facilities, cooling water, or other flows with permits. This can be a major source of contaminants even with minor flows when concentrations are very high, but discharges are not a known influence on Crystal Lake.
5. Wildlife, Mainly Waterfowl – Pollutants released directly to the lake by birds, beavers, muskrats or other wildlife using the lake. Human inputs are not typically counted in this category. Pet wastes might be counted but are usually incorporated into the stormwater loading. No flow is usually associated with wildlife inputs, but contaminant loads are often assigned based on the number of animal units present on a yearly basis. These are most influential in smaller ponds in settings that attract many birds, like urban parks. Crystal Lake has some problems with Canada geese, which can provide substantial loads of nutrients to lakes.
6. Internal Recycling and Loading – Pollutants that entered the lake from the above sources and are retained by the lake, usually by incorporation into the lake bottom sediments, but are recycled and put back into the water column. This can include release from the sediment, as with dissociation of iron and phosphorus under anoxia, release from plants after uptake from sediment as "leakage" or upon senescence. It can also include stirring up of the bottom by wind or foraging fish like carp or catfish. This can be a major portion of the load in lakes with long detention times, and as it is most often associated with summer, it may be disproportionately important in supporting algae blooms. The potential for release from sediments exposed to anoxia in Crystal Lake is high and would be expected to be an important phosphorus loading mechanism.

A proper loading analysis considers each of the above source categories and works to bracket likely inputs associated with each. Often this involves first assessing the quantity of water from each source, then the concentration of associated pollutants, although it is possible to directly estimate loads as export coefficients based on direct measurements elsewhere, applied to land uses or lake area in the subject case. While no approach is better than direct measurement, the number of measurements necessary to adequately represent all sources of pollutants, seasonality of inputs, and variability in concetrations of inputs is often impractical to collect and loading models are utilized to support analysis, as is the case here. Multiple approaches with consideration of the range of possible inputs are therefore often applied and in this report the Lake Loading Response Model (LLRM) was utilized and is described below. Woodard & Curran utilized two other models that estimate the watershed runoff nutrient load, inclusive of groundwater and atmospheric deposition.

Atmospheric Deposition

On average, about 48 inches (1.2 meters) of precipitation lands directly on Crystal Lake and the surrounding land every year; the precipitation landing directly on the pond provides about 109 acre-feet (134,000 m^3/yr) of water. Average phosphorus concentration in precipitation varies over geographic area and with weather pattern (e.g., from the north, south, east or west), but is generally low in the northeast. Values tend to be between 5 and 25 µg/L, based on unpublished data from many areas of New England, with a value of 10 µg/L applied to Crystal Lake in the absence of any actual data for the area. This suggests an average annual load of about 2.9-3.1 lb/yr (1.3-1.4 kg/yr), with a plausible range of 1.5 to 7.3 lb/yr (0.7 to 3.3 kg/yr). Particles containing phosphorus may fall from the sky even in dry weather, and may constitute as much as half the input, but most of these particulates will not contain readily available phosphorus and will become part of the sediment, the load from which is accounted for separately.

Values applied in the LLRM (AECOM, 2019), which apply an aerial export coefficient to the area of the lake, resulted in an estimated phosphorus load of 2.9 lb/yr (1.3 kg/yr) to Crystal Lake from atmospheric sources (direct precipitation). An annual phosphorus load averaging between 2.2 and 4.4 lb/yr (1-2 kg/yr) is expected but may vary by about 25% in either direction as a function of wetter or drier years. This is not a substantial load to this lake, and little can be done about it through local management anyway.

Applying the same process to nitrogen, an estimated input from atmospheric sources is 122 lb/yr (55.5 kg/yr). As with phosphorus, this load cannot be easily managed, but it could be a significant load of nitrogen.

Direct Groundwater Seepage

Groundwater seeps directly into the lake from surrounding land. Often this groundwater carries wastewater contaminants where on-site wastewater disposal systems are used and can be an important source of phosphorus under certain conditions, but generally soil does an acceptable job of removing phosphorus and the Crystal Lake watershed is sewered. Seepage can be measured directly with seepage meters, and samples can be taken with porewater samplers or from nearby wells to assess quality, but we are unaware of any such study in the Crystal Lake watershed. Consequently, groundwater input quantity and quality must be estimated by calculation.

Groundwater seeps into lakes through porous soils at rates than tend to be between 1 and 40 $L/m^2/day$, based on many unpublished lake studies with which WRS has been involved. The depth to which porous soils extend into the waterbody varies by lake and even within lake by slope. Assuming that seepage occurs from the shoreline to a depth of 16.5 feet (5 meters), an area of 18.4 acres, based on where thicker muck deposits occur and inhibit groundwater flow, and assuming seepage rates of 2 to 4 $L/m^2/day$, a range appropriate to watershed soils and impervious cover, groundwater inflow would range from 16,600 to 33,000 m^3 per year, or 13.5 to 26.7 acre-feet.

Another way to look at possible seepage is that it will be a portion of the rainfall that is not converted to runoff. If 30-40% of the precipitation becomes runoff, this leaves 29-34 inches to evaporate, be taken up by plants, or infiltrate into the ground. About 10-20% of that would be likely to enter the lake, equating to a volume of 14,500 to 29,000 m^3 per year, or 11.8 to 23.5 acre-feet, a reasonable match for the range in the alternative calculation above.

In LLRM, groundwater inflow is calculated based on the land use features and literature rates for infiltration and lateral movement of groundwater. For Crystal Lake, the estimated groundwater inflow is about 23,000 m^3 per year, or 18.6 acre-feet, within the range estimated above.

We have no data for phosphorus levels in groundwater entering Crystal Lake, but would not expect levels to average more than 50 µg/L. With no current wastewater impacts, concentrations may be near the normal natural background of about 10 µg/L, but there may be historic inputs still working their way through the ground and some fertilizer and other urban landscape factors will increase the groundwater nutrient levels, more for nitrogen than phosphorus. Applying a phosphorus concentration of 20 µg/L to a flow of 15,000 to 30,000 m^3/yr suggests a groundwater phosphorus load of 0.3 to 0.6 kg/yr (0.7 to 1.3 lb/yr), an almost trivial input. For nitrogen, concentrations are likely to be higher, often >1 mg/L in groundwater in urban areas. At an average of 3 mg/L for groundwater nitrogen, a load of nitrogen to the lake of 45 to 90 kg/yr (99 to 198 lb/yr) is estimated.

In the LLRM model groundwater phosphorus loading is not itemized separately from baseflow, which includes dry weather surface flows as well, but the total phosphorus input during baseflow conditions based on the applied areas, export coefficients and attenuation values is only 0.2 kg/yr (0.4 lb/yr). As there are no actual flowing tributaries beyond stormwater discharges that should not flow during dry weather, this estimate should represent groundwater inputs and is consistent with the values above. For nitrogen, the LLRM estimate is 100 kg/yr (220 lb/yr), a bit higher than that estimated above.

Watershed Runoff (Stormwater)

Surface water flows enter Crystal Lake from seven active storm drainage systems and directly from land not served by piped systems. Runoff generated by storms will reach the lake fairly quickly, although there may be some detention in depressions and catch basins. Storm runoff will supply substantial flow in bursts, but the drains should be dry during periods without rainfall, except possibly for some groundwater interception.

A portion of the incoming watershed load will be particulates that do not directly contribute to the effective load of nutrients at the time that they enter the lake. The concept of an effective load is important to grasp, as loading analyses should consider generation of a load at the source, any attenuation of that load on the way to the lake, and the form in which the load enters, which translates into its utility to algae and its immediate effect. Most analyses will tend to overestimate the effective load, as data for forms of phosphorus are often lacking. Many of the input sources will include some unavailable phosphorus, and watershed runoff inputs are most susceptible to this influence, as those inputs include soil, sticks, leaves and other matter that does not rapidly or immediately give up associated phosphorus. Much of this particulate and unavailable load may therefore be more accurately expressed as internal load and counting it as part of the external load "double counts" that phosphorus and leads to overestimation of effective loading. We have tried to account for this phenomenon in the following calculations, but it does add uncertainty to estimates and the available nutrient loads expressed herein may be considerably smaller than watershed runoff loads exhibited in the Woodard & Curran models as those models reflect total phosphorus and not only available and dissolved phosphorus.

Direct measurement of flow and phosphorus concentration in the drainage systems feeding Crystal Lake has not been extensively studied, but some sampling was conducted in the past, and Woodard & Curran sampled three stormwater discharges during two storms in October of 2019 to complement existing data (Table 6). Measurements are not exactly first flush samples but are during periods of higher flows earlier in most storms, so results reflect higher concentrations for assessed contaminants and as previously described nutrient concentrations in stormwater increases in fall samples due to leaf litter inputs to streets and paved areas (Selbig 2016). Values collected in past studies are lower but still elevated. All values obtained suggest poor stormwater quality and elevated nutrients.

Based on the estimated runoff of 30-40% of precipitation on the watershed (59-79 acre-feet of runoff per year) and a phosphorus concentration averaging 0.181 mg/L (half the mean of 0.363 mg/L for all sampling, which represents predominantly peak and near peak concentrations), with 50% of the input phosphorus assumed to be dissolved and available, the available phosphorus load from runoff to Crystal Lake would be 6.6 to 8.8 kg/yr (14.5-19.4 lb/yr). The same approach for total nitrogen with a concentration of about 1.6 mg/L (half the mean for stormwater data, but no assumption of attenuation during the storm or lower availability as is expected for nitrogen) suggests an available nitrogen load of 116 to 156 kg/yr (255-343 lb/yr).

More complex estimation from a breakdown of land uses in the watershed and land use-specific export coefficients that reflect attenuation and availability is applied in LLRM. That approach suggests a dissolved and available phosphorus load of about 9.1 kg/yr (20 lb/yr), slightly more than the range calculated above. For nitrogen, the LLRM watershed load is estimated at 189 kg/yr (416 lb/yr), also higher than the estimates above. While there is certainly variability around these estimates, they are consistent and generally believable within the context of what we know of the Crystal Lake watershed and alternative calculation approaches.

Discharges

We are unaware of any permitted discharges (e.g., wastewater or cooling water) to Crystal Lake. Here we refer to releases from activities subject to regulation as discharges under the Clean Water Act and related state statutes. No discharge inputs of phosphorus or nitrogen are therefore assumed.

Wildlife

Studies of wildlife inputs of phosphorus to lakes have focused on waterfowl (Manny et al. 1975, Portnoy 1990, Scherer et al. 1995) and established a range of likely "exports" per bird per year, with variation based mainly on bird size (e.g., gulls vs. ducks vs. geese). If bird counts are available, one can estimate inputs with some degree of reliability. In the absence of counts, the exercise is highly speculative.

We are unaware of any bird counts for Crystal Lake. Bear in mind that bird feces added to the land around the lake is part of the watershed load, definitely an issue for the beach complex and associated park and possibly some residential properties, but not a direct wildlife load under this analysis. Here we consider just direct loading from wildlife, mainly birds in this case. Assigning a fairly arbitrary number of 10 waterfowl being present for half the year, mainly based on Canada geese sightings, we have 5 bird-years. An average value of 0.2 kg/bird-year is reasonable from the literature, yielding a bird-related phosphorus load of 1 kg/yr (2.2 lb/yr). For nitrogen, an average value of 0.95 kg/bird-year is assigned, yielding an estimate for nitrogen loading from wildlife of 4.8 kg/yr (10.6 lb/yr). These estimates are incorporated into the LLRM but could easily be off by 100% in either direction.

An assumed phosphorus load from wildlife of 2.2 lb/yr (1 kg/yr) is unlikely to represent a significant source in any year but may have long-term implications as such inputs will tend to accumulate in sediment and could increase the internal load over time. As a relatively low load when compared to watershed and internal nutrient sources, it does not warrant much additional effort. However, bird management in a situation like that at Crystal Lake may be warranted on the basis of bacteria and the mess they make at the beach and in the adjacent park.

Internal Recycling and Loading

Internal recycling of nutrients can involve multiple processes. Plants pull nutrients from the sediment and may either leak some of those nutrients into the water column or release them upon typical fall senescence. Bottom feeding fish or wind and boats in shallow areas can resuspend sediment and processes in the water column may make some of the associated nutrients available. Decay of organic matter in shallow water releases phosphorus into the water column, and this can be a significant source where highly organic sediments are found in shallow water. Most often substantial internal loading is a function of release of phosphorus from iron complexes under anoxic conditions near the sediment-water interface. This tends to happen in deeper water, below the thermocline, but can occur anywhere that the surficial sediment goes anoxic. Anoxia arises when oxygen consumption exceeds the rate of resupply. Even with adequate oxygen in the overlying water column, sediments can experience anoxia and release phosphorus from iron compounds.

Release of phosphorus from iron-bound forms in surficial sediments is a function of the concentration of iron-bound phosphorus and the extent and duration of anoxia. Once stratification begins, replenishment of deep water oxygen is strongly curtailed, while decomposition accelerates as temperatures rise. Oxygen near the bottom is used up first, with the anoxic interface rising from the bottom as oxygen is consumed and not replaced. As that anoxic interface rises, more sediment area is exposed to anoxia and iron-bound phosphorus may be released. The actual release process is a function of redox potential, the intensity of electron stripping from available compounds, preferentially oxygen, but later nitrate and eventually sulfate. While oxygen can only decline to a concentration of zero, redox potential can continue to decline, going negative, increasing the rate of phosphorus release even after oxygen is depleted.

In Crystal Lake, thermal stratification occured between 16.5 and 20 feet (5 and 6 m) in 2019. The boundary could be slightly shallower or deeper in any given year, mostly dependent on spring weather conditions. Oxygen was lost from the bottom to the boundary between upper and lower water layers, called the thermocline, in 2019 and likely is in most years. An area of 6.8 to 9.1 acres (25,000 to 36,800 m^2) is therefore exposed to low oxygen during summer in most years and therefore represents the target area for any control of internal phosphorus loading.

Phosphorus release rates will vary with redox potential, which can continue to get more negative even after oxygen is depleted. Low release rates of about 0.5 $mg/m^2/day$ are almost guaranteed, with rates as high as 20 $mg/m^2/day$ possible (Nurnberg 1984, 1987). Peak release rates on the order of 6-12 $mg/m^2/day$ are often recorded at the height of anoxia, but the average release rate over the summer is likely to be lower. Further, the area that is exposed to anoxia increases from about early June through August in most temperate lakes, increasing the potential contributing area as the summer progresses. There may be releases during winter as well, under the ice with minimal photosynthesis to add oxygen and ongoing (albeit slowed by low temperature) decomposition at the bottom.

Once phosphorus has been released from the sediment into the overlying water, it will tend to accumulate in the hypolimnion and lead to elevated concentrations such as those observed in 2019. Some diffusion into the epilimnion is expected, and algae growth may be substantial near the thermocline or on sediment where enough light penetrates. It is also possible that there are mixing events during the summer for water as deep as 23 feet, but it is expected that the water column will be fairly stable during the period of stratification.

Given the explanations above, internal loading can be a major portion of the annual load, but could vary substantially depending on where the thermocline sets up and how much area of the pond is exposed to anoxia and for how long. There could be a winter internal load that sets the stage for spring algae blooms and there is likely a summer internal load that would strongly favor cyanobacteria based on temperature at the time and an expected low N:P ratio. We have only data to addresss a possible summer load, which is usually the largest portion of any internal load by far.

There are several ways to approach estimation of internal phosphorus loading from anoxic sediments. The change in phosphorus level in the hypolimnion or the difference between epilimnetic and hypolimnetic phosphorus levels can be used to estimate increased mass of phosphorus where stratification is strong. Nutrient data for Crystal Lake prior to 2019 are limited, but we know that the epilimnetic phosphorus concentration was <10 µg/L in May of 2019. Phosphorus concentrations near the bottom (maximum of 114 µg/L) are higher than near the thermocline (maximum of 17 µg/L), suggesting a gradient in the deep water layer and an average change of 66 µg/L (half the difference between epilimnetic and bottom concentrations) over the course of the summer in a volume of 52 acre-feet or 63,700 m3 (water > 16.5 feet or 5 m deep). This equates to an internal load of 4.2 kg or 9.2 lb/yr, the amount of increase in the bottom water layer over the summer. However, some phosphorus will move into the upper waters by diffusion and mixing even during stratification, so this is likely an underestimate.

If we consider the mass of phosphorus in 3 layers of lake water colum set at 0-4 m, 4-6 m and 6-9 m, each matched to the values for phosphorus obtained in May and September, the difference will approximate the summer loading to Crystal Lake. The starting phosphorus concentration was <10 µg/L, so the actual starting concentration was likely between 5 and 10 µg/L . The summer surface phosphorus level increased by at least 4 µg/L, while the mid-depth concentration rose by at least 7 µg/L and the deep phosphorus concentration increased by at least 104 µg/L. If we assume that the starting phosphorus concentration was 10 µg/L at all depths, the change in mass over the summer was just over 6 kg (13.2 lb). If we assume the starting phosphorus concentration was 5 µg/L, the change in mass was 12 kg (26.4 lb). A relatively small amount of phosphorus would have been added by stormwater or precipitation or groundwater during the relatively dry 2019 summer, so an internal load closer to 13.2 than 26.4 lb/yr seems likely.

The 2019 sediment data can also be used to calculate the rate of phosphorus release from sediment during exposure to low oxygen. Calculation for the period of June through August with 6-12 kg released over 9.1 acres yields an average release rate range of 1.8-3.6 $mg/m^2/day$, a range that is commonly encountered in Massachusetts lakes experiencing low oxygen in deeper water. In a year with earlier stratification the release rate would go up over the greater time of stratification and raise this average. In a year of shallower stratification the release rate would apply to a greater area. The reverse would be true if stratification set up later or at a deeper depth, resulting in considerable year to year variation.

If we work with an increasing release rate ranging from 1.8-3.6 $mg/m^2/day$ with a 3 ac area exposed during June at 1.8 $mg/m^2/day$, 3 more acres at that rate in July plus the original 3 acres at 2.7 $mg/m^2/day$, and 3 more acres exposed at 1.8 $mg/m^2/day$ in August, 3 acres at 2.7 $mg/m^2/day$, and the original 3 acres at 3.6 $mg/m^2/day$, the total phosphorus release would be 5.3 kg (11.7 lb). Exposure to low oxygen extends into September by about two weeks, so a total closer to 6 kg (13.2 lb) may be a reasonable representation of the internal load in 2019 by this approach.

Another approach to estimating internal load involves assessing the mass of iron-bound and biogenic phosphorus in surficial sediments that might be subject to release and estimating releases as a percentage of that total. From the sediment data in Table 4, the average of the two most available fractions is 568 mg P/kg sediment. Percent solids averages 12.8% and the expected specific gravity is about 1.1. This means that in the upper 10 cm (4 inches) of organic sediment in every square meter at depths where low oxygen occurs, there are about 7.8 g of potentially available phosphorus waiting to be released from each square meter of sediment below a depth of about 5 m. From experience, no more than 10% of the iron-bound phosphorus and 5% of the biogenic phosphorus is released in any year on average. If we assume that 7% of the iron-bound phosphorus and 2% of the biogenic phosphorus are released, about 0.19 g/m^2 would be released over the area exposed to low oxygen. Using the 5 m contour as the contributing area, an internal load of 7 kg is projected for the summer. At the 6 m contour, more indicative of 2019, the internal load would be about 5.2 kg/yr, consistent with the values estimated above. An internal load of between 5 and 7 kg/yr (11-15.4 lb/yr) is suggested as typical for Crystal Lake under current conditions.

In LLRM, a phosphorus release rate of 1.8 g/m2/day was assigned to an area of 3.7 ha (9.1 acres) for a period of 90 days, yielding an internal phosphorus load of 5.8 kg/yr (12.8 lb/yr). This is smaller than the estimated watershed load but much larger than the other possible sources. However, the internal load is all associated with summer, while the watershed load is more evenly distributed throughout the year. As a result, the internal load is the single largest source during the summer, and is likely to be the difference between algae blooms or lower productivity in any year.

Nitrogen is not internally recycled to the extent observed for phosphorus, but is more abundant overall and the internal load is typically 5-10 times the internal phosphorus load, mainly as ammonium nitrogen. A large increase in deep water total Kjeldahl nitrogen was observed over the summer, almost certainly a build-up of released ammonium, and the change in mass is about 67 kg based on limited data. A release rate of 15 mg/m2/day was assigned in LLRM, using the same area and duration as for phosphorus, and yields an internal nitrogen load of 48.6 kg/yr (107 lb/yr).

Loading Summary and Management Scenarios

The Lake Loading Response Model was used to generate load estimates for water, phosphorus and nitrogen. Varying assumptions with regard to export coefficients, attenuation, and details of loading lead to changes in each loading component, but LLRM provides a single estimate of "steady state" loading (the average annual input of water and nutrients over a period of years) for any set of assumed input values. While no model can completely represent reality, the intention is to describe the actual situation in Crystal Lake with a model to a level of reliability that allows us to ask "what if?" questions like "What if the internal load was reduced by 90%?" or "What if the watershed load could be reduced by 20%?" Key metrics are the new concentration of phosphorus, water clarity, and the probability of having an algae bloom, expressed as a percentage of time when chlorophyll-a concentration exceeds some identified threshold like 10 µg/L.

The current best estimate of water, phosphorus and nitrogen loads (Table 7) suggests that slightly less than half the water entering the pond is directly from precipitation on the lake surface and slightly less than half from the watershed, mostly as runoff during storms. A little over half the effective phosphorus input comes from the watershed while just over one third is from internal loading, with smaller amounts from direct precipitation and wildlife. However, it should be noted that the internal load is almost entirely a summer phenomenon while the watershed runoff load is spread more evenly throughout the year; there is a higher risk of algae blooms in the summer that relates to both temperature and low nitrogen to phosphorus ratios in the lake. Almost two thirds of the nitrogen load from the watershed while 15-20% comes from either direct precipitation or internal loading and a very small fraction is attributable to wildlife.

In-lake nutrient concentrations that result from the current loading scenario provide a benchmark against which other possible scenarios can be compared (Table 8). Under the modeled current loading of phosphorus and nitrogen it is expected that the phosphorus concentration will average 18 µg/L, nitrogen will average 601 µg/L, and chlorophyll-a will average 6.6 µg/L, while there will be a 14% probability of having a mild algae bloom and water clarity will average 2.5 m (8.3 feet). These are not extremely adverse conditions, and in fact the public beach remained functional and open for all but the last couple of weeks of August 2019. However, the very high clarity observed

Table 7: Crystal Lake Current Loading Summary

CRYSTAL LAKE LOAD SUMMARY						
Source	Water (cu. m/yr)	% Water Load	Available Phosphorus (lb/yr)	% Phosphorus Load	Available Nitrogen (lb/yr)	% Nitrogen Load
Atmospheric	134310	54.6%	2.9	7.7%	122.1	18.6%
Internal	0	0.0%	12.8	33.7%	106.9	16.3%
Wildlife	0	0.0%	2.2	5.8%	10.5	1.6%
Wastewater	0	0.0%	0.0	0.0%	0.0	0.0%
Watershed	111680	45.4%	20.1	52.8%	416.3	63.5%
Total	245990	100.0%	38.1	100.0%	655.7	100.0%

in May was greatly reduced by late June and cyanobacteria became dominant later in summer, coincident with low oxygen at depths of 18 feet (5.5 m) and phosphorus release from the sediment in low oxygen areas. From the current scenario, if it is a particularly wet year (more runoff) or a year in which low oxygen is experienced longer and/or over more of the lake, the phosphorus concentration could rise to 21-22 µg/L and water clarity would decline somewhat, with almost a doubling of the probability of an algae bloom. Instead of a couple of weeks of unacceptable conditions, the problem could occur for a whole month, most likely beginning in early August.

For comparison, under original background conditions, prior to human settlement of the watershed, average phosphorus is projected to have been about 5 µg/L with nitrogen at 304 µg/L, both low values, with clarity >20 feet (>6 m) and minimal probability of an algae bloom.

It is apparent from this analysis (Tables 7 and 8) that the internal load and the watershed load are the dominant sources of phosphorus to Crystal Lake and must be addressed to achieve sustained desirable conditions. The watershed load is the largest single source, but it is the internal load that favors cyanobacteria by virtue of focused occurrence during the period of highest temperature and being associated with the lowest N:P ratio. The internal load can be reduced by as much as 90% by several methods, while achieving load reductions of more than 25% in urban watersheds is challenging.

The internal load is derived from the sediment when exposed to low oxygen levels; removal of the sediment, provision of adequate oxygen, or inactivation of the phosphorus in the sediment can all provide major reductions in the internal load (Cooke et al. 2005). The watershed load comes from a variety of sources and is driven by precipitation that creates runoff. Some control of sources and minimization of runoff is possible, but major reductions have been elusive in watershed management (Osgood 2017). Urbanization raises loads of many contaminants by an order of magnitude while the best management practices (BMP) rarely reduce the load by 50% and it is difficult to apply BMPs to the entire watershed. Yet a combination of internal load control and watershed management could achieve the desired conditions.

If the internal load could be reduced by 90%, a practical goal based on our experience in MA, the phosphorus concentration would decline to 13 µg/L, average clarity would be 3.3 m (10 feet) and there would only be about a 2% chance of an algae bloom. Reductions in the watershed runoff load of 10 or 20% would decrease the average phosphorus concentration 1 or 2 µg/L respectively

Table 8: In-Lake Conditions Relating to a Range of Possible Loading Scenarios

SUMMARY TABLE FOR SCENARIO TESTING	Existing Conditions		Background Conditions	Wet Year	Low Oxygen Year	90% Reduction in Internal Load	10% Reduction in Watershed Load	20% Reduction in Watershed Load	90% Internal Load and 20% Watershed Load Reduction
	Calibrated Model Value	Actual Data	Model Value	Model Value	Model Value	Model Value	Model Value	Model Value	Model Value
Phosphorus (ug/L)	18	17-20	5	22	21	13	17	16	11
Nitrogen (ug/L)	601	615	304	585	612	601	571	540	540
Mean Secchi (m)	2.5	2.6	6.1	2.2	2.3	3.3	2.6	2.7	3.8
Peak Secchi (m)	4.3	6.0	6.4	4.1	4.2	4.8	4.4	4.5	5.0
Mean Chlorophyll (ug/L)	6.6	6.6	1.1	8.2	7.7	4.0	6.1	5.7	3.2
Peak Chlorophyll (ug/L)	22.8	27.7	4.7	28.2	26.6	14.5	21.3	19.8	11.8
Bloom Probability									
Probability of Chl >10 ug/L	13.7%		0.0%	26.1%	22.1%	1.9%	10.8%	8.2%	0.6%
Probability of Chl >15 ug/L	2.8%		0.0%	7.3%	5.7%	0.2%	2.0%	1.4%	0.0%
Probability of Chl >20 ug/L	0.7%		0.0%	2.1%	1.6%	0.0%	0.4%	0.3%	0.0%

and the probability of blooms would decline to 11 and 8% respectively. Getting a reduction of more than 20% from an urban watershed is very challenging, although not impossible when the watershed is small, if a substantial maintenance budget can be sustained. Yet, if the internal load is reduced by 90% and the watershed load is reduced by 20% the phosphorus concentration would decline to 11 µg/L and the bloom probability would be <1%.

Management Options Review

Running through the list of options for managing Crystal Lake, some techniques are clearly more applicable than others and relatively few have no drawbacks. For example, algaecides could certainly be used to prevent blooms, but careful tracking of algae represents a lot of effort and simply waiting until a bloom arises to treat is not likely to be acceptable to permitting agencies as a long-term solution.

Techniques that represent scientifically sound approaches consistent with all known goals for management of Crystal Lake include structural and non-structural watershed runoff controls, dredging, oxygenation, and phosphorus inactivation. As previously discussed, management of the watershed is important to the long-term health of the lake but will not likely result in achievement of ideal in-lake conditions by itself. Some means to address internal recycling will be necessary to restore Crystal Lake and reduce the occurrence of algae blooms.

Dredging

Dredging is true lake restoration, removing accumulated sediment and setting the lake back in time. While dredging does not affect ongoing watershed inputs, it can control internal loading and minimize oxygen demand. Dredging is very expensive, however, and if there is any sediment contamination, the cost can rise sharply. However, if there is nearby land to be reclaimed (i.e., sand and gravel pits), disposal costs can be minimized. Yet to remove just a foot of sediment from the minimum 10-acre area affected by anoxia and phosphorus release from sediment the cost would be at least $500,000, based on a typical low end cost of $50,000 per acre-foot from other New England projects. If phosphorus-rich sediment is more than a foot deep, more sediment would have to be removed at greater cost. If there is contamination that affects disposal options, and the average levels of some metals and hydrocarbons in Massachusetts lakes exceeds disposal standards, the cost will rise sharply. While attractive on a technical level, this is probably not an economically viable approach, particularly where recovering depth is not really an issue.

Oxygenation

Oxygenation could be highly beneficial in Crystal Lake. The available evidence suggests that the onset of cyanobacteria blooms coincided with the anoxic zone reaching a depth where a substantial portion of the pond bottom was affected. If oxygen was added to the hypolimnion of Crystal Lake, it could prevent anoxia and limit internal phosphorus loading. Maintenance of oxygen at >2 mg/L near the bottom minimizes phosphorus release from iron-phosphate complexes (Wagner 2015). Oxygen addition can be accomplished by circulation or injection without complete pond mixing; there are three methods for circulating and four methods for non-destratifying oxygenation (Wagner 2105). Pumped circulation systems (e.g., Solarbees, Resmix) are less useful in this case and would require structures at the surface of the lake that would be less aesthetically appealing and could move poor quality bottom water to the surface, potentially fostering algae blooms. For non-destratifying oxygenation, systems that release oxygen bubbles will not have a large enough vertical rise to allow total absorption of those bubbles, leading to destratification, and placement of chambers in the lake in which water would be oxygenated would require more bottom preparation and ongoing maintenance than the City is likely to find tolerable. This leaves use of diffused air to keep the pond mixed and sidestream supersaturation (oxygenation chambers on shore) to add oxygen without mixing the pond are most applicable.

The area of the pond >16.5 feet (>5 m) deep is small and circulation should be very affordable but is not likely to be as effective as non-destratifying oxygenation as a function of ongoing watershed inputs that would be mixed in the lake to a greater degree than with non-destratifying oxygenation. For circulation, a system of diffusers would have to be deployed and a compressor run from about May through early September. In a very warm summer, the system may be unable to keep up with heat input, resulting in some stratification and some anoxia, but conditions should be improved over the current situation. At a typical capital cost of about $1500/ac and an operational cost of about $100/ac, circulation would cost about $14,000 to install and $1,000 per year to run. This may be affordable and may curtail cyanobacterial dominance but will not likely prevent algae blooms as fertility is likely to remain elevated.

For sidestream supersaturation, water would be pumped out of the target zone of the lake and oxygenated to beyond normal saturation for the ambient temperature, then released back into the target zone to oxygenate it. Such a system would need to run in at least May through July and probably well into August to keep oxygen >2 mg/L through the summer. About 10% of the target zone of 81,800 m^3 or 66.3 ac-ft would have to be addressed by sidestream supersaturation, covering the 36,800 m^2 or 9.1 ac that contribute the most phosphorus. At a typical installation cost of $8000/ac for smaller waterbodies and an operational cost of $1000/ac, sidestream supersaturation can be expected to cost about $73,000 to install and $9,000 per year to operate. This could prevent much of the internal recycling and reduce bloom frequency and severity while enhancing habitat for fish and other aquatic animals.

A more recent option for oxygenation that may deserve to be considered separately from sidestream supersaturation is the use of nanobubbles, or very small (<0.2 µm) bubbles created in a chamber on shore and released into the lake in a stream of water pumped from the lake into the chamber and the flowing back by gravity. The mass transfer of oxygen is functionally the same as sidestream supersaturation, but nanobubble technology can use air, enriched air (about 40% oxygen instead of 21%), or pure oxygen and the bubbles are small enough that the negative charge on their surface will counter their buoyancy and minimize vertical rise in the water column. Deep lake water could be pumped into the chamber where the nanobubbles are added then sent back to the deep zone of the lake to add oxygen and prevent low oxygen conditions from occurring. The details of the difference between true dissolved oxygen and nanobubbles is not entirely clear; the definition of "dissolved" is usually anything <0.45 µm, so the nanobubbles are by definition a dissolved substance. The cost is not well known, as there are few installations focusing on the bottom water layer of lakes, but it may be lower than for sidestream supersaturation as currently practices, with a rough estimate of $5000 to $7000 per acre. That would suggest a cost of about $45,000 to $63,700 for installation with an unknown operational cost.

Phosphorus Inactivation

As dredging is very expensive and oxygenation by either circulation or direct oxygen injection has an ongoing operational cost, phosphorus inactivation has been more popular for lakes not used for water supply on a large scale and both desiring certain additional benefits (e.g., greater storage capacity, lower iron concentrations) and having ratepayers to support ongoing operational costs. In recreational lakes, just preventing algae blooms is usually sufficient to meet use goals and can be accomplished with phosphorus inactivation at lower cost.

Phosphorus inactivation can be used three ways: to treat incoming water high in phosphorus, to strip phosphorus from the water column in a lake, or to bind phosphorus in surficial sediments and make reserves less susceptible to release under anoxia. All are applicable, but the most advantageous approach would be a treatment of the sediment area subject to anoxia with a phosphorus binder such as aluminum. The track record for such treatments is favorable, including past efforts in New England, and the empirical evidence that higher Al:Fe ratios in the sediment prevents phosphorus release (Norton et al. 2008) also favors this approach. A reduction of 90% of the internal load could be achieved. This technique is implemented once and provides improvement for at least 6 years in shallow, unstratified lakes and on average for 21 years in stratified lakes (Huser et al. 2015). Crystal Lake would be considered to be stratified, although the volume associated with stratification in all years is not large and the area that appears critical in recent internal load generation may be subject to mixing in some summers. Yet extended benefits would be projected for Crystal Lake with treatment of all areas beyond the water depth at which low oxygen occurs, about 18 feet (5.5 m) in Crystal Lake with treatment at deeper than 16.5 feet (5 m) to provide a margin of safety.

Knowledge of the distribution of soft, organic sediment that harbors the greatest available phosphorus reserves is helpful here, and we found that there was soft, organic sediment to depths as shallow as 13 feet, but coverage was complete at >16 feet (just under 5 m). This further supports treatment of all areas deeper than 16.5 feet (5 m).

The dose is often determined by laboratory assays, but such assays were not part of this project and with such a relatively small treatment area (9.1 acres) it is reasonable to pick the dose as a factor of ten times the available phosphorus mass in the upper 4 inches (10 cm) of the sediment in the target area. Five sediment samples were tested (Table 4) and the variation was not extreme, so a single dose applied to the target area is appropriate. Based on the sediment features determined by testing, the mass of phosphorus in each square meter averages 7.9 g/m^2, with most of this in the biogenic phosphorus form. Treating the iron-bound fraction with aluminum at 10-20 to 1 and the biogenic portion at 5-7 to 1, the total aluminum dose would be between 43 and 67 g/m^2. This is firmly in the middle of the range of treatment doses used in Massachusetts to date.

The cost for aluminum treatments will vary with labor needs and chemical costs. A typical current cost factor of $45 per g/m^2 per acre treated is applicable, suggesting a range of costs of $17,600 to $27,500 for the recommended target area in Crystal Lake. This treatment would occur over about a week sometime in late April to mid-May, preferably before the docks are put in, as that is the best launching and staging area for such a treatment.

There is an alternative worth considering in this case, which would be to do several sequential treatments at lower doses over a period of several years. Each treatment also strips the water column of most phosphorus, something that could be beneficial with the ongoing watershed load until watershed management can be implemented. As long as the dose in each treatment is adequate to lower phosphorus in the water column, the partial inactivation of phosphorus in the sediment should also be adequate to provide a couple of years of much-reduced release from surficial sediment and low water column phosphorus concentrations. With a detention time of about 2 years, a single treatment should depress the water column phosphorus concentration for at least 2 years. A surface sediment treatment of 20 g/m^2 is about the minimum dose to control internal loading for multiple years. So it would be possible to apply the aluminum in two or three events, each 2 years apart, resulting in the total dose of 43 to 67 g/m^2 that will completely inactivate surficial sediment phosphorus but allowing phosphorus in the water column to be stripped several times. This would accomplish the targeted surficial sediment phosphorus inactivation while providing multiple water column stripping events that would enhance lake conditions until watershed management actions could be more fully implemented.

A 20 g/m^2 aluminum dose applied to water >16.5 feet (>5 m) deep equates to a volumetric dose of <4 mg/L on average and >2 mg/L in the deepest part of the lake, quite adequate to stripping the water column of phosphorus while adding enough aluminum to curtail internal loading for at least several years. The slightly increased cost relating to additional mobilization for sequential treatments may be worthwhile since this approach would also address the results of watershed loading over a period of time long enough to allow significant reductions in watershed inputs to be achieved. If 3 sequential treatments were conducted with 2 years between treatments, each with a dose of 20 g/m^2, the total cost exclusive of any inflationary changes or alteration of chemical costs should be no more than $30,000, exclusive of outreach, permitting and project management costs and assuming no inflationary or other unanticipated future costs.

The cost over the expected period of benefit of an aluminum treatment is lower than for any other in-lake option. Each sequential treatment would require about 2 days to apply, minimizing disruption at the lake. About one typical tanker load of aluminum sulfate and one-half tanker load of sodium aluminate would be applied at a 2:1 ratio (alum to aluminate) to keep the pH balanced. A 30-foot barge is often used for aluminum treatments on larger lakes, but for a smaller application such as this, a 16-foot skiff would most likely be used. Such treatments have been done elsewhere in Massachusetts, the closest one being at Chestnut Hill Reservoir in Boston just last year.

Permitting for aluminum treatment in Massachusetts involves a local Order of Conditions under the Wetlands Protection Act and a License to Apply Chemicals from the MA DEP. Such permits are routinely granted; 37 aluminum treatments were permitted in 2019. The biggest risk with aluminum treatment is possible toxicity to fish and invertebrates if the pH is not controlled during application. Some aluminum compounds cause the pH to rise while others cause it to decline, and a pH between 6 and 8 avoids toxicity at normally applied doses. Selection of aluminum compounds and related buffering agents as warranted, along with careful monitoring during treatment, has eliminated toxicity events for the last 20 years.

Conclusions and Recommendations

Based on the documented condition of Crystal Lake, it is clearly suffering from excessive internal loading and has enough ongoing watershed loading to warrant both in-lake and watershed action. The current average annual dissolved and available phosphorus load is estimated at 38.1 lb/yr (17.3 kg/yr), resulting in an average phosphorus concentration of 17-20 µg/L and allowing summer cyanobacteria blooms. A target total phosphorus load of about 22 lb/yr (10 kg/yr) is suggested, yielding an average phosphorus concentration <11 µg/L and providing acceptable conditions with regard to algae during the primary use season. It will not be possible to reach a phosphorus loading goal of 22 lb/yr and may be hard to reach even 15 kg/yr with watershed management alone; the internal load is simply too large and occurs mainly in summer, making it a dominant component of the load during the growing season.

Achieving a 90% reduction in the internal phosphorus load would reduce the total load to 26.6 lb/yr (12.1 kg/yr) and the average phosphorus concentration to 13 µg/L, leading to a low probability of algae blooms. Watershed management aimed at removing (i.e., street sweeping, leaf litter collection) and trapping (i.e., stormwater control systems) phosphorus before it enters the pond could supply the additional desired loading reduction and provide a suitable margin of safety while protecting any investment made in phosphorus inactivation in the pond. This will likely require additional structural and non-structural actions in the Crystal Lake watershed and is further described in the Woodard & Curran Watershed Management Plan.

Given a primary goal for Crystal Lake of eliminating cyanobacteria blooms, treatment with aluminum to inactivate surficial sediment phosphorus is expected to provide immediate and substantial benefit that will last up to two decades. A dose of between 43 and 67 g/m^2 should be applied to all area deeper than 16.5 feet (5 m). The overall reduction in loading and an increase in nitrogen to phosphorus ratios are expected to minimize cyanobacteria during the primary period of human use. Such a treatment could be performed incrementally; it does not have to be done all at once, and the cost of sequential additions may be warranted to provide phosphorus stripping of the water column over a period of 6 years while watershed actions are being implemented. An oxygenation system could be considered in place of phosphorus inactivation if so desired, as it provides additional water quality and habitat benefits, but will likely cost more than phosphorus inactivation and is not more likely to prevent algae blooms.

While geese are not a dominant nutrient source to the lake, they are an ongoing source and also represent a health hazard, especially at the beach. Construction fencing or other deterrents are advisable at least in the offseason to limit geese access to the beach and adjacent park area.

Monitoring is an important component of ongoing lake management. The monitoring programs that have been conducted to date at Crystal Lake by the City of Newton, the Crystal Lake Conservancy and others were instrumental in providing data used in our analyses, and it could be improved in the future. Temperature and oxygen profiles should include measurements at 3-foot intervals rather than every 10 feet. Samples for phosphorus should be collected at least at the surface and near the bottom in the deepest area of the lake on each sampling date and tested at a laboratory capable of a phosphorus detection limit of 10 µg/L (0.01 mg/L) or less. Monthly monitoring between April and September is preferred.

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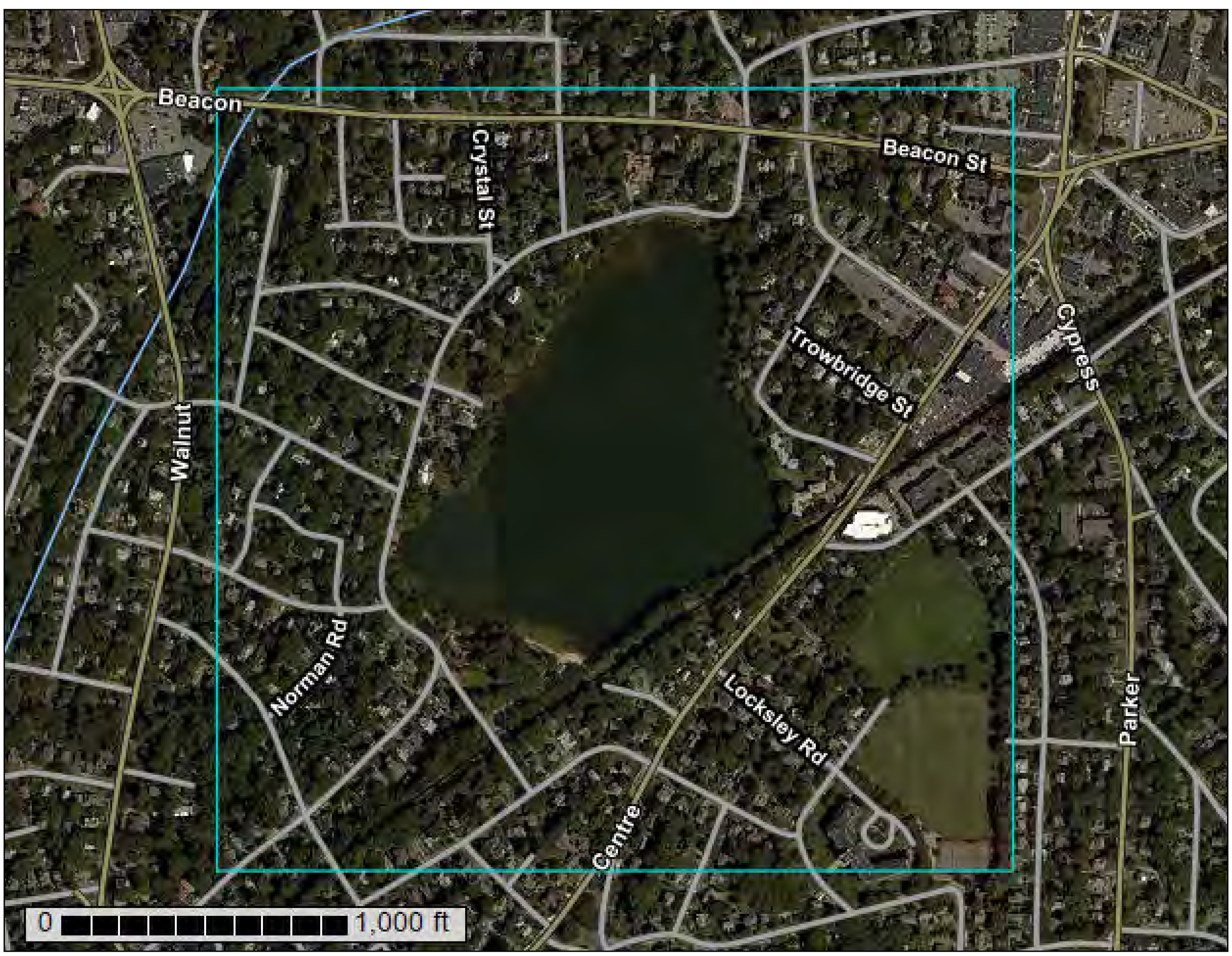
APPENDIX B: NRCS SOIL SURVEY

United States Department of Agriculture

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Middlesex County, Massachusetts



July 29, 2019

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map

Map Scale: 1:7,030 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 100, 200, 400, 600

Feet: 0, 300, 600, 1200, 1800

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:25,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Middlesex County, Massachusetts
Survey Area Data: Version 18, Sep 7, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 30, 2011—Aug 25, 2014

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Water	28.2	16.2%
602	Urban land	20.9	12.0%
626B	Merrimac-Urban land complex, 0 to 8 percent slopes	53.8	30.9%
629C	Canton-Charlton-Urban land complex, 3 to 15 percent slopes	27.2	15.6%
631C	Charlton-Urban land-Hollis complex, 3 to 15 percent slopes, rocky	34.1	19.6%
654	Udorthents, loamy	10.1	5.8%
Totals for Area of Interest		**174.3**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Middlesex County, Massachusetts

1—Water

Map Unit Setting

National map unit symbol: 996p
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Water: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Water

Setting

Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Dip
Down-slope shape: Linear
Across-slope shape: Linear

602—Urban land

Map Unit Setting

National map unit symbol: 9950
Elevation: 0 to 3,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Urban land: 85 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Urban Land

Setting

Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land

Minor Components

Udorthents, wet substratum

Percent of map unit: 5 percent
Hydric soil rating: No

Rock outcrop

Percent of map unit: 5 percent
Landform: Ledges
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Head slope
Down-slope shape: Concave
Across-slope shape: Concave

Udorthents, loamy

Percent of map unit: 5 percent
Hydric soil rating: No

626B—Merrimac-Urban land complex, 0 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2tyr9
Elevation: 0 to 820 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 140 to 250 days
Farmland classification: Not prime farmland

Map Unit Composition

Merrimac and similar soils: 45 percent
Urban land: 40 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Merrimac

Setting

Landform: Kames, eskers, moraines, outwash terraces, outwash plains
Landform position (two-dimensional): Backslope, footslope, shoulder, summit
Landform position (three-dimensional): Side slope, crest, riser, tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy glaciofluvial deposits derived from granite, schist, and gneiss over sandy and gravelly glaciofluvial deposits derived from granite, schist, and gneiss

Typical profile

Ap - 0 to 10 inches: fine sandy loam
Bw1 - 10 to 22 inches: fine sandy loam
Bw2 - 22 to 26 inches: stratified gravel to gravelly loamy sand
2C - 26 to 65 inches: stratified gravel to very gravelly sand

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat excessively drained

Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to very high (1.42 to 99.90 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 2 percent
Salinity, maximum in profile: Nonsaline (0.0 to 1.4 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 1.0
Available water storage in profile: Low (about 4.6 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: A
Hydric soil rating: No

Description of Urban Land

Typical profile
M - 0 to 10 inches: cemented material

Properties and qualities
Slope: 0 to 8 percent
Depth to restrictive feature: 0 inches to manufactured layer
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 to 0.00 in/hr)
Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D
Hydric soil rating: Unranked

Minor Components

Sudbury
Percent of map unit: 5 percent
Landform: Outwash plains, terraces, deltas
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Tread, dip
Down-slope shape: Concave
Across-slope shape: Linear
Hydric soil rating: No

Hinckley
Percent of map unit: 5 percent
Landform: Deltas, outwash plains, eskers, kames
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Nose slope, crest, head slope, side slope, rise
Down-slope shape: Convex
Across-slope shape: Convex, linear
Hydric soil rating: No

Windsor

Percent of map unit: 5 percent
Landform: Deltas, outwash plains, dunes, outwash terraces
Landform position (three-dimensional): Riser, tread
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Hydric soil rating: No

629C—Canton-Charlton-Urban land complex, 3 to 15 percent slopes

Map Unit Setting

National map unit symbol: 9959
Elevation: 0 to 1,000 feet
Mean annual precipitation: 32 to 54 inches
Mean annual air temperature: 43 to 54 degrees F
Frost-free period: 110 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Canton and similar soils: 40 percent
Charlton and similar soils: 30 percent
Urban land: 25 percent
Minor components: 5 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Canton

Setting

Landform: Hills
Landform position (two-dimensional): Backslope, footslope
Landform position (three-dimensional): Base slope, side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable loamy eolian deposits over friable sandy basal till derived from granite and gneiss

Typical profile

H1 - 0 to 8 inches: fine sandy loam
H2 - 8 to 21 inches: fine sandy loam
H3 - 21 to 65 inches: gravelly loamy sand

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: 18 to 30 inches to strongly contrasting textural stratification
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
Depth to water table: More than 80 inches

Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 2.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: A
Hydric soil rating: No

Description of Charlton

Setting

Landform: Drumlins, ground moraines
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 22 inches: sandy loam
H3 - 22 to 65 inches: gravelly sandy loam

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: A
Hydric soil rating: No

Description of Urban Land

Setting

Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land

Minor Components

Montauk

Percent of map unit: 2 percent
Landform: Hillslopes
Landform position (two-dimensional): Shoulder, summit

Landform position (three-dimensional): Nose slope, head slope
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

Scituate

Percent of map unit: 2 percent
Landform: Hillslopes, depressions
Landform position (two-dimensional): Toeslope, summit
Landform position (three-dimensional): Head slope, base slope
Down-slope shape: Linear
Across-slope shape: Concave
Hydric soil rating: No

Udorthents, loamy

Percent of map unit: 1 percent
Hydric soil rating: No

631C—Charlton-Urban land-Hollis complex, 3 to 15 percent slopes, rocky

Map Unit Setting

National map unit symbol: vr1g
Elevation: 0 to 1,000 feet
Mean annual precipitation: 32 to 54 inches
Mean annual air temperature: 43 to 54 degrees F
Frost-free period: 110 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Charlton and similar soils: 40 percent
Urban land: 40 percent
Hollis and similar soils: 10 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Charlton

Setting

Landform: Drumlins, ground moraines
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable loamy eolian deposits over friable loamy basal till derived from granite and gneiss

Typical profile

H1 - 0 to 5 inches: fine sandy loam
H2 - 5 to 22 inches: sandy loam
H3 - 22 to 65 inches: gravelly sandy loam

Properties and qualities

Slope: 3 to 15 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 6.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: A
Hydric soil rating: No

Description of Urban Land

Setting

Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Excavated and filled land

Description of Hollis

Setting

Landform: Ridges, hillslopes
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Friable, shallow loamy basal till over granite and gneiss

Typical profile

H1 - 0 to 2 inches: fine sandy loam
H2 - 2 to 14 inches: fine sandy loam
H3 - 14 to 18 inches: unweathered bedrock

Properties and qualities

Slope: 3 to 15 percent
Percent of area covered with surface fragments: 9.0 percent
Depth to restrictive feature: 8 to 20 inches to lithic bedrock
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.14 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 2.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: D
Hydric soil rating: No

Minor Components

Canton

Percent of map unit: 4 percent
Landform: Hills
Landform position (two-dimensional): Backslope, toeslope
Landform position (three-dimensional): Side slope, base slope
Down-slope shape: Linear
Across-slope shape: Convex
Hydric soil rating: No

Udorthents, loamy

Percent of map unit: 2 percent
Hydric soil rating: No

Rock outcrop

Percent of map unit: 2 percent
Landform: Ledges
Landform position (two-dimensional): Summit
Landform position (three-dimensional): Head slope
Down-slope shape: Concave
Across-slope shape: Concave

Scituate

Percent of map unit: 1 percent
Landform: Hillslopes, depressions
Landform position (two-dimensional): Toeslope, summit
Landform position (three-dimensional): Base slope, head slope
Down-slope shape: Linear
Across-slope shape: Concave
Hydric soil rating: No

Montauk

Percent of map unit: 1 percent
Landform: Hillslopes
Landform position (two-dimensional): Shoulder, summit
Landform position (three-dimensional): Nose slope, head slope
Down-slope shape: Convex
Across-slope shape: Convex
Hydric soil rating: No

654—Udorthents, loamy

Map Unit Setting

National map unit symbol: vr1l
Elevation: 0 to 3,000 feet
Mean annual precipitation: 32 to 50 inches
Mean annual air temperature: 45 to 50 degrees F
Frost-free period: 110 to 200 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents, loamy, and similar soils: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents, Loamy

Setting

Parent material: Loamy alluvium and/or sandy glaciofluvial deposits and/or loamy glaciolacustrine deposits and/or loamy marine deposits and/or loamy basal till and/or loamy lodgment till

Properties and qualities

Depth to restrictive feature: More than 80 inches
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None

Minor Components

Udorthents, sandy

Percent of map unit: 10 percent
Hydric soil rating: No

Udorthents, wet substratum

Percent of map unit: 5 percent
Hydric soil rating: Yes

Urban land

Percent of map unit: 5 percent
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope
Down-slope shape: Linear
Across-slope shape: Linear

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APPENDIX C: BASELINE POLLUTANT LOAD CALCULATIONS

COMMITMENT & INTEGRITY
DRIVE RESULTS

WOODARD & CURRAN
980 Washington Street, | Suite 325
Dedham, Massachusetts 02026
Tel: 800.446.5518

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	9/10/2019
CHECKED BY:	HCP	DATE:	10/18/2019
PROJECT NO.	230525.03	SHEET NO.	1

Baseline Pollutant Loading Calculations

Lake Outfall #1 Baseline Conditions

Location: Laurel Street/Lake Ave

Drainage Area: 4.19 AC

Land Use:			
	High Density Residential	Total Impervious	1.92 AC
		Pervious HSG A (2.41 IN/HR)	2.27 AC

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	4.52	27.68	858.99

BASELINE LAKE OUTFALL #1

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	1.92	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	2.27	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	4.19				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			4.52	27.68	858.99	1.36

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Baseline Pollutant Loading Calculations

Lake Outfall #2 Baseline Conditions

Location: Lake Ave

Drainage Area: 1.32 AC

Land Use:	**High Density Residential**	**Total Impervious**	**0.67 AC**
		Pervious HSG A (2.41 IN/HR)	**0.65 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	**1.58**	**9.64**	**299.31**

BASELINE LAKE OUTFALL #2

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	0.67	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	0.65	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	1.32				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			1.58	9.64	299.31	0.47

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Baseline Pollutant Loading Calculations

Lake Outfall #3 Baseline Conditions

Location:	**Norwood Ave/Trowbridge Street**		
Drainage Area:	**1.96 AC**		
Land Use:	**Commercial**	**Total Impervious**	**0.04 AC**
		Pervious HSG A (2.41 IN/HR)	**0.01 AC**
	High Density Residential	**Total Impervious**	**1.00 AC**
		Pervious HSG A (2.41 IN/HR)	**0.91 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	**2.42**	**14.96**	**460.62**

BASELINE LAKE OUTFALL #3

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious	0.04	1	1	1	1
High Density Residential Impervious	Impervious	1.00	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	0.92	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	1.96				
			2.42	14.96	460.62	0.76

* Note:Only fill in the yellow highlighted cells.

*Note: Orange cells provide the option to enter total existing load without land use distribution.

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Baseline Pollutant Loading Calculations

Lake Outfall #5 Baseline Conditions

Location: Saxon Road & Terrace/Lakewood Road/Norman Road/Lake Ave

Drainage Area: 7.27 AC

Land Use:	High Density Residential	Total Impervious	2.51 AC
		Pervious HSG A (2.41 IN/HR)	4.76 AC

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	5.97	36.67	1,135.71

BASELINE LAKE OUTFALL #5

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	2.51	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	4.76	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	7.27				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			5.97	36.67	1135.71	1.78

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Baseline Pollutant Loading Calculations

Lake Outfall #6 Baseline Conditions

Location: Saxon Terrace/Lake Ave

Drainage Area: 0.94 AC

Land Use:	**High Density Residential**	**Total Impervious**	**0.39 AC**
		Pervious HSG A (2.41 IN/HR)	**0.56 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	**0.92**	**5.61**	**174.03**

BASELINE LAKE OUTFALL #6

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	0.39	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	0.56	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	0.94				

* Note:Only fill in the yellow highlighted cells.

*Note: Orange cells provide the option to enter total existing load without land use distribution.

0.92	5.61	174.03	0.27

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Baseline Pollutant Loading Calculations

Lake Outfall #7 Baseline Conditions

Location: Saxon Road/Berwich Road/Lake Ave

Drainage Area: 4.53 AC

Land Use:	**High Density Residential**	**Total Impervious**	**1.87 AC**
		Pervious HSG A (2.41 IN/HR)	**2.66 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	4.41	27.04	838.31

BASELINE LAKE OUTFALL #7

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	1.87	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	2.66	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	4.53				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			4.41	27.04	838.31	1.32

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Baseline Pollutant Loading Calculations

Lake Outfall #8 Baseline Conditions

Location: Kenmore Street/Moreland Ave/Albion Street/Newberry Street & Terrace/Crystal Street/Lake Ave

Drainage Area: 14.73 AC

Land Use:			
	Forest	Total Impervious	0.10 AC
		Pervious HSG A (2.41 IN/HR)	0.01 AC
	High Density Residential	Total Impervious	6.86 AC
		Pervious HSG A (2.41 IN/HR)	7.75 AC

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	16.31	100.02	3,134.95

BASELINE LAKE OUTFALL #8

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious	0.10	1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	6.86	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious	0.01	1	1	1	1
Developed Pervious A	Pervious	7.75	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	14.73				

* Note:Only fill in the yellow highlighted cells.

*Note: Orange cells provide the option to enter total existing load without land use distribution.

16.31	100.02	3134.95	4.91

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Baseline Pollutant Loading Calculations

Railyard Ballast Drainage Baseline Conditions

Location:	**Lake Ave/Rogers Street**		
Drainage Area:	**5.56 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**2.22 AC**
		Pervious HSG A (2.41 IN/HR)	**2.91 AC**
	Highway	**Total Impervious**	**0.23 AC**
		Pervious HSG A (2.41 IN/HR)	**0.20 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	**5.56**	**34.51**	**1,335.51**

BASELINE RAILYARD BALLAST

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious	0.23	1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	2.22	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	3.11	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	5.56				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			5.56	34.51	1335.51	1.97

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Baseline Pollutant Loading Calculations

Overland Flow Baseline Conditions

Location: Surrounding Lake

Drainage Area: 14.62 AC

Land Use:	Forest	Total Impervious	0.01 AC
		Pervious HSG A (2.41 IN/HR)	1.47 AC
	High Density Residential	Total Impervious	3.09 AC
		Pervious HSG A (2.41 IN/HR)	8.14 AC
	Highway	Total Impervious	0.63 AC
		Pervious HSG A (2.41 IN/HR)	0.43 AC
	Water	Drainage Area	0.85 AC

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	8.45	53.09	2,391.67

BASELINE OVERLAND

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious	0.01	1	1	1	1
Highway Impervious	Impervious	0.63	1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	3.09	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious	1.47	1	1	1	1
Developed Pervious A	Pervious	8.57	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	13.76				

* Note:Only fill in the yellow highlighted cells.

*Note: Orange cells provide the option to enter total existing load without land use distribution.

8.45	53.09	2391.67	3.37

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Baseline Pollutant Loading Calculation Summary

Baseline Conditions Summary

Location: Crystal Lake

Drainage Area: 55.11 AC

Land Use:	**Commercial**	**Total Impervious**	**0.04 AC**
		Pervious HSG A (2.41 IN/HR)	**0.01 AC**
	Forest	**Total Impervious**	**0.11 AC**
		Pervious HSG A (2.41 IN/HR)	**1.49 AC**
	High Density Residential	**Total Impervious**	**20.52 AC**
		Pervious HSG A (2.41 IN/HR)	**30.61 AC**
	Highway	**Total Impervious**	**0.85 AC**
		Pervious HSG A (2.41 IN/HR)	**0.62 AC**
	Water	**Drainage Area**	**0.85 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	50.14	309.22	10,629.10

APPENDIX D: EXISTING POLLUTANT LOAD CALCULATIONS

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Non-Structural BMP Credit Equations

Non-Structural BMP Equations used in accordance with Attachment 2 to Appendix F of the MA MS4 Permit

1. Enhanced Sweeping Program

$Credit_{sweeping} = Ia_{swept} \times PLE_{IC\text{-}land\ use} \times PRF_{sweeping} \times AF$ **(Equation 2-1 in Attachment 2 to Appendix F)**

Where:

Ia_{swept} = Area of impervious roadway surface that is swept under the enhanced sweeping program (acres).

$PLE_{IC\text{-}land\ use}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1 in Attachment 2 to Appendix F).

$PRF_{sweeping}$ = Phosphorus Reduction Factor for sweeping based on sweeper type and frequency (see Table 2-3 in Attachment 2 to Appendix F). **A PRF value of 0.05 was used for weekly sweeping with a Mechanical Broom Sweeper under existing conditions and 0.10 under proposed conditions for a high efficiency regenerative air-vacuum.**

AF = Annual Frequency for sweeping. **An AF of 0.75 was used since sweeping does not occur in Dec/Jan/Feb.**

2. Catch Basin Cleaning

$Credit_{CB} = Ia_{CB} \times PLE_{IC\text{-}land\ use} \times PRF_{CB}$ **(Equation 2-2 in Attachment 2 to Appendix F)**

Where:

Ia_{CB} = All impervious watershed drainage area to catch basins (acres).

$PLE_{IC\text{-}land\ use}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1 in Attachment 2 to Appendix F).

PRF_{CB} = Phosphorus Reduction Factor for sweeping based on sweeper type and frequency (see Table 2-3 in Attachment 2 to Appendix F). **A PRF value of 0.02 was used for semi-annual catch basin cleaning.**

2. Enhanced Organic Waste and Leaf Litter Collection Program

$Credit_{leaf\ litter} = (Watershed\ Area) \times PLE_{IC\text{-}land\ use} \times 0.05$ **(Equation 2-3 in Attachment 2 to Appendix F)**

Where:

Watershed Area = All impervious area (acre) from which runoff discharges to the TMDL waterbody or its tributaries in the Watershed.

$PLE_{IC\text{-}land\ use}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1 in Attachment 2 to Appendix F).

0.05 = 5% phosphorus reduction factor for organic waste and leaf litter collection program in the Watershed.

Note:

Attachment 2 to Appendix F of the MA MS4 Permit does not provide guiandance for calculating non-structural BMP removal credit for TN or TSS. **NC = Not Calculat**

ATTACHMENT 2 TO APPENDIX F

Phosphorus Reduction Credits for Selected Enhanced Non-Structural BMPs

The permittee shall use the following methods to calculate phosphorus load reduction credits for the following enhanced non-structural control practices implemented in the Watershed:

1) Enhanced Sweeping Program;
2) Catch Basin Cleaning;
   and
3) Organic Waste and Leaf Litter Collection program

The methods include the use of default phosphorus reduction factors that EPA has determined are acceptable for calculating phosphorus load reduction credits for these practices.

The methods and annual phosphorus load export rates presented in this attachment are for the purpose of counting load reductions for various BMPs treating storm water runoff from varying site conditions (i.e., impervious or pervious surfaces) and different land uses (e.g. industrial and commercial) within the impaired watershed. Table 2-1 below provides annual phosphorus load export rates by land use category for impervious and pervious areas. The estimates of annual phosphorus load and load reductions resulting from BMP implementation are intended for use by the permittee to measure compliance with its Phosphorus Reduction Requirement under the permit.

Examples are provided to illustrate use of the methods. In calculating phosphorus export rates, the permittee shall select the land use category that most closely represents the actual use for the area in question. For watersheds with institutional type uses, such as government properties, hospitals, and schools, the permittee shall use the commercial land use category for the purpose of calculating phosphorus loads. Table 2-2 provides a crosswalk table of land use codes between land use groups in Table 2-1 and the codes used by Mass GIS. For pervious areas, permittees should use the appropriate value for the hydrologic soil group (HSG) if known, otherwise, assume HSG C conditions.

<u>Alternative Methods and/or Phosphorus Reduction Factors</u>: A permittee may propose alternative methods and/or phosphorus reduction factors for calculating phosphorus load reduction credits for these non-structural practices. EPA will consider alternative methods and/or phosphorus reduction factors, provided that the permittee submits adequate supporting documentation to EPA. At a minimum, supporting documentation shall consist of a description of the proposed method, the technical basis of the method, identification of alternative phosphorus reduction factors, supporting calculations, and identification of references and sources of information that support the use of the alternative method and/or factors in the Watershed. If EPA determines that the alternative methods and/or factors are not adequately supported, EPA will notify the permittee and the permittee may receive no phosphorus reduction credit other than a reduction credit calculated by the permittee following the methods in this attachment for the identified practices.

Table 2-1: Proposed average annual distinct P Load export rates for use in estimating P Load reduction credits in the MA MS4 Permit

Phosphorus Source Category by Land Use	Land Surface Cover	P Load Export Rate, lbs/acre/year	P Load Export Rate, kg/ha/yr
Commercial (Com) and Industrial (Ind)	Directly connected impervious	1.78	2.0
	Pervious	See* DevPERV	See* DevPERV
Multi-Family (MFR) and High-Density Residential (HDR)	Directly connected impervious	2.32	2.6
	Pervious	See* DevPERV	See* DevPERV
Medium -Density Residential (MDR)	Directly connected impervious	1.96	2.2
	Pervious	See* DevPERV	See* DevPERV
Low Density Residential (LDR) - "Rural"	Directly connected impervious	1.52	1.7
	Pervious	See* DevPERV	See* DevPERV
Highway (HWY)	Directly connected impervious	1.34	1.5
	Pervious	See* DevPERV	See* DevPERV
Forest (For)	Directly connected impervious	1.52	1.7
	Pervious	0.13	0.13
Open Land (Open)	Directly connected impervious	1.52	1.7
	Pervious	See* DevPERV	See* DevPERV
Agriculture (Ag)	Directly connected impervious	1.52	1.7
	Pervious	0.45	0.5
*Developed Land Pervious (DevPERV) – HSG A	Pervious	0.03	0.03
*Developed Land Pervious (DevPERV) – HSG B	Pervious	0.12	0.13
*Developed Land Pervious (DevPERV) – HSG C	Pervious	0.21	0.24
*Developed Land Pervious (DevPERV) – HSG C/D	Pervious	0.29	0.33
*Developed Land Pervious (DevPERV) – HSG D	Pervious	0.37	0.41

Notes:

- For pervious areas, if the hydrologic soil group (HSG) is known, use the appropriate value from this table. If the HSG is not known, assume HSG C conditions for the phosphorus load export rate.
- Agriculture includes row crops. Actively managed hay fields and pasture lands. Institutional land uses such as government properties, hospitals and schools are to be included in the commercial and industrial land use grouping for the purpose of calculating phosphorus loading.
- Impervious surfaces within the forest land use category are typically roadways adjacent to forested pervious areas.

Table 2-2: Crosswalk of Mass GIS land use categories to land use groups for P load calculations

Mass GIS Land Use LU_CODE	Description	Land Use group for calculating P Load - 2013/14 MA MS4
1	Crop Land	Agriculture
2	Pasture (active)	Agriculture
3	Forest	Forest
4	Wetland	Forest
5	Mining	Industrial
6	Open Land includes inactive pasture	open land
7	Participation Recreation	open land
8	spectator recreation	open land
9	Water Based Recreation	open land
10	Multi-Family Residential	High Density Residential
11	High Density Residential	High Density Residential
12	Medium Density Residential	Medium Density Residential
13	Low Density Residential	Low Density Residential
14	Saltwater Wetland	Water
15	Commercial	Commercial
16	Industrial	Industrial
17	Urban Open	open land
18	Transportation	Highway
19	Waste Disposal	Industrial
20	Water	Water
23	cranberry bog	Agriculture
24	Powerline	open land
25	Saltwater Sandy Beach	open land
26	Golf Course	Agriculture
29	Marina	Commercial
31	Urban Public	Commercial
34	Cemetery	open land
35	Orchard	Forest
36	Nursery	Agriculture
37	Forested Wetland	Forest
38	Very Low Density residential	Low Density Residential
39	Junkyards	Industrial
40	Brush land/Successional	Forest

<u>(1) Enhanced Sweeping Program</u>: The permittee may earn a phosphorus reduction credit for conducting an enhanced sweeping program of impervious surfaces. Table 2-2 below outlines the default phosphorus removal factors for enhanced sweeping programs. The credit shall be calculated by using the following equation:

$$\text{Credit}_{\text{sweeping}} = \text{IA}_{\text{swept}} \times \text{PLE}_{\text{IC-land use}} \times \text{PRF}_{\text{sweeping}} \times \text{AF} \qquad \textbf{(Equation 2-1)}$$

<u>Where:</u>

$\text{Credit}_{\text{sweeping}}$ = Amount of phosphorus load removed by enhanced sweeping program (lb/year)

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

$\text{PLE}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1)

$\text{PRF}_{\text{sweeping}}$ = Phosphorus Reduction Factor for sweeping based on sweeper type and frequency (see Table 2-3).

AF = Annual Frequency of sweeping. For example, if sweeping does not occur in Dec/Jan/Feb, the AF would be 9 mo./12 mo. = 0.75. For year-round sweeping, AF=1.0[1]

As an alternative, the permittee may apply a credible sweeping model of the Watershed and perform continuous simulations reflecting build-up and wash-off of phosphorus using long-term local rainfall data.

Table 2-3: Phosphorus reduction efficiency factors ($\text{PRF}_{\text{sweeping}}$) for sweeping impervious areas

Frequency[1]	Sweeper Technology	$\text{PRF}_{\text{sweeping}}$
2/year (spring and fall)[2]	Mechanical Broom	0.01
2/year (spring and fall)[2]	Vacuum Assisted	0.02
2/year (spring and fall)[2]	High-Efficiency Regenerative Air-Vacuum	0.02
Monthly	Mechanical Broom	0.03
Monthly	Vacuum Assisted	0.04
Monthly	High Efficiency Regenerative Air-Vacuum	0.08
Weekly	Mechanical Broom	0.05
Weekly	Vacuum Assisted	0.08
Weekly	High Efficiency Regenerative Air-Vacuum	0.10

[1]For full credit for monthly and weekly frequency, sweeping must be conducted year round. Otherwise, the credit should be adjusted proportionally based on the duration of the sweeping season (using AF factor).

[2] In order to earn credit for semi-annual sweeping the sweeping must occur in the spring following snow-melt and road sand applications to impervious surfaces and in the fall after leaf-fall and prior to the onset to the snow season.

Example 2-1: Calculation of enhanced sweeping program credit (Credit $_{sweeping}$): A permittee proposes to implement an enhanced sweeping program and perform weekly sweeping from March 1 – December 1 (9 months) in their Watershed, using a vacuum assisted sweeper on 20.3 acres of parking lots and roadways in a high-density residential area of the Watershed. For this site the needed information is:

IA_{swept}	= 20.3 acres
$PLE_{IC\text{-}HDR}$	= 2.32 lb/acre/yr (from Table 2-1)
$PRF_{sweeping}$	= 0.08 (from Table 2-3)
AF	= (9 months / 12 months) = 0.75

Substitution into equation 2-1 yields a Credit $_{sweeping}$ of 3.2 pounds of phosphorus removed per year.

$$Credit_{sweeping} = IA_{swept} \times PLE_{land\ use} \times PRF_{sweeping} \times AF$$
$$= 20.3 \text{ acres} \times 2.32 \text{ lbs/acre/yr} \times 0.08 \times 0.75$$
$$= \mathbf{2.8\ lbs/yr}$$

(2) Catch Basin Cleaning: The permittee may earn a phosphorus reduction credit, Credit $_{CB}$, by removing accumulated materials from catch basins (i.e., catch basin cleaning) in the Watershed such that a minimum sump storage capacity of 50% is maintained throughout the year. The credit shall be calculated by using the following equation:

$$Credit_{CB} = IA_{CB} \times PLE_{IC\text{-}land\ use} \times PRF_{CB} \qquad \textbf{(Equation 2-2)}$$

Where:

$Credit_{CB}$ = Amount of phosphorus load removed by catch basin cleaning (lb/year)

IA_{CB} = Impervious drainage area to catch basins (acres)

$PLE_{IC\text{-}and\ use}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1)

PRF_{CB} = Phosphorus Reduction Factor for catch basin cleaning (see Table 2-4)

Table 2-4: Phosphorus reduction efficiency factor (PRF $_{CB}$) for semi-annual catch basin cleaning

Frequency	Practice	PRF $_{CB}$
Semi-annual	Catch Basin Cleaning	0.02

Example 2-2: Calculation for catch basin cleaning credit (Credit $_{CB}$):
A permittee proposes to clean catch basins in their Watershed (i.e., remove accumulated sediments and contaminants captured in the catch basins) that drain runoff from 15.3 acres of medium-density residential impervious area. For this site the needed information is:

IA_{CB} = 15.3 acre
$PLE_{IC\text{-}MDR}$ = 1.96 lbs/acre/yr (from Table 2-1)
PRF_{CB} = 0.02 (from Table 2-4)

Substitution into equation 2-2 yields a Credit $_{CB}$ of 0.6 pounds of phosphorus removed per year:

$$\text{Credit}_{CB} = IA_{CB} \times PLE_{IC\text{-}MDR} \times PRF_{CB}$$
$$= 15.3 \text{ acre} \times 1.96 \text{ lbs/acre/yr} \times 0.02$$
$$= \mathbf{0.6\ lbs/yr}$$

<u>(3) Enhanced Organic Waste and Leaf Litter Collection program</u>: The permittee may earn a phosphorus reduction credit by performing regular gathering, removal and disposal of landscaping wastes, organic debris, and leaf litter from impervious surfaces from which runoff discharges to the TMDL waterbody or its tributaries. In order to earn this credit (Credit $_{leaf\ litter}$), the permittee must gather and remove all landscaping wastes, organic debris, and leaf litter from impervious roadways and parking lots at least once per week during the period of September 1 to December 1 of each year. Credit can only be earned for those impervious surfaces that are cleared of organic materials in accordance with the description above. The gathering and removal shall occur immediately following any landscaping activities in the Watershed and at additional times when necessary to achieve a weekly cleaning frequency. The permittee must ensure that the disposal of these materials will not contribute pollutants to any surface water discharges. The permittee may use an enhanced sweeping program (e.g., weekly frequency) as part of earning this credit provided that the sweeping is effective at removing leaf litter and organic materials. The Credit $_{leaf\ litter}$ shall be determined by the following equation:

$$\text{Credit}_{leaf\ litter} = (\text{Watershed Area}) \times (PLE_{IC\text{-}land\ use}) \times (0.05) \qquad \textbf{(Equation 2-3)}$$

<u>Where:</u>
Credit $_{leaf\ litter}$ = Amount of phosphorus load reduction credit for organic waste and leaf litter collection program (lb/year)
Watershed Area = All impervious area (acre) from which runoff discharges to the TMDL waterbody or its tributaries in the Watershed
$PLE_{IC\text{-}land\ use}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lbs/acre/yr) (see Table 2-1)
0.05 = 5% phosphorus reduction factor for organic waste and leaf litter collection program in the Watershed

<u>Example 2-3: Calculation for organic waste and leaf litter collection program credit (Credit $_{leaf\ litter}$):</u> A permittee proposes to implement an organic waste and leaf litter collection program by sweeping the parking lots and access drives at a minimum of once per week using a mechanical broom sweeper for the period of September 1 to December 1 over 12.5 acres of impervious roadways and parking lots in an industrial/commercial area of the Watershed. Also, the permittee will ensure that organic materials are removed from impervious areas immediately following all landscaping activities at the site. For this site the needed information to calculate the Credit $_{leaf\ litter}$ is:

Watershed Area = 12.5 acres; and
PLE $_{IC\text{-}commercial}$ = 1.78 lbs/acre/yr (from Table 2-1)

Substitution into equation 2-4 yields a Credit $_{leaf\ litter}$ of 1.1 pounds of phosphorus removed per year:

Credit $_{leaf\ litter}$ = (12.5 acre) x (1.78 lbs/acre/yr) x (0.05)
= 1.1 lbs/yr

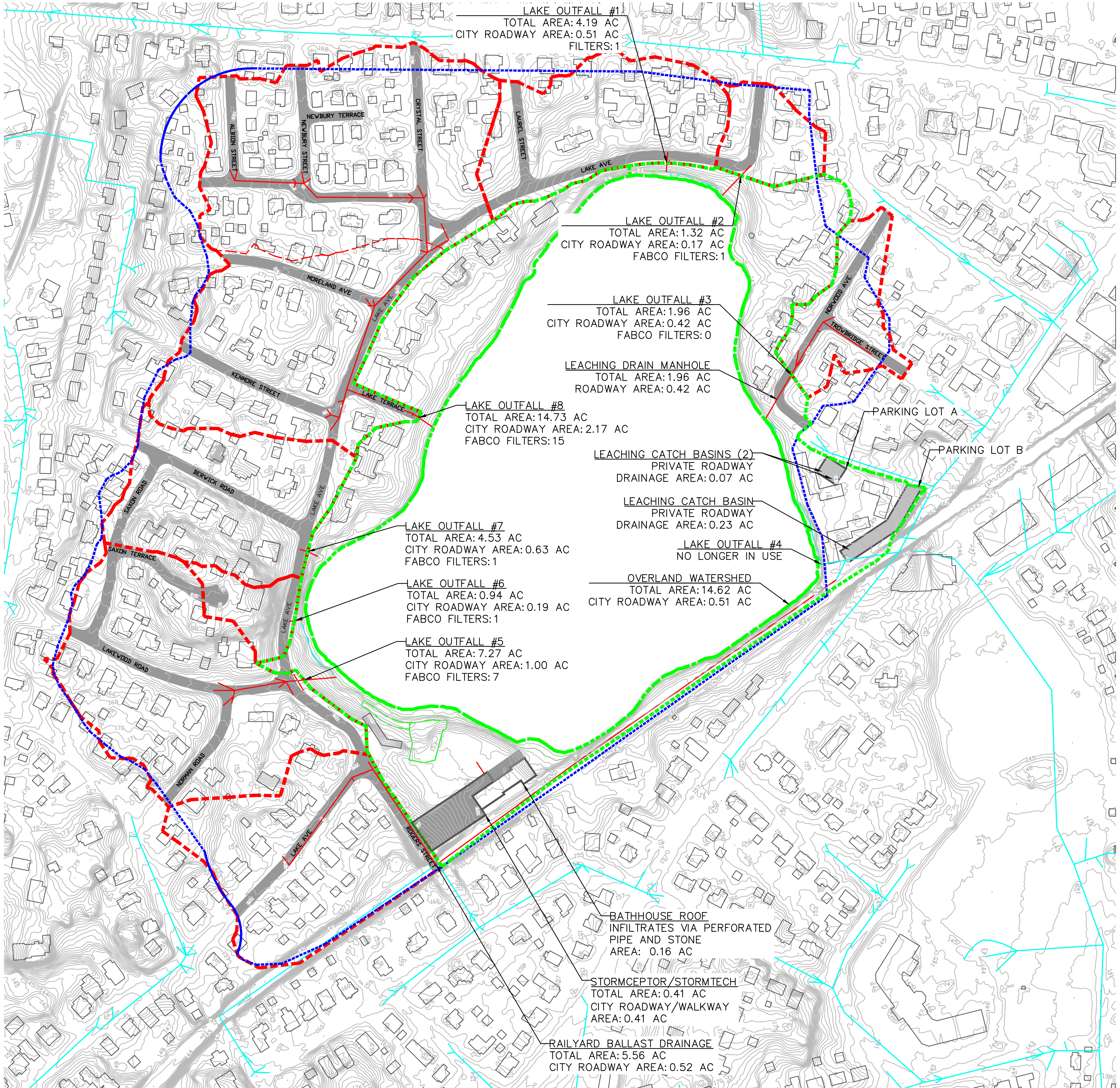
The permittee also may earn a phosphorus reduction credit for enhanced sweeping of roads and parking lot areas (i.e., Credit $_{sweeping}$) for the three months of use. Using equation 2-1, Credit $_{sweeping}$ is:

Credit $_{sweeping}$ = IA $_{swept}$ x PLE $_{IC\text{-}land\ use}$ x PRF $_{sweeping}$ x AF **(Equation 2-1)**
IA $_{swept}$ = 12.5 acre
PLE $_{IC\text{-}commercial}$ = 1.78 lbs/acre/yr (from Table 2-1)
PRF $_{sweeping}$ = 0.05 (from Table 2-3)
AF = 3 mo./12 mo. = 0.25

Substitution into equation 2-1 yields a Credit $_{sweeping}$ of 0.28 pounds of phosphorus removed per year.

Credit $_{sweeping}$ = IA $_{swept}$ x PLE $_{IC\text{-}commercial}$ x PRF $_{sweeping}$ x AF
= 12.5 acre x 1.78 lbs/acre/yr x 0.05 x 0.25
= 0.3 lbs/yr

CRYSTAL LAKE NEWTON, MA
SUB–WATERSHED FIGURE



LEGEND

- EXISTING CRYSTAL LAKE DRAINAGE SYSTEM
- EXISTING DRAINAGE SYSTEM
- SUB–WATERSHED
- OVERLAND SUB–WATERSHED
- WATERSHED DELINEATION PROVIDED BY CITY
- AREA DRAINING TO EXISTING BMP
- APPROXIMATE CITY ROADWAY LIMIT
- APPROXIMATE PRIVATE ROADWAY LIMIT
- EXISTING BUILDING

N

300' 0 300' 600'

BAR SCALE
1" = 300'
CHECK GRAPHIC SCALE BEFORE USING

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EXISTING WATERSHED

DESIGNED BY: CNQ
DRAWN BY: CNQ
CHECKED BY: HCP
FIGURE 3-1 EXISTING WAT*.dwg

CITY OF NEWTON, MA
1000 COMMONWEALTH AVE
NEWTON CENTRE, MA 02459

CRYSTAL LAKE MANAGEMENT PLAN

JOB NO: 230525.03
DATE: JANUARY 2020
SCALE: 1" = 300'

FIGURE 3-1

\\woodardcurran.net\shared\Projects\0230525.03 Newton MA - Crystal Lake Watershed Assessment\wip\Drawings\Figures\Figure 3-1 Existing Watershed.dwg Dec 30, 2019 - 8:42am CNQUINN

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CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	9/10/2019
CHECKED BY:	HCP	DATE:	10/18/2019
PROJECT NO.	230525.03	SHEET NO.	1

Existing Pollutant Loading Calculations

Lake Outfall #1 Existing Conditions

Location:	**Laurel Street/Lake Ave**		
Drainage Area:	**4.19 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**1.92 AC**
		Pervious HSG A (2.41 IN/HR)	**2.27 AC**
		Impervious Roadway	**0.51 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.04	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.09	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.22	NC	NC
Pollutant Load Reduction (lbs/yr)	0.35	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	4.52	27.68	858.99
Non-Structural BMP Reduction	0.35	NC	NC
Pollutant Load Remaining (lbs/yr)	**4.17**	**27.68**	**858.99**

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Existing Pollutant Loading Calculations

Lake Outfall #2 Existing Conditions

Location:	**Lake Ave**		
Drainage Area:	**1.32 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**0.67 AC**
		Pervious HSG A (2.41 IN/HR)	**0.65 AC**
		Impervious Roadway	**0.17 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.01	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.03	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.08	NC	NC
Pollutant Load Reduction (lbs/yr)	0.12	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	1.58	9.64	299.31
Non-Structural BMP Reduction	0.12	NC	NC
Pollutant Load Remaining (lbs/yr)	**1.46**	**9.64**	**299.31**

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Existing Pollutant Loading Calculations

Lake Outfall #3 Existing Conditions (Page 1/2)

Location: Norwood Ave/Trowbridge Street

Drainage Area: 1.96 AC

Land Use:	**Commercial**	**Total Impervious**	**0.04 AC**
		Pervious HSG A (2.41 IN/HR)	**0.01 AC**
		Impervious Roadway	**0.04 AC**
	High Density Residential	**Total Impervious**	**1.00 AC**
		Pervious HSG A (2.41 IN/HR)	**0.91 AC**
		Impervious Roadway	**0.38 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.04	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.05	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.12	NC	NC
Pollutant Load Reduction (lbs/yr)	0.21	NC	NC

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Lake Outfall #3 Existing Conditions (Page 2/2)

Structural BMP - Leaching Manhole (48")

Location	**Norwood Avenue**	
Design Date	**November, 2016**	
Land Use	**High Density Residential**	
Physical Storage Volume*	**0.001 ACRE-FEET**	***Assumed sump depth of 5' based on field observations, measurement not taken**
Drainage Area (Impervious)	**0.42 ACRE**	
Infiltrated (Treated) Depth of Runoff	**0.04 INCHES**	**< 0.1 inch - Therefore, no reduction credit was taken**
Soil Infiltration Rate	**2.41 IN/HR**	

	TP	TN	TSS
Structural BMP Removal Efficiency	N/A	N/A	N/A
Pollutant Load Reduction (lbs/yr)	0.00	0.00	0.00

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	2.42	14.96	460.62
Structural BMP Reduction	0.00	0.00	0.00
Non-Structural BMP Reduction	0.21	NC	NC
Pollutant Load Remaining (lbs/yr)	**2.21**	**14.96**	**460.62**

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Existing Pollutant Loading Calculations

Lake Outfall #5 Existing Conditions

Location:	**Saxon Road & Terrace/Lakewood Road/Norman Road/Lake Ave**		
Drainage Area:	**7.27 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**2.51 AC**
		Pervious HSG A (2.41 IN/HR)	**4.76 AC**
		Impervious Roadway	**1.00 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.09	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.12	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.29	NC	NC
Pollutant Load Reduction (lbs/yr)	0.50	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	5.97	36.67	1,135.71
Non-Structural BMP Reduction	0.50	NC	NC
Pollutant Load Remaining (lbs/yr)	**5.47**	**36.67**	**1,135.71**

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Existing Pollutant Loading Calculations

Lake Outfall #6 Existing Conditions

Location: Saxon Terrace/Lake Ave

Drainage Area: 0.94 AC

Land Use:	**High Density Residential**	**Total Impervious**	**0.39 AC**
		Pervious HSG A (2.41 IN/HR)	**0.56 AC**
		Impervious Roadway	**0.19 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.02	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.02	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.04	NC	NC
Pollutant Load Reduction (lbs/yr)	0.08	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	0.92	5.61	174.03
Non-Structural BMP Reduction	0.08	NC	NC
Pollutant Load Remaining (lbs/yr)	**0.84**	**5.61**	**174.03**

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Existing Pollutant Loading Calculations

Lake Outfall #7 Existing Conditions

Location:	**Saxon Road/Berwich Road/Lake Ave**		
Drainage Area:	**4.53 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**1.87 AC**
		Pervious HSG A (2.41 IN/HR)	**2.66 AC**
		Impervious Roadway	**0.63 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.05	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.09	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.22	NC	NC
Pollutant Load Reduction (lbs/yr)	0.36	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	4.41	27.04	838.31
Non-Structural BMP Reduction	0.36	NC	NC
Pollutant Load Remaining (lbs/yr)	**4.05**	**27.04**	**838.31**

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Existing Pollutant Loading Calculations

Lake Outfall #8 Existing Conditions

Location: Kenmore Street/Moreland Ave/Albion Street/Newberry Street & Terrace/Crystal Street/Lake Ave

Drainage Area: 14.73 AC

Land Use:	Forest	Total Impervious	0.10 AC
		Pervious HSG A (2.41 IN/HR)	0.01 AC
	High Density Residential	Total Impervious	6.86 AC
		Pervious HSG A (2.41 IN/HR)	7.75 AC
		Impervious Roadway	2.17 AC

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.19	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.32	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.80	NC	NC
Pollutant Load Reduction (lbs/yr)	1.31	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	16.31	100.02	3,134.95
Non-Structural BMP Reduction	1.31	NC	NC
Pollutant Load Remaining (lbs/yr)	**15.00**	**100.02**	**3,134.95**

COMMITMENT & INTEGRITY
DRIVE RESULTS

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Dedham, Massachusetts 02026
Tel: 800.446.5518

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	9/10/2019
CHECKED BY:	HCP	DATE:	10/18/2019
PROJECT NO.	230525.03	SHEET NO.	1

Existing Pollutant Loading Calculations

Railyard Ballast Drainage Existing Conditions

Location:	**Lake Ave/Rogers Street**		
Drainage Area:	**5.56 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**2.22 AC**
		Pervious HSG A (2.41 IN/HR)	**2.91 AC**
		Impervious Roadway	**0.52 AC**
	Highway	**Total Impervious**	**0.23 AC**
		Pervious HSG A (2.41 IN/HR)	**0.20 AC**

Non-Structural BMPs Load Reduction Credit

	TP	**TN**	**TSS**
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.05	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.11	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.27	NC	NC
Pollutant Load Reduction (lbs/yr)	0.43	NC	NC

Total Load

	TP	**TN**	**TSS**
Pollutant Load Generated (lbs/yr)	5.56	34.51	1,335.51
Non-Structural BMP Reduction	0.43	NC	NC
Pollutant Load Remaining (lbs/yr)	**5.13**	**34.51**	**1,335.51**

COMMITMENT & INTEGRITY
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Existing Pollutant Loading Calculations

Overland Flow Existing Conditions (Page 1/3)

Location:	**Surrounding Lake**		
Drainage Area:	**14.62 AC**		
Land Use:	**Forest**	**Total Impervious**	**0.01 AC**
		Pervious HSG A (2.41 IN/HR)	**1.47 AC**
	High Density Residential	**Total Impervious**	**3.09 AC**
		Pervious HSG A (2.41 IN/HR)	**8.14 AC**
		Impervious Roadway	**0.88 AC**
	Highway	**Total Impervious**	**0.63 AC**
		Pervious HSG A (2.41 IN/HR)	**0.43 AC**
	Water	**Drainage Area**	**0.85 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.05, AF = 0.75)	0.08	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.16	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.40	NC	NC
Pollutant Load Reduction (lbs/yr)	0.64	NC	NC

Structural BMP - Infiltrating Roof Drain

Location	**Crystal Lake Bath House - Rogers Street**	
Design Date	**Unknown**	
Land Use	**High Density Residential**	
Physical Storage Volume*	**0.001 ACRE-FEET**	***Storage Equation: 3'W x 11'L x 6"H of perforated stone plus 11' of 6" drainage pipe**
Drainage Area (Impervious HDR)	**0.18 ACRE**	
Infiltrated (Treated) Depth of Runoff	**0.08 INCHES**	**< 0.1 inch - Therefore, no reduction credit was taken**
Soil Infiltration Rate	**2.41 IN/HR**	

	TP	TN	TSS
Structural BMP Removal Efficiency	N/A	N/A	N/A
Pollutant Load Reduction (lbs/yr)	0.00	0.00	0.00

DRIVE RESULTS

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PROJECT NO.	230525.03	SHEET NO.	1

Overland Flow Existing Conditions (Page 2/3)

Structural BMP - Leaching Catch Basins Lot A (48")

Location Norwood Avenue Condo Parking Lot A, 2 Structures
Design Date Unknown
Land Use High Density Residential

	Each	Total	
Physical Storage Volume*	**0.001 ACRE-FEET**	**-**	***Used sump depth of 5' based off field observations, measurement not taken**
Drainage Area (Impervious HDR)	**0.03 ACRE**	**0.07 ACRE-FEET**	***Assumed 48" diameter**
Infiltrated (Treated) Depth of Runoff	**0.50 INCHES**	**-**	
Soil Infiltration Rate	**2.41 IN/HR**	**-**	

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	0.16	0.97	30.23
Structural BMP Removal Efficiency	86.0%	96.5%	98.5%
Pollutant Load Reduction (lbs/yr)	0.14	0.94	29.78

Structural BMP - Leaching Catch Basin Lot B (48")

Location Norwood Avenue Condo Parking Lot B
Design Date Unknown
Land Use High Density Residential

Physical Storage Volume*	**0.001 ACRE-FEET**	***Used sump depth of 5' based off field observations, measurement not taken**
Drainage Area (Impervious HDR)	**0.23 ACRE**	***Assumed 48" diameter**
Infiltrated (Treated) Depth of Runoff	**0.07 INCHES**	**< 0.1 inch - Therefore, no reduction credit was taken**
Soil Infiltration Rate	**2.41 IN/HR**	

	TP	TN	TSS
Structural BMP Removal Efficiency	N/A	N/A	N/A
Pollutant Load Reduction (lbs/yr)	0.00	0.00	0.00

EXISTING LEACHING CATCH BASINS (2) LOT A

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	0.07	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious		1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	0.07				

* Note:Only fill in the yellow highlighted cells.

*Note: Orange cells provide the option to enter total existing load without land use distribution.

0.16	0.97	30.23	0.05

Return to Planning Level Analysis Page

EXISTING LEACHING CATCH BASINS (2) LOT A SUMMARY

1. Management Objective

Select Pollutant Type ->	TP	Total BMP Cost ($)	$3,122
Enter Target Load Reduction (%) ->	30.0%	Total Pollutant Load Reduction (%)	86.0%

2. Optimization Target

Select an option ->	BMP Storage Capacity	Total BMP Storage Capacity (gal)	935

3. Watershed Information

Enter Land Use Area ->	Click Here	Total Impervious Area (ac)	0.1

4. BMP Information

Enter Drainage Area ->	Click Here	Total Treated Impervious Area (ac)	0.1

5. Optimal Solution

BMP Type	Design Storage Capacity (ft^3)	BMP Cost ($)	Treated Impervious Area (ac)	O&M (hr/yr)	Load Reduction (lbs)	Treated Runoff Depth (in)
Biofiltration with ISR	-	$ -	-	-	-	-
Bioretention	-	$ -	-	-	-	-
Dry Pond	-	$ -	-	-	-	-
Grass Swale*	-	$ -	-	-	-	-
Gravel Wetland	-	$ -	-	-	-	-
Infiltration Basin	-	$ -	-	-	-	-
Infiltration Chambers*	-	$ -	-	-	-	-
Infiltration Trench	125	$ 3,122	0.07	-	0.14	0.50
Porous Pavement*	-	$ -	-	-	-	-
Sand Filter	-	$ -	-	-	-	-
Wet Pond	-	$ -	-	-	-	-

Note:Only fill in the yellow highlighted cells.

* Place holder for future option (not implemented)

Planning Level Analysis

The purpose of this tool is to provide decision-makers a comprehensive overview of stormwater management opportunities in a given watershed. The tool will characterize the watershed characteristics and opportunities for applying a variety of BMP technologies to various source areas based on land use, soils, and impervious cover. There are two approaches of the planning-level analysis tool:

1: BMP Storage Capacity – to evaluate the changes in hydrologic and water quality benefits as the BMP/LID sizes are increased in fixed increments; and
2: BMP Drainage Area – to determine how much impervious area would require treatment if specified BMP design capacities are selected for each HRU type to be treated.

Run Single Scenario

Run Optimize Scenario

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DRIVE RESULTS

WOODARD & CURRAN

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PROJECT NO.	230525.03	SHEET NO.	1

Overland Flow Existing Conditions (Page 3/3)

Structural BMP - ADS STORMTECH SC-740 CHAMBERS

Location Crystal Lake Bath House - Rogers Street

Design Date October 2011-April 2012

Land Use High Density Residential

Physical Storage Volume* 0.020 ACRE-FEET

Drainage Area (Impervious HDR) 0.41 ACRE

Infiltrated (Treated) Depth of Runoff 0.59 INCHES

Soil Infiltration Rate 2.41 IN/HR

*Estimate based off design plans and installation photo, see HydroCAD Chamber Wizard

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	0.94	5.72	178.21
Structural BMP Removal Efficiency	90.5%	97.9%	99.9%
Pollutant Load Reduction (lbs/yr)	0.85	5.60	178.04

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	8.45	53.09	2,391.67
Non-Structural BMP Reduction	0.64	NC	NC
Structural BMP Reduction	0.99	6.54	207.81
Pollutant Load Remaining (lbs/yr)	**6.82**	**46.55**	**2,183.86**

EXISTING ADS STORMTECH CHAMBERS

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	0.41	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious		1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	0.41				
			0.94	5.72	178.21	0.28

* Note:Only fill in the yellow highlighted cells.

*Note: Orange cells provide the option to enter total existing load without land use distribution.

Return to Planning Level Analysis Page

EXISTING ADS STORMTECH CHAMBERS SUMMARY

1. Management Objective			
Select Pollutant Type ->	TP	Total BMP Cost ($)	$21,721
Enter Target Load Reduction (%) ->	30.0%	Total Pollutant Load Reduction (%)	90.5%

2. Optimization Target			
Select an option ->	BMP Storage Capacity	Total BMP Storage Capacity (gal)	6,505

3. Watershed Information			
Enter Land Use Area ->	Click Here	Total Impervious Area (ac)	0.4

4. BMP Information			
Enter Drainage Area ->	Click Here	Total Treated Impervious Area (ac)	0.4

Planning Level Analysis

The purpose of this tool is to provide decision-makers a comprehensive overview of stormwater management opportunities in a given watershed. The tool will characterize the watershed characteristics and opportunities for applying a variety of BMP technologies to various source areas based on land use, soils, and impervious cover. There are two approaches of the planning-level analysis tool:

1: BMP Storage Capacity – to evaluate the changes in hydrologic and water quality benefits as the BMP/LID sizes are increased in fixed increments; and
2: BMP Drainage Area – to determine how much impervious area would require treatment if specified BMP design capacities are selected for each HRU type to be treated.

5. Optimal Solution

BMP Type	Design Storage Capacity (ft^3)	BMP Cost ($)	Treated Impervious Area (ac)	O&M (hr/yr)	Load Reduction (lbs)	Treated Runoff Depth (in)
Biofiltration with ISR	-	$ -	-	-	-	-
Bioretention	-	$ -	-	-	-	-
Dry Pond	-	$ -	-	-	-	-
Grass Swale*	-	$ -	-	-	-	-
Gravel Wetland	-	$ -	-	-	-	-
Infiltration Basin	-	$ -	-	-	-	-
Infiltration Chambers*	-	$ -	-	-	-	-
Infiltration Trench	870	$ 21,721	0.41	-	0.85	0.59
Porous Pavement*	-	$ -	-	-	-	-
Sand Filter	-	$ -	-	-	-	-
Wet Pond	-	$ -	-	-	-	-

Note:Only fill in the yellow highlighted cells.

* Place holder for future option (not implemented)

Run Single Scenario

Run Optimize Scenario

Return to Home Page

Summary for Pond 1E: Existing Bath House ADS

[43] Hint: Has no inflow (Outflow=Zero)

Volume	Invert	Avail.Storage	Storage Description
#1A	0.00'	0.012 af	**13.00'W x 34.10'L x 3.75'H Field A** 0.038 af Overall - 0.008 af Embedded = 0.030 af x 40.0% Voids
#2A	1.00'	0.008 af	**ADS_StormTech SC-740 +Cap** x 8 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 2 Rows of 4 Chambers
		0.020 af	Total Available Storage

Storage Group A created with Chamber Wizard

COMMITMENT & INTEGRITY DRIVE RESULTS

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980 Washington Street, | Suite 325
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Tel: 800.446.5518

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	9/10/2019
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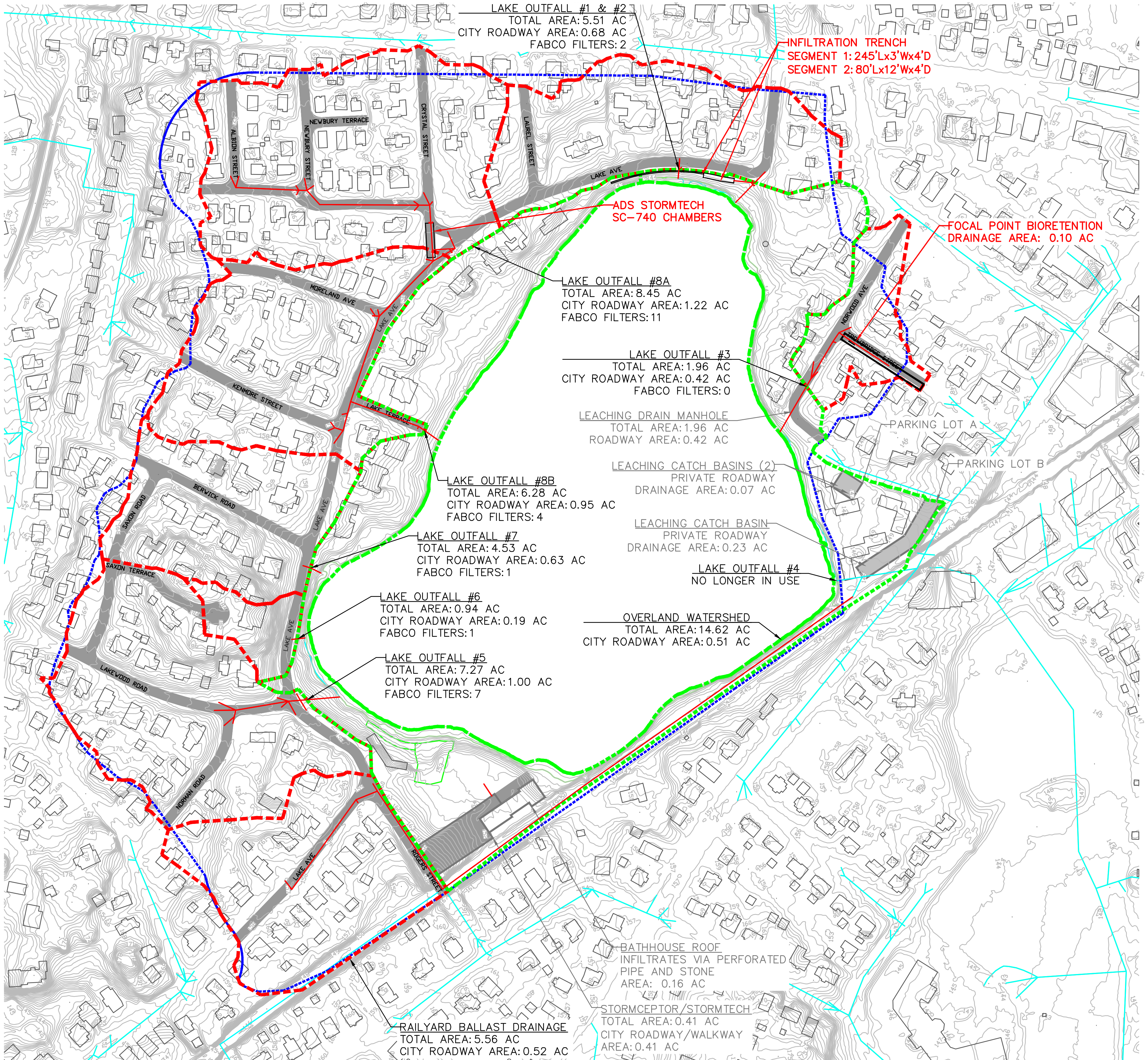
PROJECT NO.	230525.03	SHEET NO.	1

Existing Pollutant Load Calculation Summary

Existing Conditions Summary			
Location:	**Crystal Lake**		
Drainage Area:	**55.11 AC**		
Land Use:	**Commercial**	**Total Impervious**	**0.04 AC**
		Pervious HSG A (2.41 IN/HR)	**0.01 AC**
		Impervious Roadway	0.04 AC
	Forest	**Total Impervious**	**0.11 AC**
		Pervious HSG A (2.41 IN/HR)	**1.49 AC**
	High Density Residential	**Total Impervious**	**20.52 AC**
		Pervious HSG A (2.41 IN/HR)	**30.61 AC**
		Impervious Roadway	6.45 AC
	Highway	**Total Impervious**	**0.85 AC**
		Pervious HSG A (2.41 IN/HR)	**0.62 AC**
	Water	**Drainage Area**	**0.85 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	50.14	309.22	10,629.10
Non-Structural BMP Reduction	4.00	NC	NC
Structural BMP Reduction	0.99	6.54	207.81
Pollutant Load Remaining (lbs/yr)	**45.15**	**302.68**	**10,421.29**
Percent Reduction	**10.0%**	**2.1%**	**2.0%**

APPENDIX E: PROPOSED POLLUTANT LOAD CALCULATION



CRYSTAL LAKE NEWTON, MA
SUB-WATERSHED FIGURE

LEGEND

- EXISTING CRYSTAL LAKE DRAINAGE SYSTEM
- EXISTING DRAINAGE SYSTEM
- SUB-WATERSHED
- OVERLAND SUB-WATERSHED
- WATERSHED DELINEATION PROVIDED BY CITY
- AREA DRAINING TO EXISTING BMP
- PROPOSED BMP FOOTPRINT
- APPROXIMATE CITY ROADWAY LIMIT
- APPROXIMATE PRIVATE ROADWAY LIMIT
- EXISTING BUILDING

N

300' 0 300' 600'

BAR SCALE
1" = 300'
CHECK GRAPHIC SCALE BEFORE USING

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PROPOSED WATERSHED

DESIGNED BY: CNQ
DRAWN BY: CNQ
CHECKED BY: HCP
FIGURE 3-3 PROPOSED WAT*.dwg

CITY OF NEWTON, MA
1000 COMMONWEALTH AVE
NEWTON CENTRE, MA 02459

CRYSTAL LAKE MANAGEMENT PLAN

JOB NO: 230525.03
DATE: JANUARY 2020
SCALE: 1" = 300'

FIGURE 3-3

COMMITMENT & INTEGRITY
DRIVE RESULTS

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Proposed Pollutant Loading Calculations

Lake Outfall #1 & #2 Proposed Conditions (Page 1/2)

Location: **Laurel Street/Lake Ave**

Drainage Area: **5.51 AC**

Drainage Area	**High Density Residential**	**Total Impervious**	**2.59 AC**
		Pervious HSG A (2.41 IN/HR)	**2.92 AC**
		Impervious Roadway	**0.68 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.12	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.12	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.30	NC	NC
Pollutant Load Reduction (lbs/yr)	0.54	NC	NC

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Lake Outfall #1 & #2 Proposed Conditions (Page 2/2)

Structural BMP - Infiltrating Trench

Location Cronin's Cove

Design Date TBD

Land Use High Density Residential

Physical Storage Volume* 0.06 ACRE-FEET *See HydroCAD Summary

Drainage Area (Impervious) 2.59 ACRE

Infiltrated (Treated) Depth of Runoff 0.29 INCHES

Soil Infiltration Rate 2.41 IN/HR

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	6.10	37.32	1,158.30
Structural BMP Removal Efficiency	65.7%	86.5%	84.5%
Pollutant Load Reduction (lbs/yr)	4.01	32.29	978.77

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	6.10	37.32	1,158.30
Non-Structural BMP Reduction (lbs/yr)	0.54	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	4.01	32.29	978.77
Pollutant Load Remaining (lbs/yr)	**1.55**	**5.04**	**179.54**

Summary for Pond 1P: OF-1 & 2 Infiltrating Stone Trench

[43] Hint: Has no inflow (Outflow=Zero)

Volume	Invert	Avail.Storage	Storage Description
#1	0.00'	0.027 af	**3.00'W x 245.00'L x 4.00'H Prismatoid** 0.067 af Overall x 40.0% Voids
#2	0.00'	0.035 af	**12.00'W x 80.00'L x 4.00'H Prismatoid** 0.088 af Overall x 40.0% Voids
		0.062 af	Total Available Storage

PROPOSED OUTFALL 1 & 2 INFILTRATION TRENCH SUMMARY

1. Management Objective			
Select Pollutant Type ->	TP	Total BMP Cost ($)	$68,143
Enter Target Load Reduction (%) ->	30.0%	Total Pollutant Load Reduction (%)	65.7%

2. Optimization Target			
Select an option ->	BMP Storage Capacity	Total BMP Storage Capacity (gal)	20,406

3. Watershed Information			
Enter Land Use Area ->	Click Here	Total Impervious Area (ac)	2.6

4. BMP Information			
Enter Drainage Area ->	Click Here	Total Treated Impervious Area (ac)	2.6

Planning Level Analysis

The purpose of this tool is to provide decision-makers a comprehensive overview of stormwater management opportunities in a given watershed. The tool will characterize the watershed characteristics and opportunities for applying a variety of BMP technologies to various source areas based on land use, soils, and impervious cover. There are two approaches of the planning-level analysis tool:

1: BMP Storage Capacity – to evaluate the changes in hydrologic and water quality benefits as the BMP/LID sizes are increased in fixed increments; and
2: BMP Drainage Area – to determine how much impervious area would require treatment if specified BMP design capacities are selected for each HRU type to be treated.

5. Optimal Solution

BMP Type	Design Storage Capacity (ft^3)	BMP Cost ($)	Treated Impervious Area (ac)	O&M (hr/yr)	Load Reduction (lbs)	Treated Runoff Depth (in)
Biofiltration with ISR	-	$ -	-	-	-	-
Bioretention	-	$ -	-	-	-	-
Dry Pond	-	$ -	-	-	-	-
Grass Swale*	-	$ -	-	-	-	-
Gravel Wetland	-	$ -	-	-	-	-
Infiltration Basin	-	$ -	-	-	-	-
Infiltration Chambers*	-	$ -	-	-	-	-
Infiltration Trench	2,728	$ 68,143	2.59	-	4.01	0.29
Porous Pavement*	-	$ -	-	-	-	-
Sand Filter	-	$ -	-	-	-	-
Wet Pond	-	$ -	-	-	-	-

Note:Only fill in the yellow highlighted cells.

* Place holder for future option (not implemented)

Run Single Scenario

Run Optimize Scenario

Return to Home Page

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DRIVE RESULTS

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Proposed Pollutant Loading Calculations

Lake Outfall #3 Proposed Conditions (Page 1/2)

Location: Norwood Ave/Trowbridge Street

Drainage Area: 1.96 AC

Land Use:	**Commercial**	**Total Impervious**	**0.04 AC**
		Pervious HSG A (2.41 IN/HR)	**0.01 AC**
		Impervious Roadway	**0.04 AC**
	High Density Residential	**Total Impervious**	**1.00 AC**
		Pervious HSG A (2.41 IN/HR)	**0.91 AC**
		Impervious Roadway	**0.38 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.07	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.05	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.12	NC	NC
Pollutant Load Reduction (lbs/yr)	0.24	NC	NC

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Lake Outfall #3 Proposed Conditions (Page 2/2)

Structural BMP - Focal Point Bioretention

Location	**Trowbridge Street**	
Design Date	**7/27/2017**	
Land Use	**High Density Residential**	
Physical Storage Volume*	**0.001 ACRE-FEET**	***See HydroCAD Summary**
Drainage Area (Impervious)	**0.10 ACRE**	
Treated Depth of Runoff	**0.16 INCHES**	
Soil Infiltration Rate	**2.14 IN/HR**	

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	0.23	1.41	43.90
Structural BMP Removal Efficiency	20.6%	13.2%	59.0%
Pollutant Load Reduction (lbs/yr)	0.05	0.19	25.90

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	2.42	14.96	460.62
Non-Structural BMP Reduction (lbs/yr)	0.24	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	0.05	0.19	25.90
Pollutant Load Remaining (lbs/yr)	**2.13**	**14.77**	**434.72**

PROPOSED FOCAL POINT DRAINAGE AREA

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	0.10	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious		1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	0.10				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			0.23	1.41	43.90	0.07

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Summary for Pond 2P: Trowbridge Focal Point

[43] Hint: Has no inflow (Outflow=Zero)

Volume	Invert	Avail.Storage	Storage Description
#1	144.05'	34 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc) 84 cf Overall x 40.0% Voids
#2	145.80'	24 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)
		58 cf	Total Available Storage

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
144.05	48	0	0
145.80	48	84	84

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
145.80	48	0	0
146.30	48	24	24

PROPOSED OUTFALL 3 FOCAL POINT BIORETENTION SUMMARY

1. Management Objective

Select Pollutant Type ->	TP	Total BMP Cost ($)	$1,796
Enter Target Load Reduction (%) ->	30.0%	Total Pollutant Load Reduction (%)	20.6%

2. Optimization Target

Select an option ->	BMP Storage Capacity	Total BMP Storage Capacity (gal)	434

3. Watershed Information

Enter Land Use Area ->	Click Here	Total Impervious Area (ac)	0.1

4. BMP Information

Enter Drainage Area ->	Click Here	Total Treated Impervious Area (ac)	0.1

5. Optimal Solution

BMP Type	Design Storage Capacity (ft^3)	BMP Cost ($)	Treated Impervious Area (ac)	O&M (hr/yr)	Load Reduction (lbs)	Treated Runoff Depth (in)
Biofiltration with ISR	-	$ -	-	-	-	-
Bioretention	58	$ 1,796	0.10	2	0.05	0.16
Dry Pond	-	$ -	-	-	-	-
Grass Swale*	-	$ -	-	-	-	-
Gravel Wetland	-	$ -	-	-	-	-
Infiltration Basin	-	$ -	-	-	-	-
Infiltration Chambers*	-	$ -	-	-	-	-
Infiltration Trench	-	$ -	-	-	-	-
Porous Pavement*	-	$ -	-	-	-	-
Sand Filter	-	$ -	-	-	-	-
Wet Pond	-	$ -	-	-	-	-

Note:Only fill in the yellow highlighted cells.

* Place holder for future option (not implemented)

Planning Level Analysis

The purpose of this tool is to provide decision-makers a comprehensive overview of stormwater management opportunities in a given watershed. The tool will characterize the watershed characteristics and opportunities for applying a variety of BMP technologies to various source areas based on land use, soils, and impervious cover. There are two approaches of the planning-level analysis tool:

1: BMP Storage Capacity – to evaluate the changes in hydrologic and water quality benefits as the BMP/LID sizes are increased in fixed increments; and
2: BMP Drainage Area – to determine how much impervious area would require treatment if specified BMP design capacities are selected for each HRU type to be treated.

Run Single Scenario

Run Optimize Scenario

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Proposed Pollutant Loading Calculations

Lake Outfall #5 Proposed Conditions

Location: Saxon Road & Terrace/Lakewood Road/Norman Road/Lake Ave

Drainage Area: 7.27 AC

Land Use:	**High Density Residential**	**Total Impervious**	**2.51 AC**
		Pervious HSG A (2.41 IN/HR)	**4.76 AC**
		Impervious Roadway	**1.00 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.17	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.12	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.29	NC	NC
Pollutant Load Reduction (lbs/yr)	0.58	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	5.97	36.67	1,135.71
Non-Structural BMP Reduction (lbs/yr)	0.58	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	0.00	0.00	0.00
Pollutant Load Remaining (lbs/yr)	**5.39**	**36.67**	**1,135.71**

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Proposed Pollutant Loading Calculations

Lake Outfall #6 Proposed Conditions

Location: **Saxon Terrace/Lake Ave**

Drainage Area: **0.94 AC**

Land Use:	**High Density Residential**	**Total Impervious**	**0.39 AC**
		Pervious HSG A (2.41 IN/HR)	**0.56 AC**
		Impervious Roadway	**0.19 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.03	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.02	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.04	NC	NC
Pollutant Load Reduction (lbs/yr)	0.10	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	0.92	5.61	174.03
Non-Structural BMP Reduction (lbs/yr)	0.10	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	0.00	0.00	0.00
Pollutant Load Remaining (lbs/yr)	**0.82**	**5.61**	**174.03**

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Proposed Pollutant Loading Calculations

Lake Outfall #7 Proposed Conditions

Location: Saxon Road/Berwich Road/Lake Ave

Drainage Area: 4.53 AC

Land Use:	**High Density Residential**	**Total Impervious**	**1.87 AC**
		Pervious HSG A (2.41 IN/HR)	**2.66 AC**
		Impervious Roadway	**0.63 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.11	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.09	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.22	NC	NC
Pollutant Load Reduction (lbs/yr)	0.42	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	4.41	27.04	838.31
Non-Structural BMP Reduction (lbs/yr)	0.42	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	0.00	0.00	0.00
Pollutant Load Remaining (lbs/yr)	**3.99**	**27.04**	**838.31**

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Proposed Pollutant Loading Calculations

Lake Outfall #8A Proposed Conditions (Page 1/2)

Location: **Albion Street/Newberry Street & Terrace/Crystal Street/Lake Ave**

Drainage Area: **8.45 AC**

Land Use:	**High Density Residential**	**Total Impervious**	**4.37 AC**
		Pervious HSG A (2.41 IN/HR)	**4.08 AC**
		Impervious Roadway	**1.22 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.21	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.20	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.51	NC	NC
Pollutant Load Reduction (lbs/yr)	0.92	NC	NC

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Lake Outfall #8A Proposed Conditions (Page 2/2)

Structural BMP - ADS Stormtech SC-740 Infiltration Chambers

Location	**Crystal Street and Lake Ave Intersection**	
Design Date	**TBD**	
Land Use	**High Density Residential**	
Physical Storage Volume*	**0.097 ACRE-FEET**	***See HydroCAD Summary**
Drainage Area (Impervious)	**4.37 ACRE**	
Infiltrated (Treated) Depth of Runoff	**0.27 INCHES**	
Soil Infiltration Rate	**2.41 IN/HR**	

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	10.27	62.78	1,949.29
Structural BMP Removal Efficiency	63.3%	85.7%	82.7%
Pollutant Load Reduction (lbs/yr)	6.50	53.80	1,612.06

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	10.27	62.78	1,949.29
Non-Structural BMP Reduction (lbs/yr)	0.92	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	6.50	53.80	1,612.06
Pollutant Load Remaining (lbs/yr)	**2.85**	**8.98**	**337.23**

PROPOSED LAKE OUTFALL #8A

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious		1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	4.37	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious		1	1	1	1
Developed Pervious A	Pervious	4.08	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	8.45				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			10.27	62.78	1949.29	3.08

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Summary for Pond 3P: OF-8A Infiltration Chambers

[43] Hint: Has no inflow (Outflow=Zero)

Volume	Invert	Avail.Storage	Storage Description
#1A	0.00'	0.047 af	**20.50'W x 89.06'L x 4.00'H Field A** 0.168 af Overall - 0.051 af Embedded = 0.117 af x 40.0% Voids
#2A	1.00'	0.051 af	**ADS_StormTech SC-740 +Cap** x 48 Inside #1 Effective Size= 44.6"W x 30.0"H => 6.45 sf x 7.12'L = 45.9 cf Overall Size= 51.0"W x 30.0"H x 7.56'L with 0.44' Overlap 4 Rows of 12 Chambers
		0.097 af	Total Available Storage

Storage Group A created with Chamber Wizard

PROPOSED OUTFALL #8A ADS STORMTECH INFILTRATION CHAMBERS

1. Management Objective

Select Pollutant Type ->	TP	Total BMP Cost ($)	$107,101
Enter Target Load Reduction (%) ->	30.0%	Total Pollutant Load Reduction (%)	63.3%

2. Optimization Target

Select an option ->	BMP Storage Capacity	Total BMP Storage Capacity (gal)	32,072

3. Watershed Information

Enter Land Use Area ->	Click Here	Total Impervious Area (ac)	4.4

4. BMP Information

Enter Drainage Area ->	Click Here	Total Treated Impervious Area (ac)	4.4

5. Optimal Solution

BMP Type	Design Storage Capacity (ft^3)	BMP Cost ($)	Treated Impervious Area (ac)	O&M (hr/yr)	Load Reduction (lbs)	Treated Runoff Depth (in)
Biofiltration with ISR	-	$ -	-	-	-	-
Bioretention	-	$ -	-	-	-	-
Dry Pond	-	$ -	-	-	-	-
Grass Swale*	-	$ -	-	-	-	-
Gravel Wetland	-	$ -	-	-	-	-
Infiltration Basin	-	$ -	-	-	-	-
Infiltration Chambers*	-	$ -	-	-	-	-
Infiltration Trench	4,287	$ 107,101	4.37	-	6.51	0.27
Porous Pavement*	-	$ -	-	-	-	-
Sand Filter	-	$ -	-	-	-	-
Wet Pond	-	$ -	-	-	-	-

Note:Only fill in the yellow highlighted cells.

* Place holder for future option (not implemented)

Planning Level Analysis

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1: BMP Storage Capacity – to evaluate the changes in hydrologic and water quality benefits as the BMP/LID sizes are increased in fixed increments; and
2: BMP Drainage Area – to determine how much impervious area would require treatment if specified BMP design capacities are selected for each HRU type to be treated.

Run Single Scenario

Run Optimize Scenario

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Proposed Pollutant Loading Calculations

Lake Outfall #8B Proposed Conditions

Location: Kenmore Street/Moreland Ave/Lake Terrace/Lake Ave

Drainage Area: 6.28 AC

Land Use:			
	Forest	Total Impervious	0.10 AC
		Pervious HSG A (2.41 IN/HR)	0.01 AC
	High Density Residential	Total Impervious	2.49 AC
		Pervious HSG A (2.41 IN/HR)	3.68 AC
		Impervious Roadway	0.95 AC

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.17	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.12	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.30	NC	NC
Pollutant Load Reduction (lbs/yr)	0.59	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	6.04	37.24	1,185.66
Non-Structural BMP Reduction (lbs/yr)	0.59	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	0.00	0.00	0.00
Pollutant Load Remaining (lbs/yr)	**5.45**	**37.24**	**1,185.66**

PROPOSED LAKE OUTFALL #8B

Landuse Type	Impervious/Pervious	Total Area (ac)	TP Load Adjustment	TN Load Adjustment	TSS Load Adjustment	ZN Load Adjustment
Agriculture Impervious	Impervious		1	1	1	1
Forest Impervious	Impervious	0.10	1	1	1	1
Highway Impervious	Impervious		1	1	1	1
Industrial Impervious	Impervious		1	1	1	1
Commercial Impervious	Impervious		1	1	1	1
High Density Residential Impervious	Impervious	2.49	1	1	1	1
Medium Density Residential Impervious	Impervious		1	1	1	1
Low Density Residential Impervious	Impervious		1	1	1	1
Open Land Impervious	Impervious		1	1	1	1
Agriculture Pervious	Pervious		1	1	1	1
Forest Pervious	Pervious	0.01	1	1	1	1
Developed Pervious A	Pervious	3.68	1	1	1	1
Developed Pervious B	Pervious		1	1	1	1
Developed Pervious C	Pervious		1	1	1	1
Developed Pervious C/D	Pervious		1	1	1	1
Developed Pervious D	Pervious		1	1	1	1
	TOTAL Area (ac)	6.28				
* Note:Only fill in the yellow highlighted cells.			*Note: Orange cells provide the option to enter total existing load without land use distribution.			
			6.04	37.24	1185.66	1.83

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Proposed Pollutant Loading Calculations

Railyard Ballast Drainage Proposed Conditions

Location: Lake Ave/Rogers Street

Drainage Area: 5.56 AC

Land Use:	**High Density Residential**	**Total Impervious**	**2.22 AC**
		Pervious HSG A (2.41 IN/HR)	**2.91 AC**
		Impervious Roadway	**0.52 AC**
	Highway	**Total Impervious**	**0.23 AC**
		Pervious HSG A (2.41 IN/HR)	**0.20 AC**

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.09	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.11	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.27	NC	NC
Pollutant Load Reduction (lbs/yr)	0.47	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	5.56	34.51	1,335.51
Non-Structural BMP Reduction	0.47	NC	NC
Pollutant Load Remaining (lbs/yr)	**5.09**	**34.51**	**1,335.51**

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Proposed Pollutant Loading Calculations

Overland Proposed Conditions

Location: Surrounding Lake

Drainage Area: 14.62 AC

Land Use:			
	Forest	Total Impervious	0.01 AC
		Pervious HSG A (2.41 IN/HR)	1.47 AC
	High Density Residential	Total Impervious	3.09 AC
		Pervious HSG A (2.41 IN/HR)	8.14 AC
		Impervious Roadway	0.88 AC
	Highway	Total Impervious	0.63 AC
		Pervious HSG A (2.41 IN/HR)	0.43 AC
	Water	Drainage Area	0.85 AC

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.15	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.16	NC	NC
Organic Waste/Leaf Litter Collection Reduction (PRF = 0.05)	0.40	NC	NC
Pollutant Load Reduction (lbs/yr)	0.71	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	8.45	53.09	2,391.67
Non-Structural BMP Reduction (lbs/yr)	0.71	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.99	6.54	207.81
Pollutant Load Remaining (lbs/yr)	**6.75**	**46.55**	**2,183.86**

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Proposed Pollutant Load Calculation Summary

Proposed Conditions Summary

Location: **Crystal Lake**

Drainage Area: **55.11 AC**

Land Use:	**Commercial**	**Total Impervious**	**0.04 AC**
		Pervious HSG A (2.41 IN/HR)	**0.01 AC**
		Impervious Roadway	0.04 AC
	Forest	**Total Impervious**	**0.11 AC**
		Pervious HSG A (2.41 IN/HR)	**1.49 AC**
	High Density Residential	**Total Impervious**	**20.52 AC**
		Pervious HSG A (2.41 IN/HR)	**30.61 AC**
		Impervious Roadway	6.45 AC
	Highway	**Total Impervious**	**0.85 AC**
		Pervious HSG A (2.41 IN/HR)	**0.62 AC**
	Water	**Drainage Area**	**0.85 AC**

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	50.14	309.22	10,629.10
Non-Structural BMP Reduction (lbs/yr)	4.57	NC	NC
Existing Structural BMP Load Reduction (lbs/yr)	0.99	6.54	207.81
Proposed Structural BMP Reduction (lbs/yr)	10.56	86.28	2,616.73
Pollutant Load Remaining (lbs/yr)	**34.02**	**216.40**	**7,804.56**
Percent Reduction	**32.2%**	**30.0%**	**26.6%**

COMMITMENT & INTEGRITY
DRIVE RESULTS

WOODARD & CURRAN
33 Broad Street, 7th Floor
Providence, Rhode Island, 02903
Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	11/27/2019
CHECKED BY:		DATE:	
PROJECT NO.	230525.03	SHEET NO.	1

Pollutant Loading Calculations - Simple Method Average EMC Value 0.3 mg/L

Lake Outfall #5 Baseline Conditions

Location: Saxon Road & Terrace/Lakewood Road/Norman Road/Lake Ave

Drainage Area: 7.27 AC

Land Use:	**High Density Residential**	**Total Impervious**	**2.51 AC**
		Pervious HSG A (2.41 IN/HR)	**4.76 AC**
		Impervious Roadway	**1.00 AC**

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.36
Mean Conc. of the Pollutant (mg/L)	C	0.3
Contributing Drainage Area (ac)	A	7.27
Pollutant Export Load (lbs/year)	**L**	**7.54**

EPA Calculated Load	5.97
Percent Difference	**26%**

COMMITMENT & INTEGRITY
DRIVE RESULTS

WOODARD &CURRAN
33 Broad Street, 7th Floor
Providence, Rhode Island, 02903
Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	11/27/2019
CHECKED BY:		DATE:	
PROJECT NO.	230525.03	SHEET NO.	1

Pollutant Loading Calculations - Simple Method Sample Concentration

Lake Outfall #5 Baseline Conditions

Location:	**Saxon Road & Terrace/Lakewood Road/Norman Road/Lake Ave**		
Drainage Area:	**7.27 AC**		
Land Use:	**High Density Residential**	**Total Impervious**	**2.51 AC**
		Pervious HSG A (2.41 IN/HR)	**4.76 AC**
		Impervious Roadway	**1.00 AC**

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.36
Mean Conc. of the Pollutant (mg/L)	C	0.525
Contributing Drainage Area (ac)	A	7.27
Pollutant Export Load (lbs/year)	**L**	**13.20**

EPA Calculated Load	5.97
Percent Difference	**121%**

COMMITMENT & INTEGRITY
DRIVE RESULTS

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CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	11/27/2019
CHECKED BY:		DATE:	
PROJECT NO.	230525.03	SHEET NO.	1

Pollutant Loading Calculations - Simple Method Average EMC Value 0.3 mg/L

Lake Outfall #7 Baseline Conditions

Location: Saxon Road/Berwich Road/Lake Ave

Drainage Area: 4.53 AC

Land Use:	**High Density Residential**	**Total Impervious**	**1.87 AC**
		Pervious HSG A (2.41 IN/HR)	**2.66 AC**
		Impervious Roadway	**0.63 AC**

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.42
Mean Conc. of the Pollutant (mg/L)	C	0.3
Contributing Drainage Area (ac)	A	4.53
Pollutant Export Load (lbs/year)	**L**	**5.48**

EPA Calculated Load	4.41
Percent Difference	**24%**

COMMITMENT & INTEGRITY
DRIVE RESULTS

WOODARD & CURRAN
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Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	11/27/2019
CHECKED BY:		DATE:	
PROJECT NO.	230525.03	SHEET NO.	1

Pollutant Loading Calculations - Simple Method Sample Concentration

Lake Outfall #7 Baseline Conditions

Location: Saxon Road/Berwich Road/Lake Ave

Drainage Area: 4.53 AC

Land Use:	**High Density Residential**	**Total Impervious**	**1.87 AC**
		Pervious HSG A (2.41 IN/HR)	**2.66 AC**
		Impervious Roadway	**0.63 AC**

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.42
Mean Conc. of the Pollutant (mg/L)	C	0.416
Contributing Drainage Area (ac)	A	4.53
Pollutant Export Load (lbs/year)	**L**	**7.60**

EPA Calculated Load	4.41
Percent Difference	**72%**

WOODARD &CURRAN
COMMITMENT & INTEGRITY DRIVE RESULTS
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Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	11/27/2019
CHECKED BY:		DATE:	
PROJECT NO.	230525.03	SHEET NO.	1

Pollutant Loading Calculations - Simple Method Average EMC Value 0.3 mg/L

Lake Outfall #8 Baseline Conditions

Location: Kenmore Street/Moreland Ave/Albion Street/Newberry Street & Terrace/Crystal Street/Lake Ave

Drainage Area: 14.73 AC

Land Use:

Forest	Total Impervious	0.10 AC
	Pervious HSG A (2.41 IN/HR)	0.01 AC
High Density Residential	Total Impervious	6.86 AC
	Pervious HSG A (2.41 IN/HR)	7.75 AC
	Impervious Roadway	2.17 AC

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.86
Mean Conc. of the Pollutant (mg/L)	C	0.11
Contributing Drainage Area (ac)	A	0.12
Pollutant Export Load (lbs/year)	**L**	**0.10**

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.47
Mean Conc. of the Pollutant (mg/L)	C	0.3
Contributing Drainage Area (ac)	A	14.61
Pollutant Export Load (lbs/year)	**L**	**19.86**

EPA Calculated Load	16.31
Percent Difference	**22%**

COMMITMENT & INTEGRITY
DRIVE RESULTS

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Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
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PROJECT NO.	230525.03	SHEET NO.	1

Pollutant Loading Calculations - Simple Method Sample Concentration

Lake Outfall #8 Baseline Conditions

Location: Kenmore Street/Moreland Ave/Albion Street/Newberry Street & Terrace/Crystal Street/Lake Ave

Drainage Area: 14.73 AC

Land Use:	Forest	Total Impervious	0.10 AC
		Pervious HSG A (2.41 IN/HR)	0.01 AC
	High Density Residential	Total Impervious	6.86 AC
		Pervious HSG A (2.41 IN/HR)	7.75 AC
		Impervious Roadway	2.17 AC

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.86
Mean Conc. of the Pollutant (mg/L)	C	0.31
Contributing Drainage Area (ac)	A	0.12
Pollutant Export Load (lbs/year)	**L**	**0.29**

High Density Residential Pollutant Loading Variables		TP
Rainfall Depth (in)	P	47
Rainfall Concentration Factor	Pj	0.9
Runoff Coefficient	Rv	0.47
Mean Conc. of the Pollutant (mg/L)	C	0.31
Contributing Drainage Area (ac)	A	14.61
Pollutant Export Load (lbs/year)	**L**	**20.53**

EPA Calculated Load	16.31
Percent Difference	**26%**

APPENDIX F: EXISTING BMP DESIGN DOCUMENTATION

STC 900 Precast Concrete Stormceptor
(900 U.S. Gallon Capacity)
Section Thru Chamber
Plan View
Notes:
1. The Use Of Flexible Connection is Recommended at The Inlet and Outlet Where Applicable.
2. The Cover Should be Positioned Over The Outlet Drop Pipe and The Oil Port.
3. The Stormceptor System is protected by one or more of the following U.S. Patents: #4985148, #5498331, #5725760, #5753115, #5849181, #6068765, #6371690.
4. Contact a Concrete Pipe Division representative for further details not listed on this drawing.
GROUND WATER INFILTRATION SYSTEM (8) 4'X4' PRE-CAST LEACHING GALLEYS INV IN=154.75
TEST HOLE #2 ELEV 157.86
12" P.V.C.
PROPOSED DRAIN MANHOLE RIM=159.4 INV IN=155.4 INV OUT=155.3
PROPOSED STORMCEPTOR STC-900 RIM=157.8 INV IN DMH=155.1 INV IN TRENCH DRAIN=155.1 INV OUT=154.85
SILT FENCE EROSION CONTROL
FIREPLACE
20 ROGERS ST.
6" P.V.C.
JUNCTION BOX RIM=158.1 INV=156.1
EXISTING BUSHES
EXISTING 6' CHAIN LINK FENCE (WOODEN STOCKADE FENCE BEHIND)
APPROXIMATE WORK LIMIT
TEST HOLE #1 ELEV 158.39
BENCHMARK: PK NAIL SET ELEVATION 158.60
FINAL PROPOSED BITUMINOUS CONCRETE LIMIT TO BE DETERMINED IN THE FIELD AT THE TIME OF CONSTRUCTION
EXISTING CHAIN LINK FENCE ON TOP OF CONCRETE WALL
BIT. CONCRETE WALKWAY
PROPOSED 3" BIT.
GRASSED AREA
EXISTING CONCRETE CURB POOR CONDITION
PROPOSED CONC. CURB
EDGE OF PROPOSED ASPHALT PAVEMENT
4" X 27' TRENCH DRAIN ACO K100S MODEL
100' LAKE BUFFER ZONE
BIT. CONCRETE
PROPOSED 6" PERFORATED PVC PIPE & STONE (TYPICAL)
EXISTING STONE RETAINING WALL
WOOD RETAINING WALL
BITUMINOUS CONCRETE AREA
PROPOSED LOG 'WATTLE' EROSION CONTROL
PROPOSED 6" D.I. DRAIN PIPE RECEPTORS (TYPICAL)
EXISTING CONCRETE SWALE
ADVISORY NOTE
WATER SERVICE CONNECTION (UNKNOWN LOCATION!!)
RESET WATER SERVICE AS REQUIRED
ADJUST SWING GATE AS REQ'D
INSTALLED 6" PERFORATED PVC PIPE & STONE (TYPICAL)
EXISTING DOWNSPOUT DRAINS OVERLAND (TYPICAL)
EXISTING 'FOOTWASH' BASIN (SEE DETAIL)
EXISTING BATH HOUSE
FF=158.95±
SLAB GRADE BEAMS
FULL FOUNDATION WITH BASEMENT
SAND BEACH
EXISTING BIT. CONCRETE PARKING AREA
PROPOSED 4" CONCRETE FORMED & POURED TO MEET CRITICAL DESIGN GRADES
EXISTING CATCHBASINS DEBRIS FILLED AND NOT IN WORKING CONDITION
EXCAVATE & ABANDON EX. CATCHBASINS. PLUG PIPE CONNECTION
SEWER SERVICE CONNECTION
EXISTING SHOWER DRAIN
PROPOSED CONCRETE CURB & 4"x8" DUCTILE IRON BOLLARDS (SEE DETAIL)
PROPOSED DOUBLE CATCHBASIN STA. 1+28
EXISTING GRAVEL AREA TO REMAIN
EXISTING CONCRETE ACCESSIBLE RAMP AND WALL SYSTEM
EXISTING CONCRETE CURB IN POOR CONDITION
EXISTING CHAIN LINK FENCE
PROPOSED CONC. CURB
MBTA
CRYSTAL LAKE
(CURRENT SURFACE ELEVATION 147.22)
LEACHING GALLEY MANIFOLD SIDE VIEW SCALE: 1"=5'
ACCESS MANHOLE
GRASS ELEVATION=158.0
FILTER FABRIC ON OUTSIDE FACE OF CHAMBERS
6" & 8" INLETS INV=154.75
4" CONC. SPLASH PAD
20' EFFECTIVE WIDTH
PROPOSED 12" DUCTILE IRON PIPE
PROPOSED 12" PVC PIPE
DOUBLE INLET CATCH BASIN STA. 1+28
DRAIN MANHOLE
STC 900 PRECAST CONCRETE STORMCEPTOR
GROUND WATER INFILTRATION SYSTEM
BOTTOM GALLEY = 151.5
BOTTOM STONE = 150.5
DESIGNED BY:
DRAWN BY:
DRAINAGE CALC'S BY:
APPROVED BY:
STORM WATER IMPROVEMENTS AT THE CRYSTAL LAKE BATH HOUSE
CITY OF NEWTON
PROPOSED PLAN FOR THE STORM WATER IMPROVEM
AT THE
CRYSTAL LAKE BAT
(30 ROGERS STREET NEWTON HIG
SCALE: 1"=10'
Louis M. Taverna, P.E.
CITY ENGINEER

NORWOOD AVE DRAIN SYSTEM IMPROVEMENTS

New Drain Manhole Installation on Norwood Ave

Proposed work:

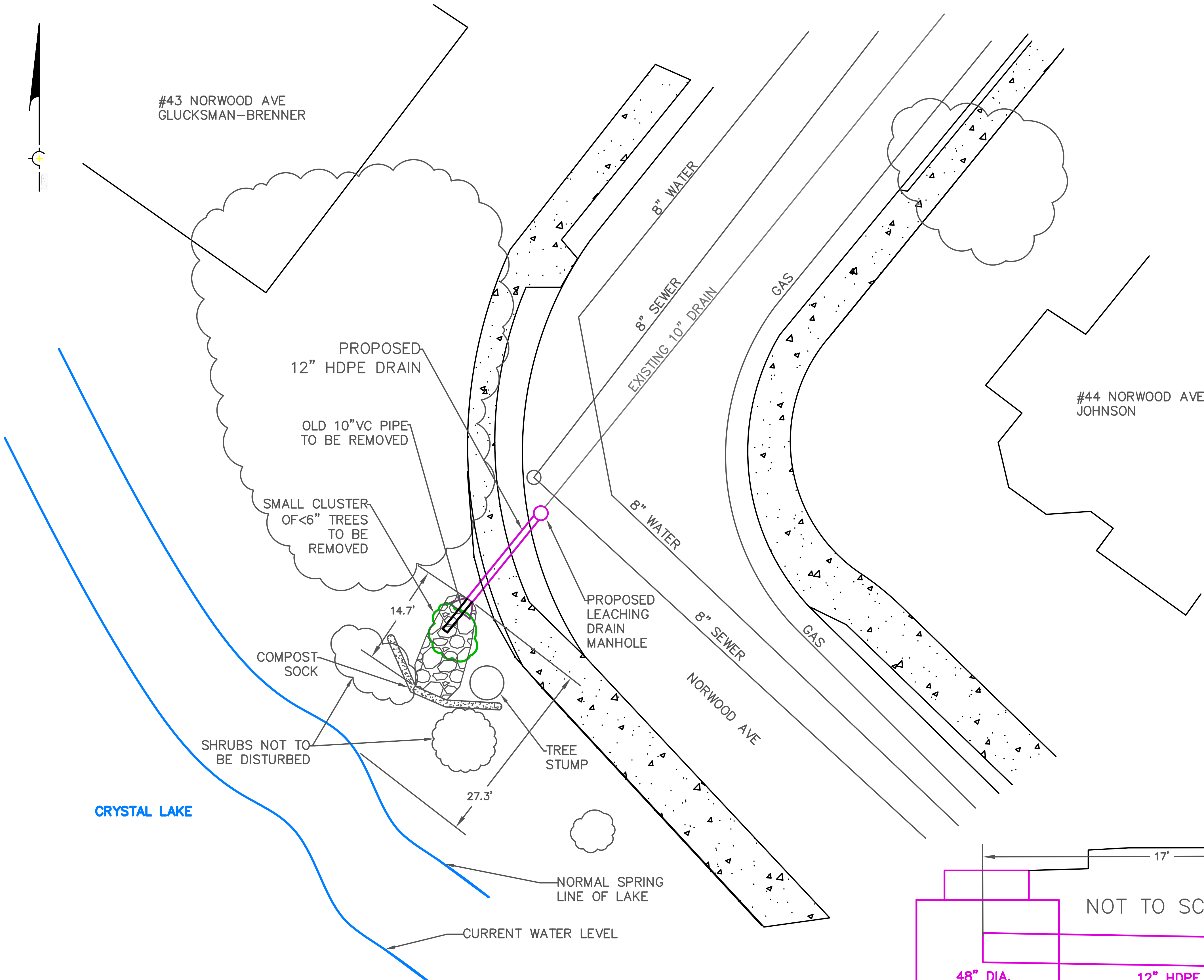
1. Install 12" compost sock around work area.
2. Remove two trees (clumped together) and brush.
3. Remove failing sections of drain pipe from the street to the existing outfall and install new 12" HDPE drain pipe.
4. Grade to install new flared end spillway, lay down and partially embed 3" to 6" rip rap stone around the outfall.
5. Saw cut trench in street.
6. Dig for the new drain manhole.
7. Install new drain manhole.
8. Loam and seed disturbed areas inside fence & stake down jute matting
9. Install asphalt in the disturbed area of the street.
10. Replace any broken sidewalk and or curbing

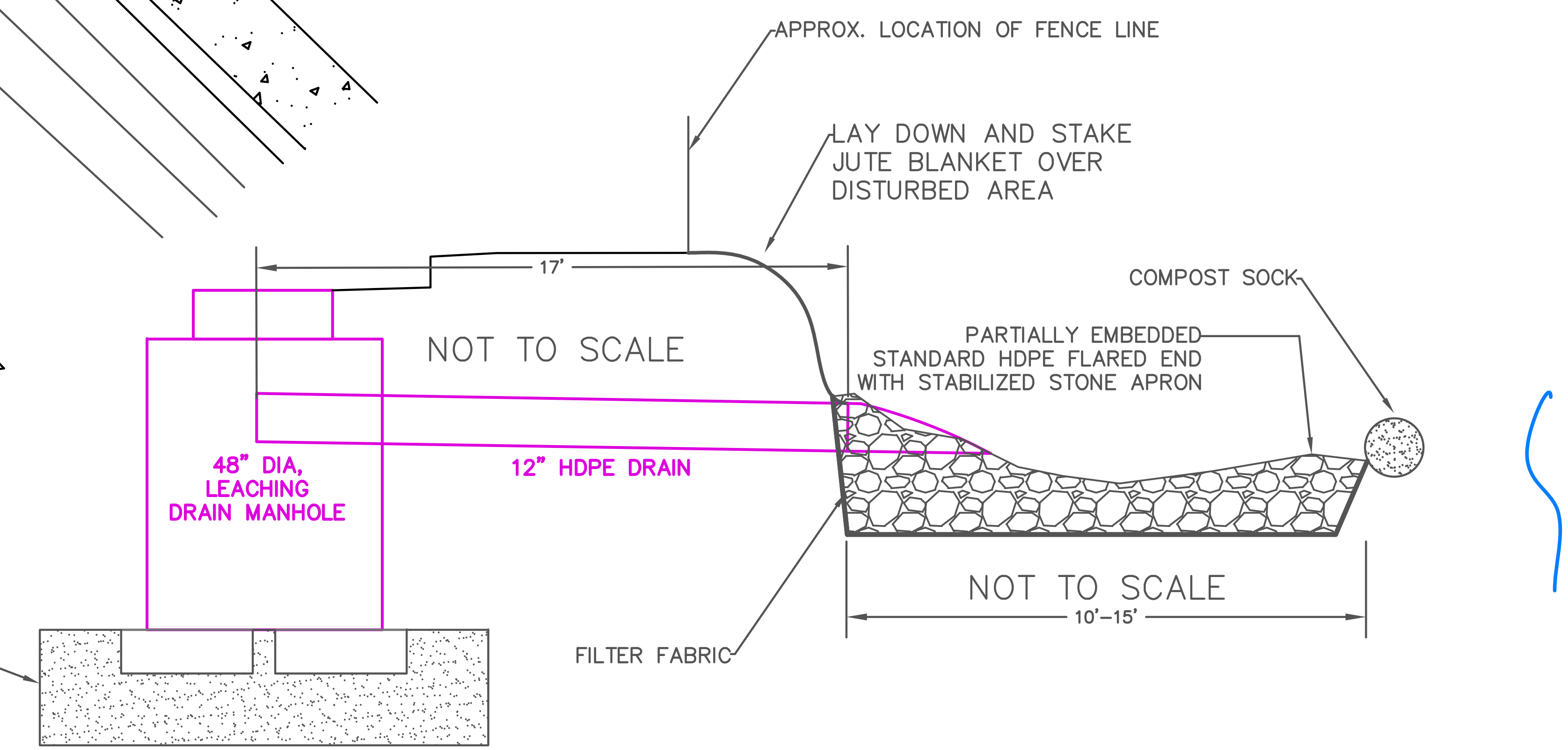
0 5 10 20 40

SCALE: 1" = 10'

REV. 3

DATE: NOVEMBER 16, 2016





CRYSTAL LAKE - DRAINAGE IMPROVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MASSACHUSETTS

ISSUED FOR CONSTRUCTION : JULY 27, 2017
ISSUED TO: NEWTON PUBLIC WORKS DEPARTMENT

LOCUS
SCALE: 1" = 400'

PROJECT TEAM

OWNER: NEWTON PUBLIC WORKS DEPARTMENT
1000 COMMONWEALTH AVE
NEWTON, MA 02459
TEL: (617) 796-1000

CIVIL ENGINEER: HIGHPOINT ENGINEERING, INC.
45 DAN ROAD, SUITE 140
CANTON, MA 02021
TEL: (781) 770-0970
ATTN: Douglas Hartnett
www highpointeng.com

LAND SURVEYOR: FIELDSTONE SURVEY SERVICES
45 MELIX AVE
PLYMOUTH, MA 02360
TEL: (774) 283-2172

INDEX OF DRAWINGS

ISSUE HISTORY:		ISSUED FOR CONSTRUCTION JULY 27, 2017
GENERAL		●
T100	TITLE SHEET	●
C100	EXISTING CONDITIONS PLAN	●
C200	WATERSHED PLAN	●
C300	DRAINAGE IMPROVEMENTS PLAN	●
C400	DETAIL SHEET	●

HIGHPOINT ENGINEERING, INC.
CANTON CORPORATE PLACE
45 DAN ROAD, SUITE 140 | CANTON, MA 02021
t 781.770.0970 | www.highpointeng.com

CLIENT:

CONSULTANT:

SEAL:
COMMONWEALTH OF MASSACHUSETTS
DOUGLAS J. HARTNETT
CIVIL
No. 37796
REGISTERED PROFESSIONAL ENGINEER
07-27-2017

CRYSTAL LAKE DRAINAGE IMPROVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MA 02459

OWNER/APPLICANT: NEWTON PUBLIC WORKS DEPARTMENT

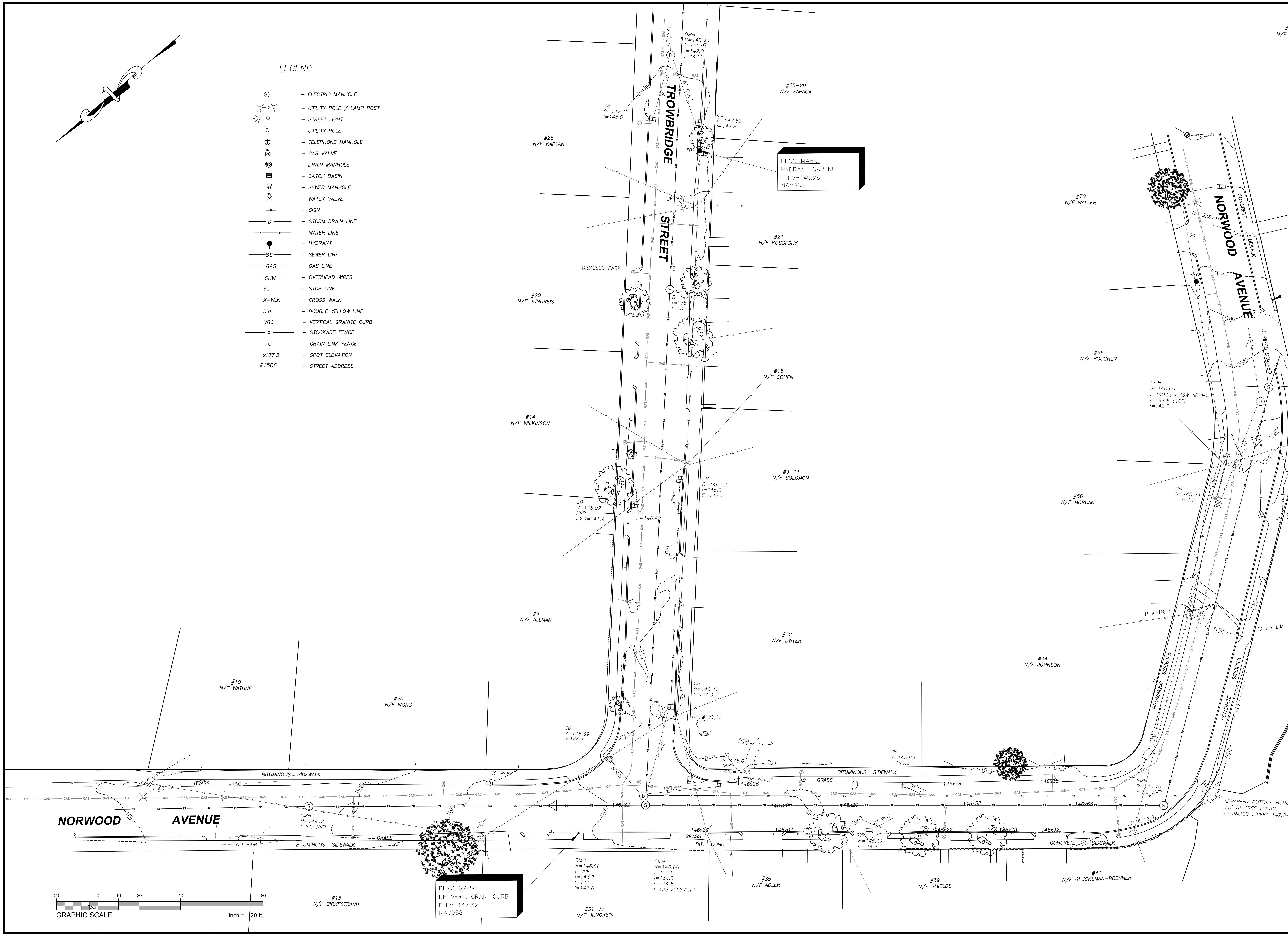
REV	DATE	DESCRIPTION

ISSUE TYPE: FOR CONSTRUCTION
ISSUE DATE: 07/27/2017
PROJECT NUMBER: 16008

DRAWN BY: AK
CHECKED BY: DJH

SHEET TITLE: TITLE SHEET

SHEET NUMBER: T100



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CLIENT:

CONSULTANT:

FIELDSTONE SURVEY SERVICES
45 MEUX AVENUE
PLYMOUTH, MA 02360
T. 774-283-2172

SEAL

CRYSTAL LAKE DRAINAGE IMPOVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MA 02459

OWNER/APPLICANT: NEWTON PUBLIC WORKS DEPARTMENT

REV	DATE	DESCRIPTION

ISSUE TYPE: FOR CONSTRUCTION

ISSUE DATE: 07/27/2017

PROJECT NUMBER: 16008

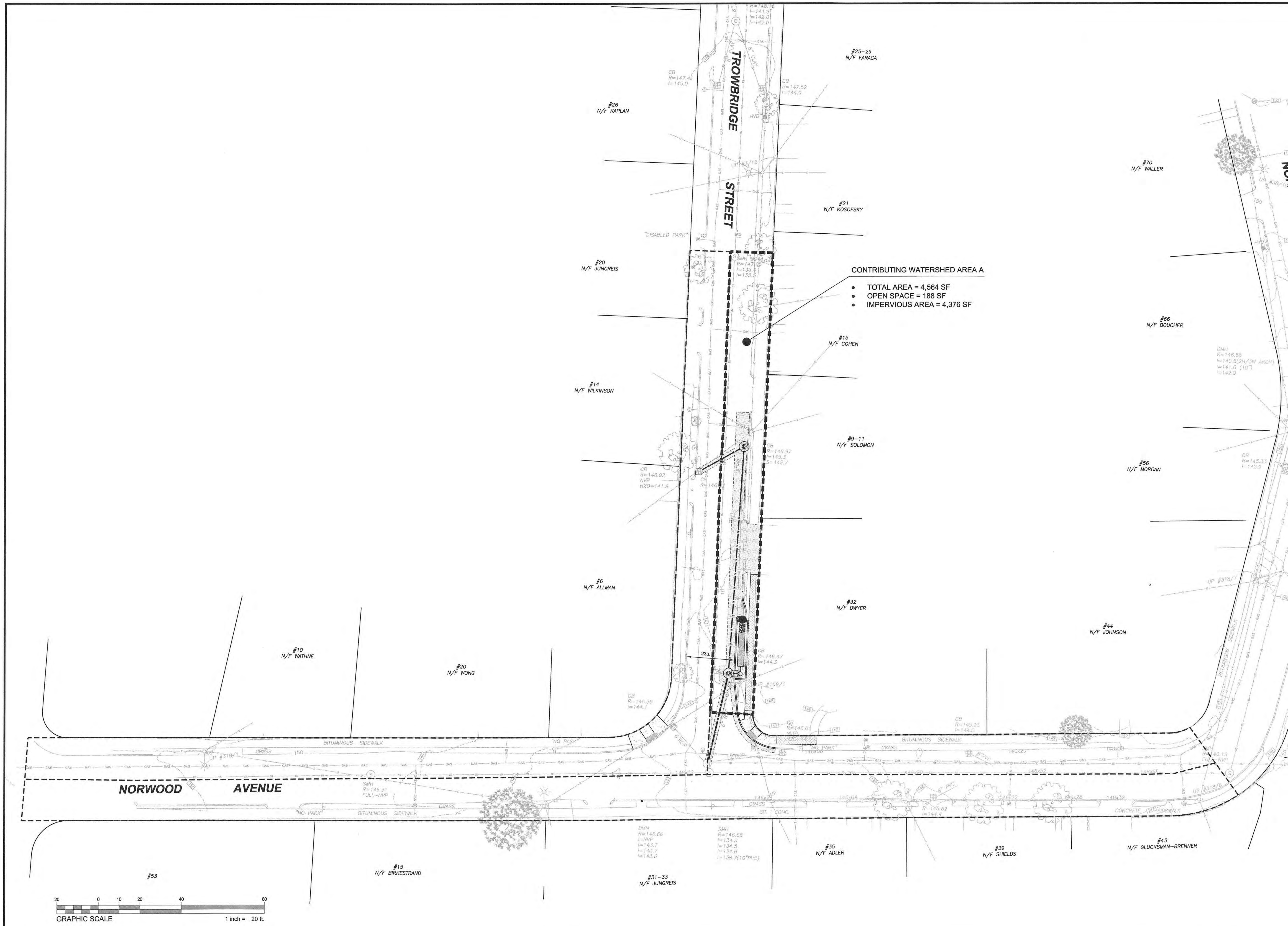
DRAWN BY: SD

CHECKED BY: SD

SHEET TITLE:

EXISTING CONDITIONS PLAN

SHEET NUMBER: C100



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CLIENT:

CONSULTANT:

SEAL:

COMMONWEALTH OF MASSACHUSETTS
DOUGLAS J. HARTNETT
CIVIL
No. 37796
REGISTERED PROFESSIONAL ENGINEER

07-27-2017

CRYSTAL LAKE DRAINAGE IMPROVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MA 02459

OWNER/APPLICANT: NEWTON PUBLIC WORKS DEPARTMENT

REV	DATE	DESCRIPTION

ISSUE TYPE:
FOR CONSTRUCTION

ISSUE DATE:
07/27/2017

PROJECT NUMBER:
16008

DRAWN BY: AK

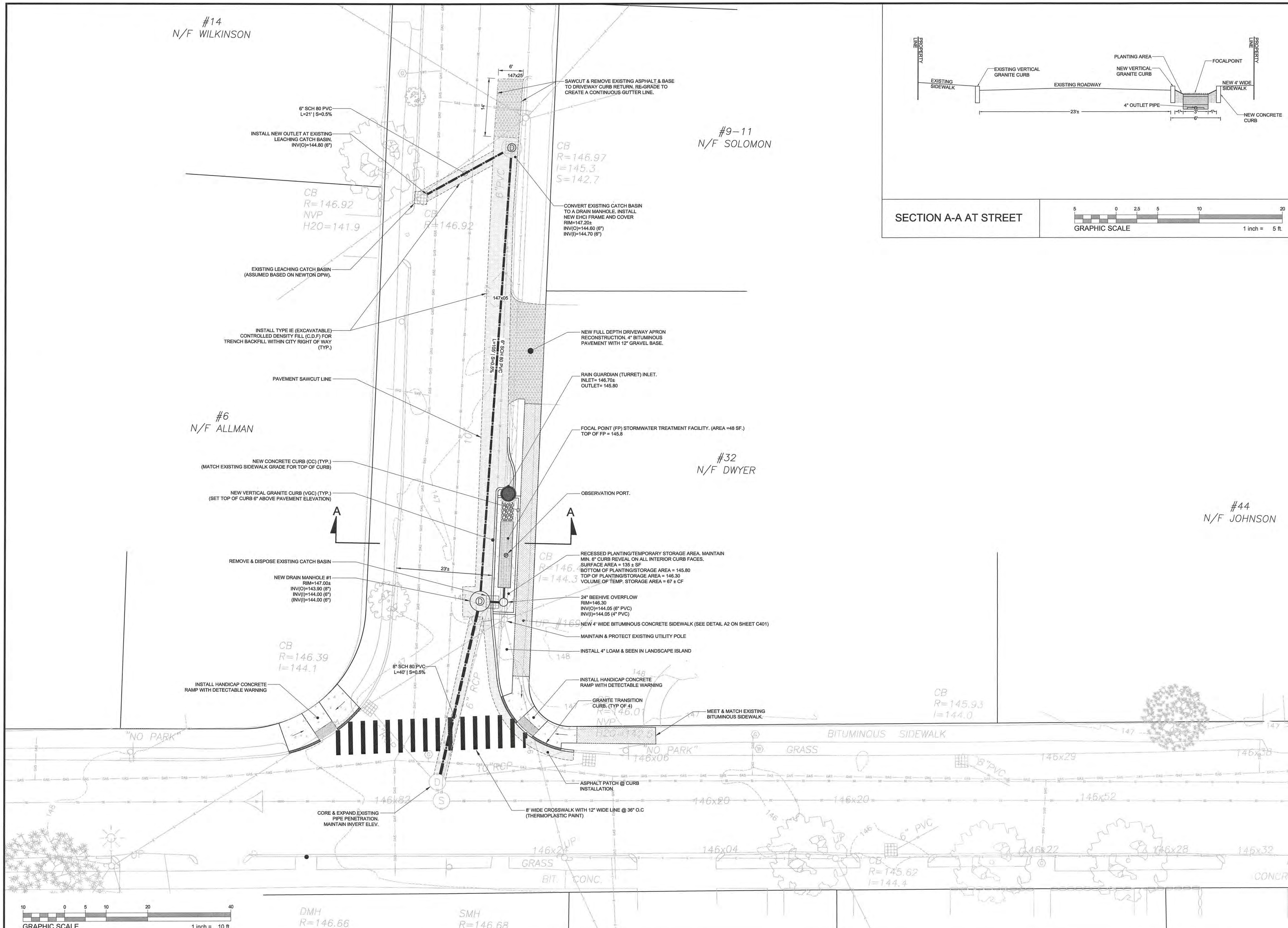
CHECKED BY: DJH

SHEET TITLE:

WATERSHED PLAN

SHEET NUMBER:

C200



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SEAL:

COMMONWEALTH OF MASSACHUSETTS
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CIVIL
No. 37796
REGISTERED PROFESSIONAL ENGINEER
07-27-2017

CRYSTAL LAKE DRAINAGE IMPROVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MA 02459

OWNER/APPLICANT: NEWTON PUBLIC WORKS DEPARTMENT

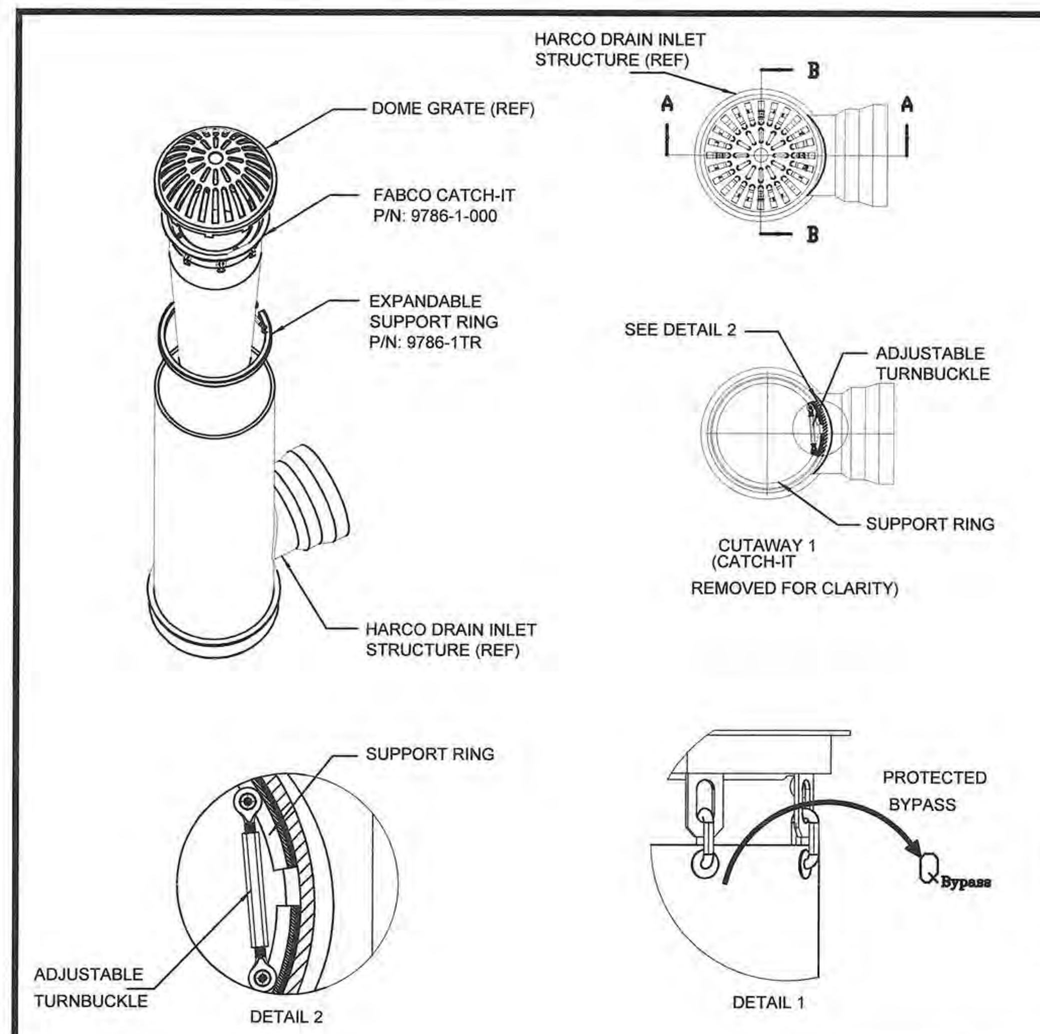
REV	DATE	DESCRIPTION

ISSUE TYPE: FOR CONSTRUCTION
ISSUE DATE: 07/27/2017
PROJECT NUMBER: 16008

DRAWN BY: AK
CHECKED BY: DJH

SHEET TITLE:
DRAINAGE IMPROVEMENTS PLAN

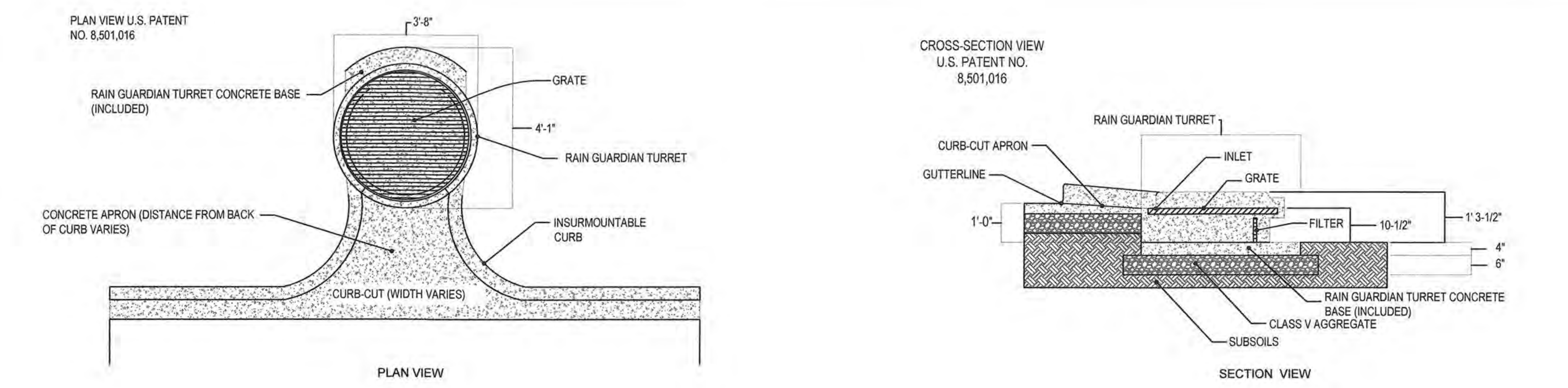
SHEET NUMBER:
C300



STRUCTURE DIAMETER (INCHES)	DEBRIS CAPACITY (CF)	FILTERED FLOWRATE (CFS)	BYPASS FLOWRATE (CFS)	TOTAL SYSTEM FLOWRATE (CFS)
12	0.77	2.2	1.2	3.4
18	1.65	2.5	1.0	3.5
24	3.60	4.9	2.4	7.3
30	6.20	4.9	2.4	7.3

NOTES:
1. STORMSACK WEIGHT (EMPTY): 12 LB MAX
2. MATERIAL:
   A) SHROUD: HIGH DENSITY POLYETHYLENE (TYPICAL WALL THICKNESS .125")
   B) SUPPORT HUB: CRS, POWDER COATED
   C) STORMSACK: WOVEN POLYPROPYLENE GEOTEXTILE (GEOTEX 117F)
   D) HARDWARE: ALUMINUM POP-RIVETS
3. RECOMMENDED MINIMUM VAULT DEPTH: 2-IN BELOW CARTRIDGE
4. TYPICAL INSTALLATION: RAISE STORM GRATE, PUSH CATCH-IT SHROUD DOWN ON FRAME SUPPORT LEDGE UNTIL LOCKING-CLIPS CLICK IN PLACE, LOWER STORM GRATE.
5. USE ONLY WITH FABCO REPLACEABLE STORMSACK.

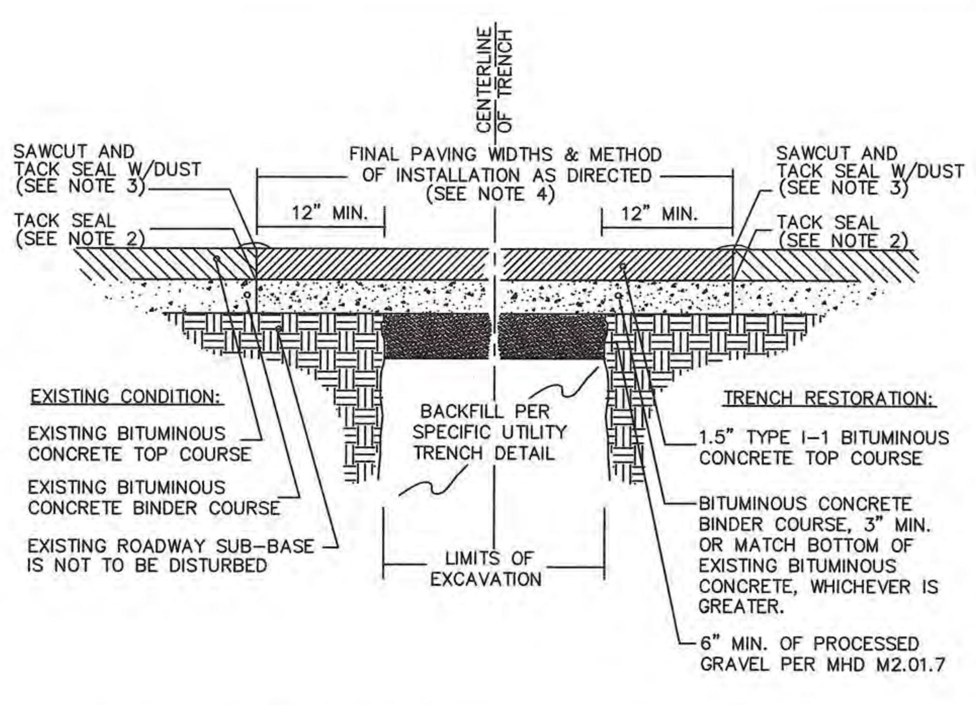
BEEHIVE OVERFLOW DETAIL C2
NOT TO SCALE



SPECIFICATIONS:

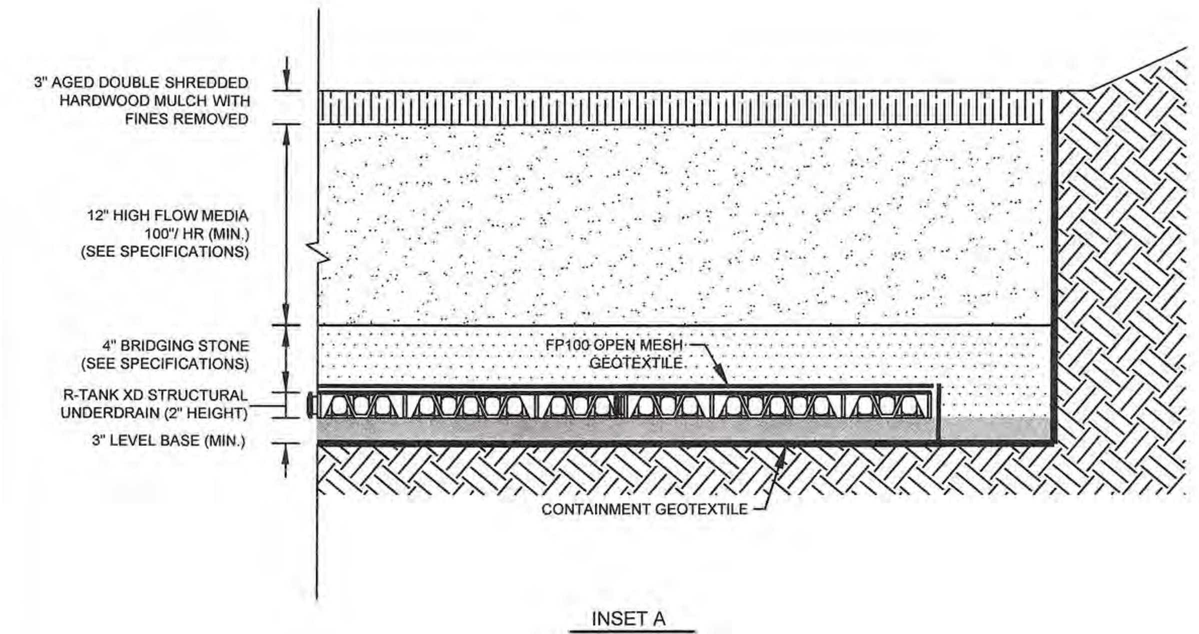
1. STEEL REINFORCED, COLD JOINT SECURED MONOLITHIC CONCRETE STRUCTURE (1,030 LBS).
2. CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH OF 4,000 PSI AT 28 DAYS. CONCRETE AIR ENTRAINED (4 PERCENT TO 8 PERCENT BY VOLUME).
3. MANUFACTURED AND DESIGNED TO ASTM C858.
4. THREE-POINT PICK USING RECESSED LIFTING POCKETS WITH A STANDARD HOOK.
5. SOIL UNDER BASE TO BE COMPACTED TO 95 PERCENT STANDARD PROCTOR.
6. TWO-PIECE LIGHT-DUTY GALVANIZED GRATE (34.5 LBS/PIECE) FOR 541 LB CONCENTRATED LOAD OR 309 LB/SQFT UNIFORM LOAD.
7. TWO-PIECE HEAVY-DUTY GALVANIZED GRATE (77.5 LBS/PIECE) FOR 2,456 LB CONCENTRATED LOAD OR 1,404 LB/SQFT UNIFORM LOAD.
8. USE EXPANSION JOINT MATERIAL BETWEEN TURRET AND BIORETENTION INLET.

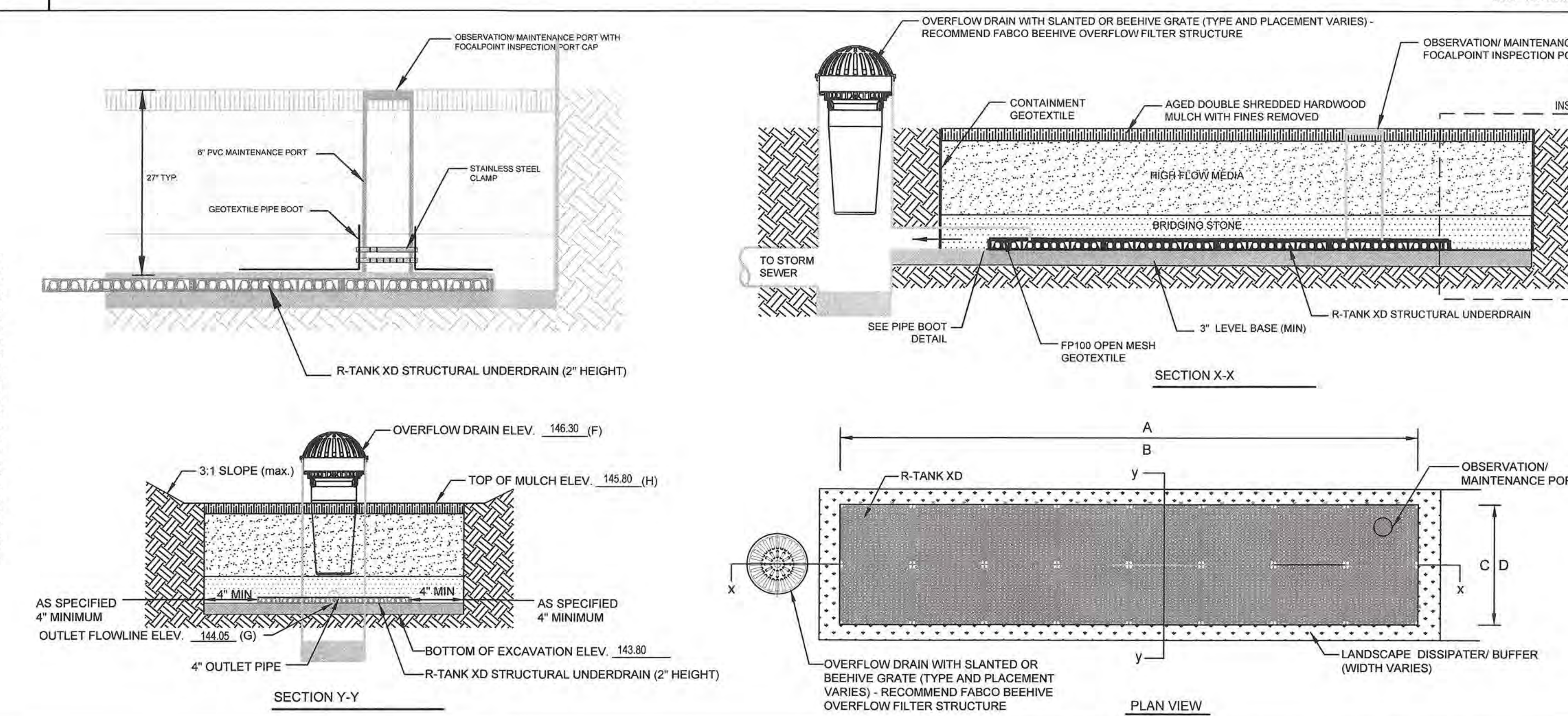
RAIN GUARDIAN (TURRET) DETAIL C1
NOT TO SCALE



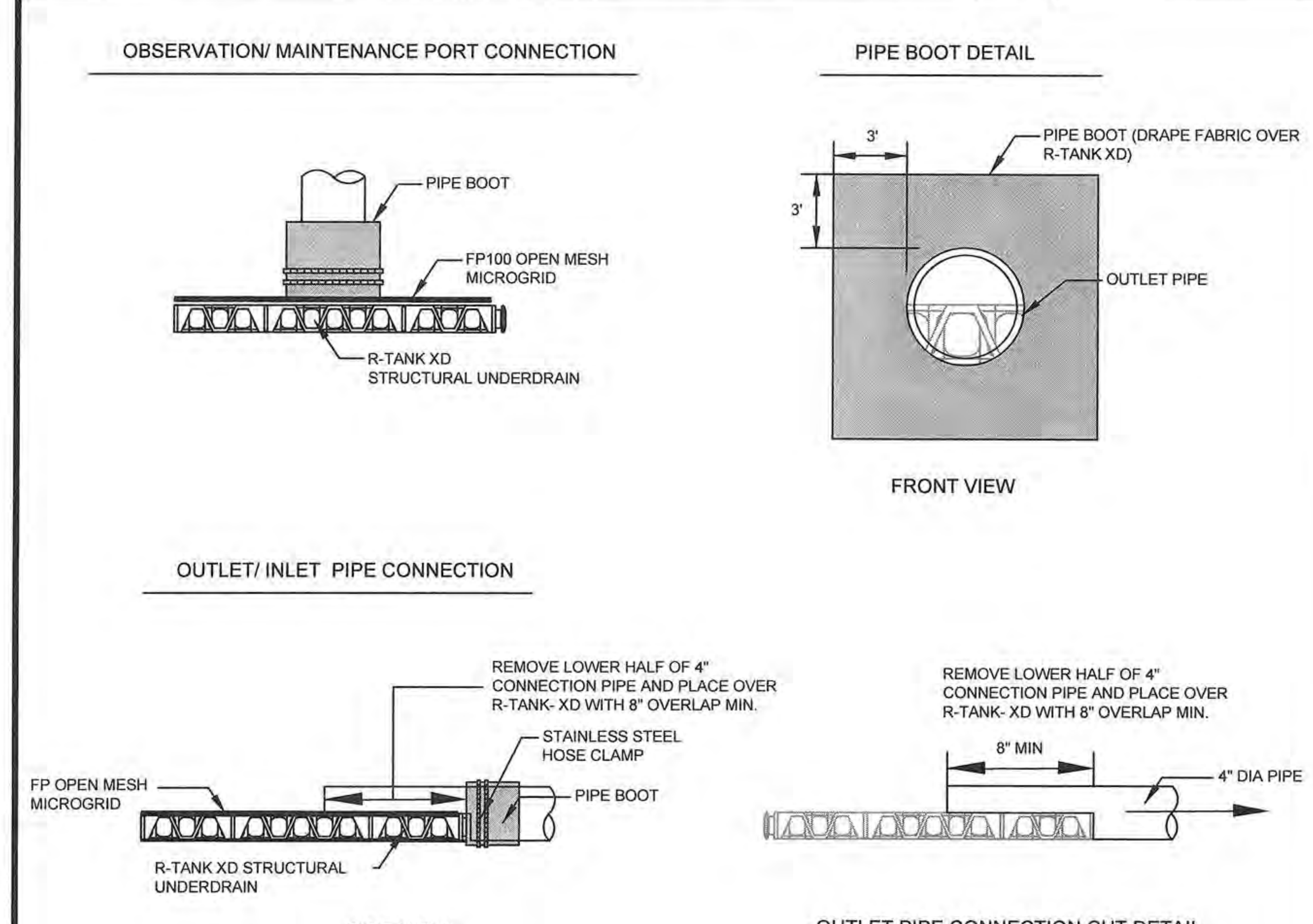
1. ALL INSTALLATION AND MATERIAL SPECIFICATIONS PER MASS. HIGHWAY DEPARTMENT STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES, 1988 AS AMENDED.
2. ALL EXPOSED BITUMINOUS CONCRETE IS TO BE TACKED PER MHD PRIOR TO NEW BITUMINOUS CONCRETE INSTALLATION.
3. ALL EXPOSED JOINTS ARE TO BE SEALED WITH TACK AND STONE DUST.
4. ANY TOP COURSE APPLIED AT A WIDTH OF 6' WIDE OR GREATER IS TO BE PLACED BY MACHINE/BOX SPREADER WHEN & AS DIRECTED BY THE CITY OF NEWTON.

TRENCH REPAIR AND PAVEMENT SECTION B2
(CITY OF NEWTON STANDARD DETAIL) NOT TO SCALE

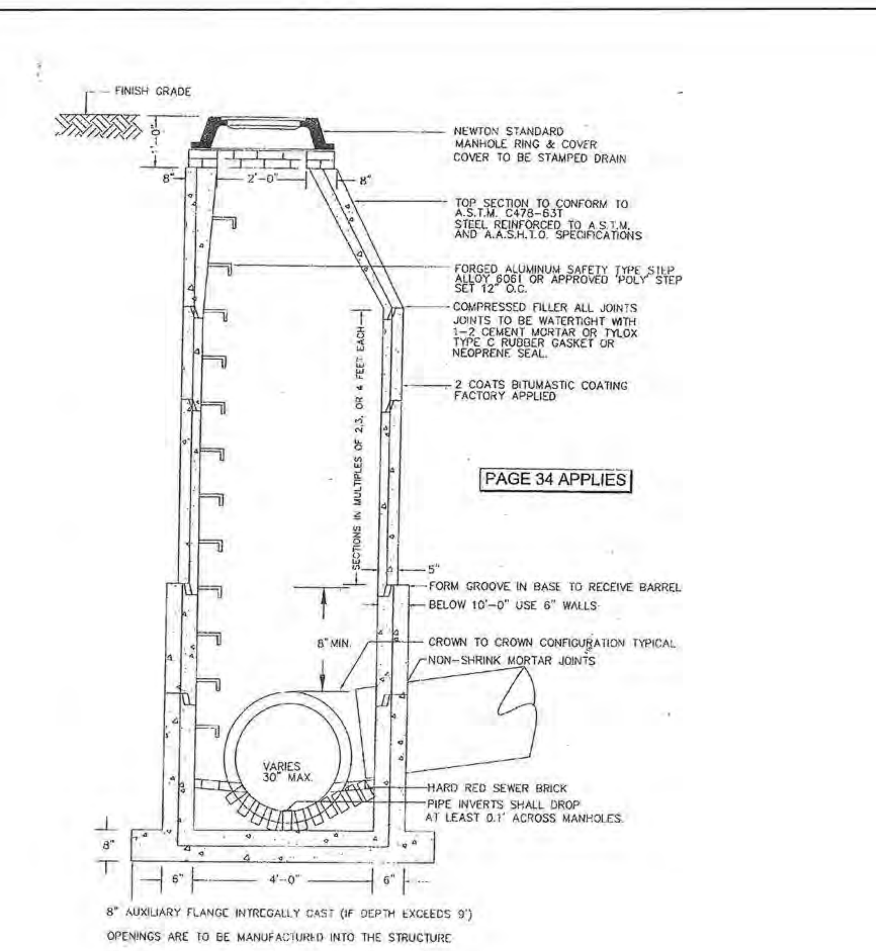




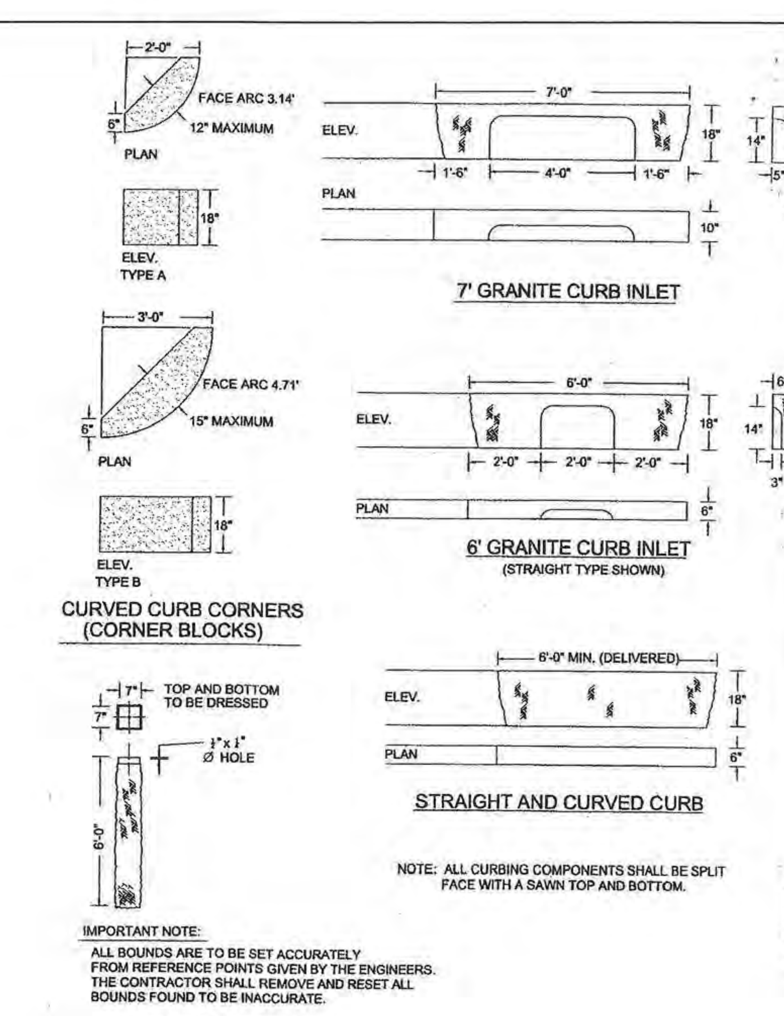
FOCAL POINT STORMWATER TREATMENT FACILITY B1
NOT TO SCALE



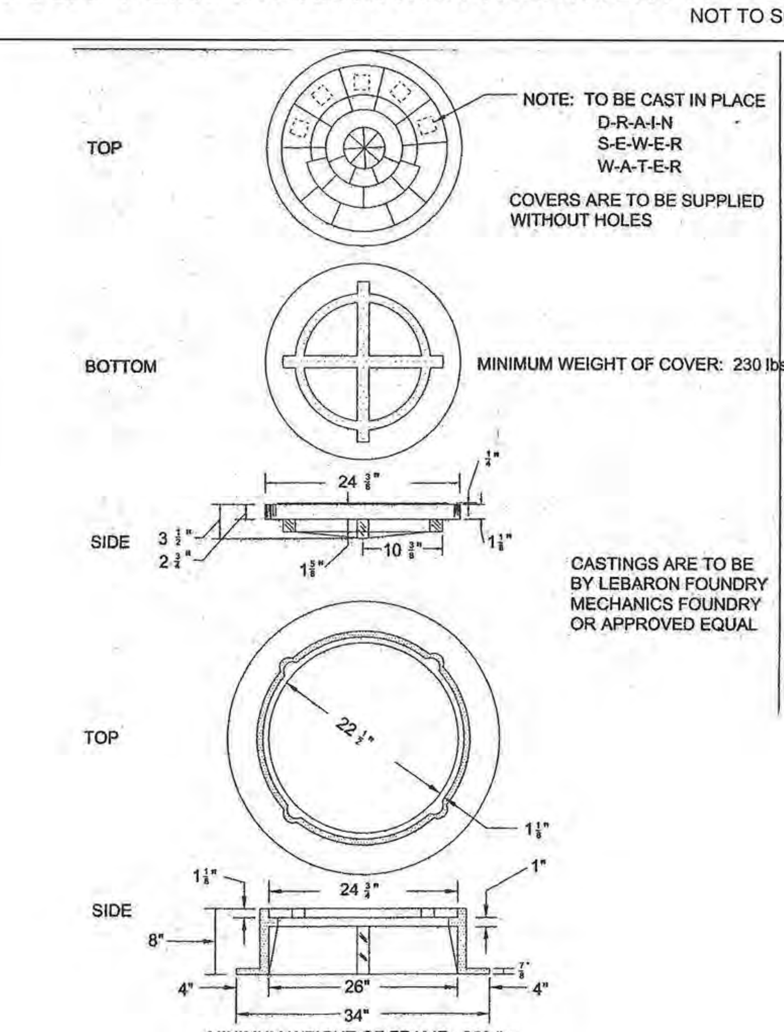
PIPE CONNECTION (FocalPoint) A4
NOT TO SCALE



PRECAST CONCRETE DRAIN MANHOLE A3
(CITY OF NEWTON STANDARD DETAIL) NOT TO SCALE



GRANITE PRODUCTS A2
(CITY OF NEWTON STANDARD DETAIL) NOT TO SCALE



DRAIN MANHOLE FRAME AND COVER A1
(CITY OF NEWTON STANDARD DETAIL) NOT TO SCALE

HIGHPOINT ENGINEERING, INC.
CANTON CORPORATE PLACE
45 DAN ROAD, SUITE 140 | CANTON, MA 02021
t 781.770.0970 | www.highpointeng.com

CLIENT:

CONSULTANT:

SEAL
COMMONWEALTH OF MASSACHUSETTS
DOUGLAS J. HARTNETT
CIVIL
No. 37796
REGISTERED PROFESSIONAL ENGINEER
07-27-2017

CRYSTAL LAKE DRAINAGE IMPROVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MA 02459

OWNER/APPLICANT: NEWTON PUBLIC WORKS DEPARTMENT

REV	DATE	DESCRIPTION

ISSUE TYPE:
FOR CONSTRUCTION

ISSUE DATE:
07/27/2017

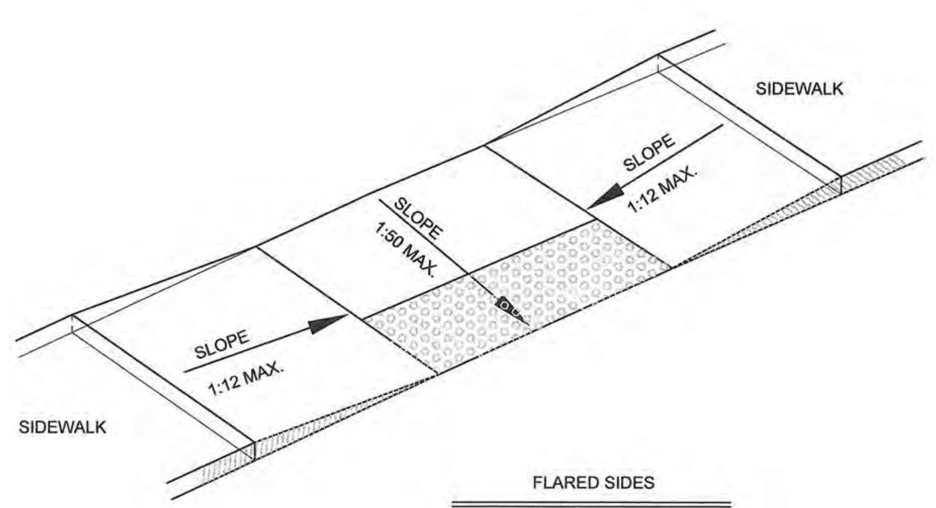
PROJECT NUMBER:
16008

DRAWN BY: AK

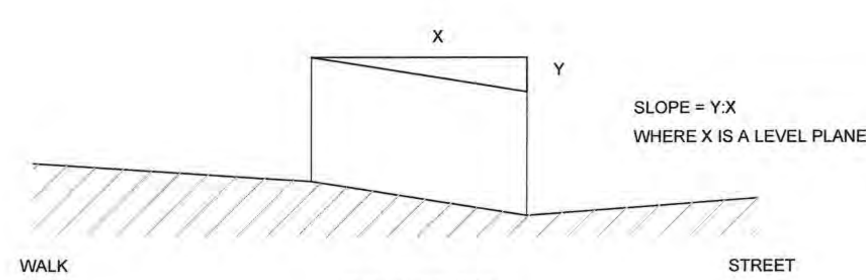
CHECKED BY: DJH

SHEET TITLE:
SITE DETAILS

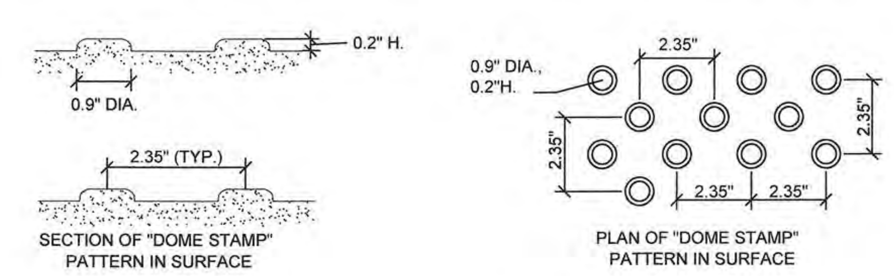
SHEET NUMBER:
C400



FLARED SIDES
NOT TO SCALE



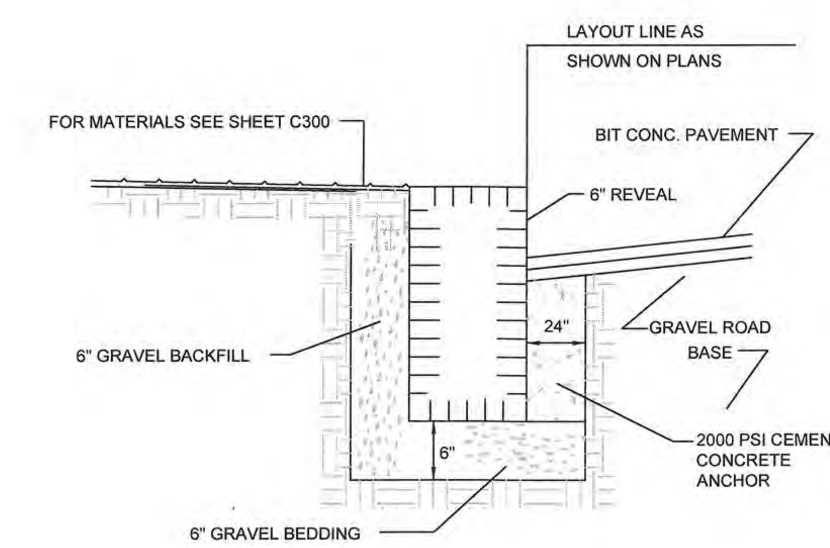
MEASUREMENT OF CURB RAMP SLOPES
NOT TO SCALE



NOTE:
DETECTABLE WARNINGS SHALL CONSIST OF RAISED TRUNCATED DOMES WITH A DIAMETER OF NOMINAL 0.9 IN., A HEIGHT OF NOMINAL 0.2 IN. AND A CENTER-TO-CENTER SPACING OF NOMINAL 2.35 IN. AND SHALL CONTRAST VISUALLY WITH ADJOINING SURFACE, EITHER LIGHT-ON-DARK, OR DARK-ON-LIGHT.

DETECTABLE WARNING
NOT TO SCALE

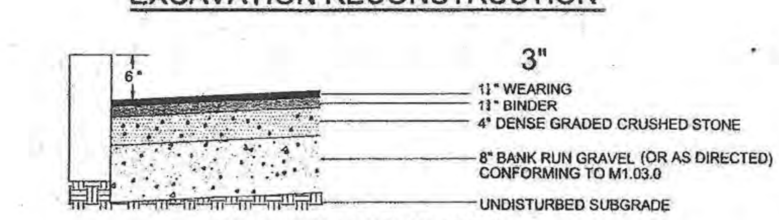
HANDICAP CONCRETE RAMP WITH DETECTABLE WARNING — NOT TO SCALE — **B1**



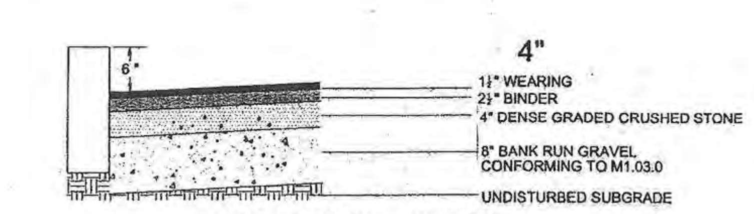
GRANITE CURBING TO CONFORM TO VA.4 TYPE PER DEPT. OF PUBLIC WORKS, MASS. STANDARD SPECIFICATIONS FOR HIGHWAYS AND BRIDGES. M6-03-1

VERTICAL GRANITE CURB — NOT TO SCALE — **B1**

EXCAVATION RECONSTRUCTION

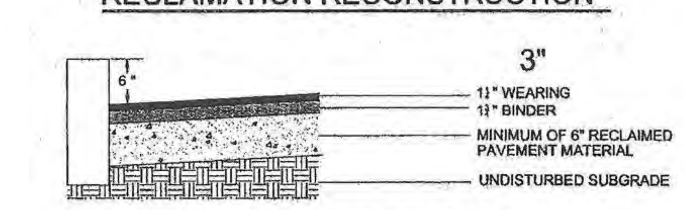


95% COMPACTION @ ALL STRATA

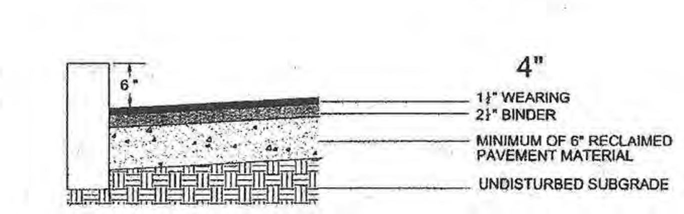


95% COMPACTION @ ALL STRATA

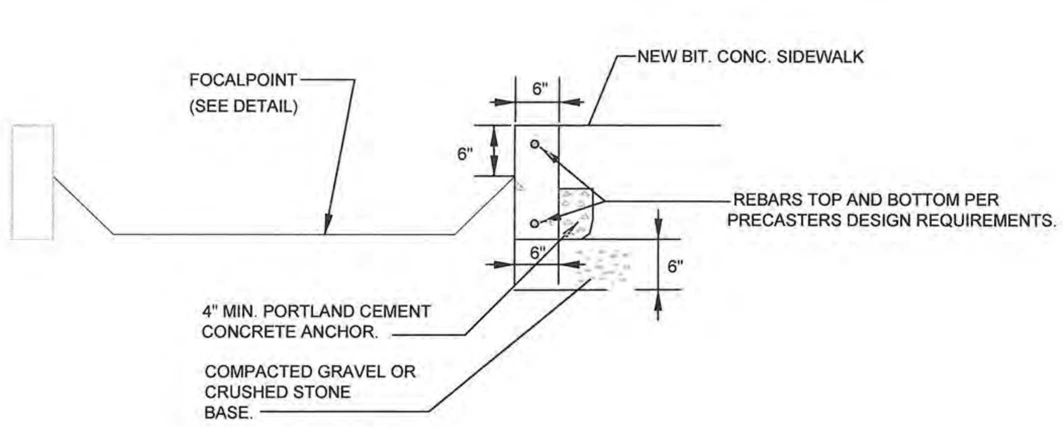
RECLAMATION RECONSTRUCTION



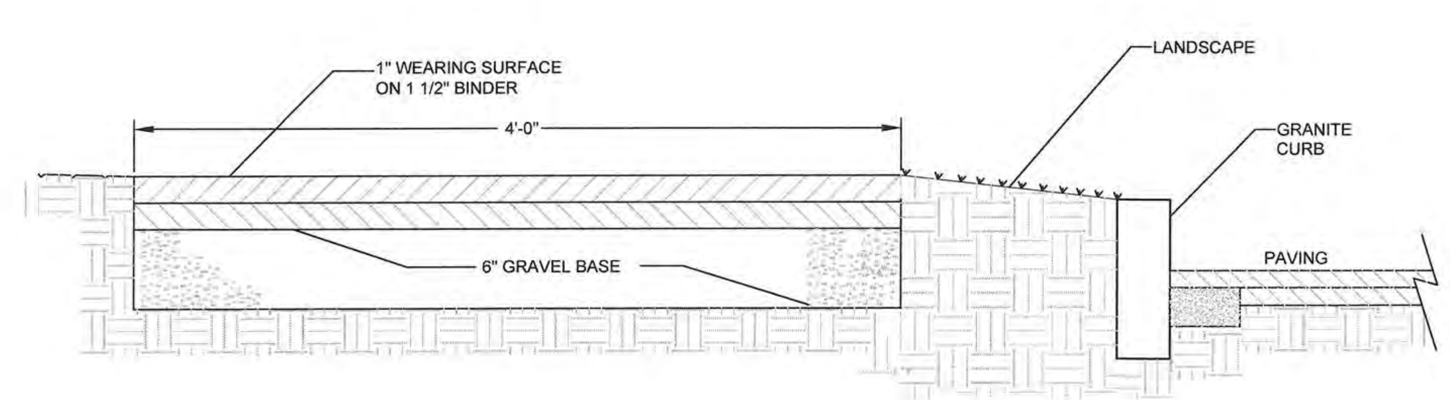
95% COMPACTION @ ALL STRATA



95% COMPACTION @ ALL STRATA



NOTE: PROVIDE EXPANSION JOINTS AT 5'-0" O.C. IF CAST IN PLACE.
(PRECAST CONC. CURBS MAY BE SUBSTITUTED)



CONCRETE CURB — NOT TO SCALE — **A3**

BITUMINOUS CONCRETE SIDEWALK — (CITY OF NEWTON STANDARD DETAIL) NOT TO SCALE — **A2**

BITUMINOUS CONCRETE ROADWAY PAVEMENTS — (CITY OF NEWTON STANDARD DETAIL) NOT TO SCALE — **A1**

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COMMONWEALTH OF MASSACHUSETTS
DOUGLAS J. HARTNETT
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CRYSTAL LAKE DRAINAGE IMPROVEMENTS

TROWBRIDGE STREET & NORWOOD AVENUE
NEWTON, MA 02459

OWNER/APPLICANT: NEWTON PUBLIC WORKS DEPARTMENT

REV	DATE	DESCRIPTION

ISSUE TYPE: FOR CONSTRUCTION
ISSUE DATE: 07/27/2017
PROJECT NUMBER: 16008
DRAWN BY: AK
CHECKED BY: DJH

SHEET TITLE: SITE DETAILS

SHEET NUMBER: C401

APPENDIX G: WISCONSIN DNR LEAF MANAGEMENT PROGRAM

BUREAU OF WATERSHED MANAGEMENT PROGRAM GUIDANCE

RUNOFF MANAGEMENT POLICY AND MANAGEMENT TEAM
Storm Water Management Program

Wisconsin Department of Natural Resources
101 S. Webster Street, P.O. Box 7921
Madison, WI 53707-7921

Interim Municipal Phosphorus Reduction Credit for Leaf Management Programs

03-08-18
EGAD Number: 3800-2018-01

Notice: This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

APPROVED:

Pam Biersach — March 8, 2018

Pam Biersach, Director
Bureau of Watershed Management

Date

A. Introduction/Statement of Problem Being Addressed

Permitted Municipal Separate Storm Sewer Systems (MS4s) will be subject to an annual average reduction for the discharge of a pollutant of concern to a surface water that has an approved TMDL. Recent studies indicate that phosphorus loads in stormwater in the fall of the year may be reduced by frequent leaf collection followed by street cleaning. Many municipalities are currently developing plans to meet TMDL limits and wish to include fall leaf management efforts in their plans.

While additional research is needed on a broader range of conditions and management methods, sufficient data is available to determine a preliminary phosphorus reduction credit for the most common municipal land use type. This credit is limited to the specific conditions and methods for which data is available. No credit has been quantified for other land uses, tree canopies, or collection programs but it is the Department's intent to expand the applicability of the guidance to more conditions and programs as additional studies are completed. This expansion is dependent on availability of funding for further data collection and evaluation.

B. Objectives

This guidance identifies a percent phosphorus reduction credit which may be taken by municipalities as part of TMDL planning and the conditions required to take that credit.

C. Background and Definitions

Urban trees provide a host of benefits to the residents and workers within a community, such as energy savings, aesthetics, airborne pollutant reduction, noise reduction, and providing bird habitat. Trees are also an important part of the hydrologic cycle. However, without adequate management of leaf litter, they also contribute to the nutrient loading in urban stormwater. Each tree species contributes a different amount of phosphorus to the stormwater, but since a diverse set of tree species is beneficial to long-term maintenance of a healthy canopy this effect is not being addressed at this time.

While there are many sources of phosphorus in urban stormwater, a primary contributor is organic detritus, especially in areas with dense overhead tree canopy (Duan et al, 2014; Hobbie et al, 2014; and Kalinosky et al, 2014). Measurement of end-of-pipe phosphorus concentrations has demonstrated that phosphorus loads in urban stormwater vary seasonally in certain medium density residential areas, with higher concentrations coinciding with leaf accumulation on streets (Selbig, 2016). As phosphorus discharges in stormwater can vary from year to year depending on timing of rainfall events, seasonal phosphorus loads were modeled over a twenty-year period with WinSLAMM to determine the average proportion that is discharged in the fall. From this information, it is estimated that on average 43% of the annual phosphorus load is discharged in the fall.

A variety of public works programs are already in place to collect leaves from the streets and properties in the fall, but until recently, little was known about the phosphorus reduction potential of different leaf collection programs. Over the last four years, the United States Geological Survey (USGS) conducted a study to characterize reductions of total and dissolved forms of phosphorus in stormwater through a municipal leaf collection and street cleaning programs in Madison, Wisconsin, USA. Some credit for phosphorus reduction is warranted based on the information.

To estimate the efficiency of leaf collection, leaves were collected three to four times at the test site and collected only once at the end of the fall at the control site. A small vehicle was used to push the leaves from the terrace into the street and then the leaves were pushed into garbage trucks. Within 24 hours of leaf collection, remaining leaf litter in the street was collected using mechanical street cleaners. Eight end-of-pipe phosphorus concentration measurements were compared at the test and control sites during the fall of 2016. Water quality data collected indicate that the collection and transfer method resulted in a 40% reduction of total phosphorus discharge in the fall at the test site versus the control site.

D. Guidance Content

A municipality may assume the specified reduction from no controls phosphorus loads provided all of the conditions are met. Further evaluation is required to determine how leaf collection methods may reduce loading to structural best management practices (BMPs) such as ponds. Therefore, this credit may not be taken in addition to phosphorus reductions from other BMPs in the drainage area at this time.

Transfer Plus Street Cleaning Method of Leaf Collection

Municipalities may assume 17% (40% reduction due to collection efforts x 43% of annual phosphorus load occurring in fall) Total Phosphorus annual load reduction for the leaf collection effort in the Medium Density Residential No Alleys (MDRNA) land use for this option. If the credit is desired for an area containing MDRNA and other land uses, the annual load reduction must be modified by the percent of the total phosphorus load from the area that is from the MDRNA. For example, the phosphorus load from a MDRNA might represent 60% of the load from the entire area. The new annual percent reduction for the area would be 10% (17% X 60%). Municipalities may apply the leaf credit to a subset of their MDRNA area if other BMPs are providing more phosphorus reduction for the remaining area. At this time credit for leaf collection is not available for other land uses or lower-density tree canopies. The Total Phosphorus annual load reduction for this option may be assumed if the following conditions are met:

1. Medium Density (2-6 units/acre) Residential (Single-family) land use without alleys. Medium Density Residential with alleys land use may be included if the alleys receive the same level of leaf collection and street cleaning as the streets.

2. Curb and gutter with storm sewer drainage systems and light parking densities during street cleaning activities.
3. An average of one or more mature trees located between the sidewalk and the curb for every 80 linear feet of curb. Where sidewalk is not present, trees within 15 feet of the curb may be counted toward tree cover. Generally, this equates to a tree canopy over the street (pavement only) of 17% or greater. Field investigations or aerial photography may be used to document the tree cover.
4. The municipality has an ordinance prohibiting residents from placement of leaves in the street and a policy stating that residents may place leaves on the terrace in bags or piles for collection.
5. Municipal leaf collection provided at least 4 times spaced throughout the months of October and November. Leaves may be pushed, vacuumed, or manually loaded into a fully enclosed vehicle, such as a garbage truck or covered dump truck. No leaf piles are left in the street overnight.
6. Within 24 hours of leaf collection, remaining leaf litter in the street must be collected using street cleaning machines, such as a mechanical broom or vacuum assisted street cleaner. A brush attachment on a skid steer is not an acceptable equivalent.

It is anticipated that additional scenarios will be added as research is completed.

E. References

Duan, S., Delaney-Newcomb, K., Kaushal, S.S., Findlay, S.E.G., Belt, K.T., 2014. Potential effects of leaf litter on water quality in urban watersheds. Biogeochemistry 121, 61–80. http://dx.doi.org/10.1007/s10533-014-0016-9.

Hobbie, S.E., Baker, L.A., Buyarski, C., Nidzgorski, D., Finlay, J.C., 2014. Decomposition of tree leaf litter on pavement: implications for urban water quality. Urban Ecosyst. 17 (2), 369–385. http://dx.doi.org/10.1007/s11252-013-0329-9.

Kalinosky, P., Baker, L.A., Hobbie, S., Bintner, R., Buyarksi, C., 2014. User support manual: estimating nutrient removal by enhanced street sweeping. Report to the Minnesota Pollution Control Agency (available at: http://larrybakerlab.cfans.umn.edu/files/2011/07/Kalinosky-et-al.-2014.-Street-Sweeping-Guidance-Manual-final-9-24-2014.docx, (accessed April 11th, 2016)).

Selbig, W.R., 2016, Evaluation of leaf removal as a means to reduce nutrient concentrations and loads in urban stormwater, Science of the Total Environment, 571, pp. 124 – 133. http://dx.doi.org/10.1016/j.scitotenv.2016.07.003

CREATED:

Amy Minser, Stormwater Engineer
On behalf of the Storm Water Liaison Team

3/8/18
Date

APPROVED:

Mary Anne Lowndes, Chief
Runoff Management Section

3/9/18
Date

Runoff Management Policy Management Team approved on February 1, 2018.
Division Administrator approved March 6, 2018.

COMMITMENT & INTEGRITY DRIVE RESULTS

WOODARD & CURRAN
33 Broad Street, 7th Floor
Providence, Rhode Island, 02903
Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	9/12/2019
CHECKED BY:	HCP	DATE:	10/18/2019
PROJECT NO.	230525.03	SHEET NO.	1

Proposed Pollutant Loading Calculations - WI DNR Comparison

Lake Outfall #5 Proposed Conditions

Location: Saxon Road & Terrace/Lakewood Road/Norman Road/Lake Ave

Drainage Area: 7.27 AC

Land Use:	High Density Residential	Total Impervious	2.51 AC
		Pervious HSG A (2.41 IN/HR)	4.76 AC
		Impervious Roadway	1.00 AC

Non-Structural BMPs Load Reduction Credit

	TP	TN	TSS
Enhanced Sweeping Reduction (PRF = 0.10, AF = 0.75)	0.17	NC	NC
Catch Basin Cleaning Reduction (PRF = 0.02)	0.12	NC	NC
Organic Waste/Leaf Litter Collection Reduction (WI DNR PRF = 0.17, Entire Watershed)	**1.01**	NC	NC
Pollutant Load Reduction (lbs/yr)	1.30	NC	NC

Total Load

	TP	TN	TSS
Pollutant Load Generated (lbs/yr)	5.97	36.67	1,135.71
Non-Structural BMP Reduction (lbs/yr)	1.30	NC	NC
Existing Structural BMP Reduction (lbs/yr)	0.00	0.00	0.00
Proposed Structural BMP Reduction (lbs/yr)	0.00	0.00	0.00
Pollutant Load Remaining (lbs/yr)	**4.67**	**36.67**	**1,135.71**

Leaf Litter Increase in Pollutant Reduction Compared to EPA **3.48 times more credit**

APPENDIX H: COST ESTIMATES

COMMITMENT & INTEGRITY
DRIVE RESULTS

CLIENT	Newton MA	DATE	11/26/2019
PROJECT	Crystal Lake	DATE	
DESIGNED BY		DATE	
COST BY		SHEET NO.	1 of 1
CHECKED BY			
PROJECT NO.	230525.03		

Conventional Broom Street Sweeping Cost Estimates

STREET SWEEPING ASSUMPTIONS					
13	Lane-miles per day		CY disposed annually	0.50	Volume per Lane Mile (yds)
1	No. of operators	2	CY disposed per trip		
$30.00	Hourly Labor Rate	$135	per CY disposed		

CAPITAL OPERATIONS AND MAINTENANCE							
Equipment & Maintenance	***Unit Cost per Hour***		***Hours per Event***	***O&M Cost per Event***		***Annual O&M Costs***	
Elgin Pelican	$	65.00	3.08	$	200.00	$	6,400.00
Disposal			1	$	300.00	$	9,600.00
			Annual Capital Replacement and Maintenance			***$***	***16,000.00***

SWEEPING LABOR					
	Lane-Miles	***Labor Cost per Event***		***Annual Sweeping Labor Costs***	
City Roadways	4.0	$	92.31	$	2,953.85
	Annual Street Sweeping Labor			***$***	***3,000.00***
	TOTAL ANNUAL STREET SWEEPING COSTS			***$***	***19,000.00***

Cost Analysis Assumptions:

1. Annual Street Sweeping Costs assume weekly sweeping of all city-owned roadways in non-winter months (April-November ~32 weeks)
2. Capital Operations and Maintenance Costs have been normalized and incorporated into an hourly rate of use.
3. Costs apply to sweeping of city-owned roads only.
4. City roadway miles per GIS analysis. Two (2) lane-miles assumed per mile of roadway.
5. Disposal volume assumed to be per trip in Crystal Lake watershed.
5. Ten (10) -hour work days.

COMMITMENT & INTEGRITY
DRIVE RESULTS

CLIENT	Newton, MA	DATE	11/26/2018
PROJECT	Crystal Lake	DATE	
DESIGNED BY	ZLH	DATE	
COST BY		SHEET NO.	1 of 1
CHECKED BY			
PROJECT NO.	230525.03		

Regenerative Air Street Sweeping Cost Estimates

STREET SWEEPING ASSUMPTIONS					
13	Lane-miles per day		CY disposed annually	0.50	Volume per Lane Mile (yds)
2	No. of operators	2	CY disposed per trip		
$30.00	Hourly Labor Rate	$135	per CY disposed		

CAPITAL OPERATIONS AND MAINTENANCE

Equipment & Maintenance	Unit Cost per Hour	Hours per Event	O&M Cost per Event	Annual O&M Costs
Tymco 500x Street Sweeper	$ 102.00	3.08	$ 313.85	$ 10,043.08
Disposal		1	$ 300.00	$ 9,600.00
		Annual Capital Replacement and Maintenance		***$ 19,643.08***

SWEEPING LABOR

	Lane-Miles in Watershed	Labor Cost per Event	Annual Sweeping Labor Costs
City Roadways	4.0	$ 184.62	$ 5,907.69
		Annual Street Sweeping Labor	***$ 6,000.00***
		TOTAL ANNUAL STREET SWEEPING COSTS	***$ 25,643.08***

Cost Analysis Assumptions:

1. Annual Street Sweeping Costs assume weekly sweeping of all city-owned roadways in non-winter months (April-November ~32 weeks)
2. Sweeper unit costs have been developed by the City of Portland, ME from 2010 estimates as hourly rate of use. Costs increased by 20% for 2019 estimates.
3. Costs apply to sweeping of city-owned roads only.
4. City roadway miles per GIS analysis. Two (2) lane-miles assumed per mile of roadway.
5. Ten (10) -hour work days.

COMMITMENT & INTEGRITY
DRIVE RESULTS

CLIENT	Newton MA	DATE	11/26/2019
PROJECT	Crystal Lake	DATE	
DESIGNED BY	ZLH	DATE	
COST BY		SHEET NO.	1 of 1
CHECKED BY			
PROJECT NO.	230525.03		

Catch Basin Cleaning Cost Estimates

	No. Catch Basins	Cost per Catch Basin	Cost per Event	Annual Costs
Catch Basin Cleaning	49	$ 40.75	$ 1,996.75	$ 3,993.50
Disposal		$ 13.50	$ 661.50	$ 1,323.00
	TOTAL ANNUAL CATCH BASIN CLEANING COSTS			***$ 5,316.50***

Cost Analysis Assumptions:

1. Assumes all catch basins are cleaned twice annually. ~0.5 tons per basin from Leominster, MA 0.45 tons per basin and Auburn, ME 0.3 tons per basin (2019)
2. Catch basin cleaning unit cost includes labor, equipment and disposal costs - as provided by City of Newton.
3. Number of catch basins determined using GIS database.
4. Costs apply to catch basins located within the ROW only.

COMMITMENT & INTEGRITY
DRIVE RESULTS

WOODARD & CURRAN
33 Broad Street, 7th Floor
Providence, Rhode Island, 02903
Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	1/6/2020
CHECKED BY:	HCP	DATE:	1/6/2020
PROJECT NO.	230525.03	SHEET NO.	1

Cronin's Cove (Outfall #1 & #2) Infiltration Trench Cost Estimate

BMP Cost Estimate (with 20% Contingency)	$150,000	
Engineering Design & Permitting (15%)	$22,500	
Total Cost	**$172,500**	over 20 years
Annual Inspection/Maintenance Cost	**$1,000**	
Annual Cost	**$9,625**	
Total Phosphorus Removed	4.01 lbs/year	
Annual Cost-Benefit	**2,401 $/lb**	

BMP Cost Estimate Includes:

1. Site Preparation: erosion control, demolition
2. Earthwork: excavation, backfill, load and haul off-site
3. Ancillary utilities: observation well, drainage pipe, 2 deep sump catch basins
4. Site Improvements: nonwoven geotextile fabric
5. Planting: site restoration

BMP Cost Estimate Does not Include:

1. Administrative Requirements: mobilization/demobilization, project manager/superintendent, field engineer, etc.
2. Quality Requirements: testing and inspections
3. Temporary Facilities and Controls
4. Execution Requirements

COMMITMENT & INTEGRITY
DRIVE RESULTS

WOODARD & CURRAN
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Providence, Rhode Island, 02903
Tel: 800.985.7897 Fax: 401.273.5087

CLIENT:	City of Newton, MA		
PROJECT:	Crystal Lake Watershed Assessment		
DESIGNED BY:	CNQ	DATE:	1/6/2020
CHECKED BY:	HCP	DATE:	1/6/2020
PROJECT NO.	230525.03	SHEET NO.	1

Outfall #8A Infiltration Chamber Cost Estimate

BMP Cost Estimate (with 20% Contingency)	$165,000	
Engineering Design & Permitting (15%)	$24,750	
Total Cost	**$189,750**	**$190,000** over 20 years
Annual Inspection/Maintenance Cost		**$1,000**
Annual Cost		**$10,500**
Total Phosphorus Removed		6.50 lbs/year
Annual Cost-Benefit		**1,615 $/lb**

BMP Cost Estimate Includes:

1. Site Preparation: erosion control, remove asphalt paving
2. Earthwork: excavation, backfill, load and haul off-site
3. Ancillary utilities: drainage pipe
4. Site Improvements: Stormtech Chambers, pavement, nonwoven geotextile fabric

BMP Cost Estimate Does not Include:

1. Administrative Requirements: mobilization/demobilization, project manager/superintendent, field engineer, etc.
2. Quality Requirements: testing and inspections
3. Temporary Facilities and Controls
4. Execution Requirements

woodardcurran.com

COMMITMENT & INTEGRITY DRIVE RESULTS