EXPERT REPORT

TMDL Attainability Analyses for Phosphorus and Fecal Coliform for Mashapaug Pond, Rhode Island

Prepared for:
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Acronym	Definition
ASCE	AMERICAN SOCIETY OF CIVIL ENGINEERS
BMP	STORMWATER BEST MANAGEMENT PRACTICE
CFR	CODE OF FEDERAL REGULATIONS
CLF	CONSERVATION LAW FOUNDATION
CSM	CONCEPTUAL SITE MODEL
CWA	CLEAN WATER ACT
DWRE	DIPLOMATE, WATER RESOURCES ENGINEER
EPA	UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
EWRI	ENVIRONMENTAL WATER RESEARCH INSTITUE
EMC	EVENT MEAN CONCENTRATION
FC	FECAL COLIFORM
FR	FEDERAL REGISTER
FRCP	FEDERAL RULES OF CIVIL PROCEDURE
GIS	GEOGRAPHIC INFORMATION SYSTEMS
HRU	HYDROLOGIC RESPONSE UNIT
IA	IMPERVIOUS AREA
LA	LOAD ALLOCATION
LID	LOW IMPACT DEVELOPMENT
LIDAR	LIGHT DETECTION AND RANGING
MSGP	MULTI-SECTOR GENERAL PERMIT
NCDC	NATIONAL CLIMATE DATA CENTER
NOI	NOTICE OF INTENT
NRCC	NORTHEAST REGIONAL CLIMATE CENTER
NRCS	NATURAL RESOURCES CONSERVATION SERVICE
NPDES	NATIONAL POLLUTION DISCHARGE ELIMINATION PERMITS
PE	PROFESSIONAL ENGINEER
PLA	POLLUTANT LOADING ANALYSES
PLER	POLLUTANT LOAD EXPORT RATES
RDA	RESIDUAL DESIGNATION AUTHORITY
RIDEM	RHODE ISLAND DEPARTMENT OF ENVIRONMENTAL MANAGEMENT
RISWM	RHODE ISLAND STORMWATER MANUAL
SWM	STORMWATER MANAGEMENT
SWMM	STORMWATER MANAGEMENT MODEL
SWPPP	STORMWATER POLLUTION PREVENTION PLAN
TMDL	TOTAL MAXIMUM DAILY LOAD
TP	TOTAL PHOSPHOROUS
TSS	TOTAL SUSPENDED SOLIDS
USDA	UNITED STATES DEPARTMENT OF AGRICULTURE
USGS	UNITED STATES GEOLOGICAL SURVEY
UWRCC	URBAN WATER RESOURCES RESEARCH COUNCIL
WEF	WATER ENVIRONMENT FEDERATION
WLA	WASTE LOAD ALLOCATION
WQV	WATER QUALITY VOLUME

1. Expert Opinion

This written report is submitted in compliance with the disclosure requirements set forth in the Federal Rules of Civil Procedure (FRCP) 26(a)(2)(B), subject to the right to supplement the report in accordance with FRCP 26(e). This report focuses on the TMDL attainability for phosphorus and fecal coliform for Mashapaug Pond, Rhode Island.

The exhibits that will be used to summarize and support the opinions expressed in this report are exhibits which appear in, are transmitted with, or referred to in this report. The exhibits may be revised to allow for presentation in a manner more suitable to the proceedings where they are used. I reserve the right to update my opinion as new information becomes available.

Disclosure items as required by FRCP 26(a)(2)(B) are listed below and can be found in the following sections:

i. A complete statement of all opinions the witness will express and the basis and reasons for them are contained within the entirety of this Report;
ii. The facts or data considered by the witness in forming them are contained or referred to within the entirety of this Report;
iii. Any exhibits that will be used to summarize or support the witness's opinions are contained or referred to within the entirety of this Report;
iv. The witness's qualifications, including a list of all publications authored in the previous 10 years (Section 1.3 and Appendix A);
v. A list of all other cases in which, during the previous 4 years, the witness testified as an expert at trial or by deposition (Section 1.3.3 and Appendix A); and
vi. A statement of the compensation to be paid for the study and testimony in the case (Section 1.3.4).

1.1. Report Objectives

Waterstone Engineering PLLC has been retained to conduct the following scope of services:

1. Conduct an analysis of pollutant loading for the watershed of Mashapaug Pond;
2. Review available documentation including permits and related studies;
3. Develop a watershed model to calculate the pollutant loading from stormwater for phosphorous and fecal coliform;
4. Calculate the load reduction potential for regulated areas for a range of performance scenarios for BMP implementation; and
5. Establish opinions related to TMDL attainability for phosphorous and fecal coliform based on potential BMP implementation scenarios.

1.2. Summary Opinions

The following opinions are based on:

1. Review of immediately relevant permits, reports and related information by EPA and RIDEM including TMDLs for Mashapaug Pond:
    a. Final Rhode Island Statewide TMDL for Bacteria Impaired Waters, September 2011
        i. Mashapaug Pond Watershed Summary
    b. Total Maximum Daily Load for Dissolved Oxygen and Phosphorus, Mashapaug Pond, Rhode Island, September 2007
2. Review of relevant regulatory requirements for Residual Designation Authority including the Fact Sheet for the RDA General Permit For Designated Discharges[1] and Basis for Phosphorus Reduction Requirements[2];
3. Review of land use and land cover data of the Site;
4. Development and analysis of a hydrologic and hydraulic model of the watershed to quantify the annual average volume of discharge from the watershed, and to quantify potential pollutant loading to Mashapaug Pond; and
5. Development and analysis of a spreadsheet model to quantify potential pollutant loading, and BMP pollutant load reduction to Mashapaug Pond.

Phosphorus TMDL Attainability:

This analysis determined that the Phosphorus TMDL can be met for Mashapaug Pond by implementing the maximum potential load reduction for all areas currently covered and not covered under the NPDES program. Phosphorous attainability would require industrial, commercial, and residential land use parcels larger than 1 acre to be managed with the best available BMP technology (bioretention systems). For the purposes of this analyses, it was assumed that government-owned properties that drain to an MS4 are regulated under NPDES, and residential, commercial, industrial, agricultural, and open space properties are not. This analysis assumed that EPA[3] would exercise the authority for use of residual designation to regulate industrial, commercial, and residential properties >1 acre. A parcel-based pollutant loading analysis identified that a minimum parcel area of 1 acre for which RDA could be applied would achieve the required load reductions.

With respect to phosphorous, a target area of >1 acre encompasses only 1% of all residential parcels, 3% of commercial parcels, and 84% of industrial parcels (23 total parcels) and reduces the existing load by 53% (243 lbs. TP). In contrast, parcel areas >2.5 acres encompass no residential parcels, no commercial parcels, and 56% of all industrial parcels (14 total parcels) and manages (removes) 50% (229 lbs. TP) of the existing load in the Mashapaug Pond watershed.

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[1] EPA (2012). Fact Sheet For The General Permit For Designated Discharges In The Charles River Watershed In Milford, Bellingham And Franklin Massachusetts. RD Fact Sheet, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.
[2] EPA (2012). Attachment 3 to Fact Sheet: Basis for Phosphorus Reduction Requirements. RD Fact Sheet Attachment 3, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.
[3] EPA (2012). Fact Sheet for the General Permit For Designated Discharges in the Charles River Watershed in Milford, Bellingham and Franklin Massachusetts. RD Fact Sheet, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.

Fecal Coliform TMDL Attainability:
This analysis indicates a tremendous 58% reduction in pollutant load could be achieved for fecal coliform however TMDL attainability does not appear to be possible at this point in time. Fecal coliform reductions would require industrial, commercial, and residential parcels larger than 1 acre to be managed with the best available BMP technology (infiltration systems). It is important to recognize that the significant bacterial load reduction would still bring tremendous benefits. It is possible that bacterial reduction requirements could be achieved with an improved understanding of the ecosystem through monitoring and modeling.

With respect to fecal coliform in Mashapaug Pond watershed, management of parcel areas >1 acre reduces the existing load by 58% (3.51E+13 Fecal Coliform CFUs). In contrast, a target area of 2.5 acres would remove 54% of the existing load (3.24E+13 Fecal Coliform CFUs).

1.3. Qualifications and Compensation

1.3.1. Education

Dr. Roseen received a Bachelor of Arts in Environmental Science/Chemistry from Clark University in 1994. Dr. Roseen received a Master of Science in Environmental Science and Engineering from the Colorado School of Mines in 1998 and a Doctor of Philosophy (Ph.D.) in Civil and Waste Resources Engineering from the University of New Hampshire in 2002. Dr. Roseen served as the Director of the University of New Hampshire Stormwater Center from 2004 through 2012, and served as a Research Assistant Professor from 2007-2012. Dr. Roseen has a Professional Engineering license for the State of New Hampshire and is a Diplomat of Water Resources Engineering ("D.WRE"), the highest professional engineering distinction in this area, through the American Academy of Water Resources Engineers.

1.3.2. Professional Experience

Dr. Roseen is the owner and principal at Waterstone Engineering, Inc. and a Water Resources Engineer in New Hampshire who offers municipal and private clients over 20 years of experience in the investigation, design, testing, and implementation of stormwater management. Dr. Roseen has many years of experience in water resources investigations and most recently, led a project team in the development of an Integrated Plan for nutrient management for stormwater and wastewater. This plan has received provisional approval by EPA and would be one of the first in the nation. Dr. Roseen is a licensed professional engineering in NH, ME, and MA. Dr. Roseen is a recognized industry leader in green infrastructure and watershed management, and the recipient of 2010 and 2016 Environmental Merit Awards by the US Environmental Protection Agency Region 1. Dr. Roseen consults nationally and locally on stormwater management and planning and directed the University of New Hampshire Stormwater Center for 10 years, and served as faculty in the Department of Civil Engineering for 5 years, and is deeply versed in the practice, policy, and planning of stormwater management. Dr. Roseen has over 20 years of experience in the investigation, design, testing, and implementation of innovative approaches to stormwater management. Dr. Roseen has led the technical analysis of dozens of nutrient and contaminant studies examining surface water pathways, system performance, management strategies, and system optimization.

Dr. Roseen has also served as Research Assistant Professor for five years. His areas of expertise include water resources engineering, stormwater management (including low impact development design), and porous pavements. Dr. Roseen also possesses additional expertise in water resource engineering including hydrology and hydraulics evaluations, stream restoration and enhancement alternatives, dam removal assessment, groundwater investigations, nutrient and TMDL studies, remote sensing, and GIS applications.

Dr. Roseen has also taught classes on Stormwater Management and Design, Fluid Mechanics, and Hydrologic Monitoring and have lectured frequently on these subjects. He is frequently called upon as an expert on stormwater management locally, regionally, and nationally.

As a consultant, Dr. Roseen has worked for private clients engaged in site development and written erosion and sediment control plans, construction management plans, conducted construction inspections, and engaged in construction inspection and reporting.

Dr. Roseen's current activities include Chairing the ASCE EWRI 2016 International Low Impact Development Conference, an annual event that draws participants from around the world to discuss advances in water resources engineering. Dr. Roseen also participate as a Control Group member for the ASCE Urban Water Resources Research Council (UWRRC). Dr. Roseen has also served on the ASCE Task Committee on Guidelines for Certification of Manufactured Stormwater BMPs, EWRI Permeable Pavement Technical Committee, and the Hydrology, Hydraulics, and Water Quality Committee of the Transportation Research Board. Dr. Roseen has also been the author or co-author of over two dozen professional publications on the topics of stormwater runoff, mitigation measures, best management practices (BMPs), etc. He has also been the recipient of several awards and other honors for his work, including the 2010 Outstanding Civil Engineering Achievement Award from the New Hampshire Chapter of the American Society of Civil Engineers, and an Environmental Merit Award from the EPA. He has extensive experience working with local, state, and regional agencies and participates on a national level for EPA Headquarters, WEF, and the White Council on Environmental Quality on urban retrofit innovations and next generation LID/GI technology and financing solutions. His resume, including a list of all publications over the past 10 years and all cases in which he has served as an expert in for the past 5 years, is provided in Appendix A: Expert Witness Resume, Publications Authored in Previous 10 years, Expert Witness Experience

1.3.3. Cases During the Previous 4 Years I have Testified as an Expert at Trial or by Deposition, or Provided Expert Witness Services

Construction General Permit (CGP), and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modeling, advice, reports and testimony in regards to construction general permit compliance, erosion and sedimentation control, and monitoring. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities.

Municipal Separate Storm Sewer System (MS4) Permit and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MS4 violations under the Clean Water Act. Such services may include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities. This service is being provided for the plaintiff for two (2) cases of significant size geographically and in project scope.

Multi Sector General Permit, Stormwater Pollution Prevention Plan, and Clean Water Act Expert Services
Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MSGP under the Clean Water Act. Such services may include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of facilities. This service is being provided for the plaintiff for over ten (10) separate cases in the northeastern United States.

Expert Study and Testimony for Erosion and Sediment Control Litigation
Dr. Roseen is currently providing expert study and testimony in defense of an undisclosed Federal Client in a $25-million-dollar lawsuit from a private entity. The plaintiff alleges impacts from upstream channel erosion and sediment transport. The efforts examine urban runoff and off-site impacts to a downstream channel and subsequent erosion and sediment transport into the downstream storm sewer system.

1.3.4. Compensation
The flat rate for all work including future deposition and testimony is $135 per hour. The compensation for this effort is entirely unrelated to the outcome of this litigation.

2. Introduction

2.1. Overview
Phosphorus and fecal coliform loads were calculated for Mashapaug Pond (RI0006017L-06) for the purpose of identifying if required reductions for the 2007-2011 Statewide TMDLs are attainable within the existing NPDES permit programs. The analytical methods used to determine the pollutant loads, waste load allocations, and assess BMP performance are consistent with those published by EPA[4], USGS[5] and others[6], and are generally accepted for water quality permitting purposes.

A pollutant load analysis was conducted using published contaminant concentrations and pollutant load export rates (existing[7] and derived) for specific hydrologic response units (HRUs) for respective combinations of land use, soil type, and impervious area. This included a review of relevant federal and state permitting documents[8] for the water bodies of interest and related studies[5,6] for methods assessment and modeling of bacteria and phosphorous loads.

The pollutant load reduction potential for each watershed was assessed assuming that new development, redevelopment, or installation of stormwater best management practice (BMP) retrofits in all runoff-producing areas would provide treatment for the 1" water quality volume (WQV). The pollutant removal

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[4] EPA (2010a)
[5] Zarriello, P. J. and L. K. Barlow (2002)
[6] Gamache, M., M. Heineman, et al. (2013)
[7] EPA (2017)
[8] RIDEM, EPA (2011)

efficiencies from the EPA (2010) [4] and the Rhode Island Stormwater Manual (RISWM)[9] for a range of BMPs were applied to each watershed in 4 scenarios (maximum, high, moderate, and minimum) to determine upper and lower bounds for pollutant load reduction attainability. This represents a conservative assessment given that site-specific feasibility for stormwater management was not considered, it is unlikely that stormwater management (SWM) would be required for all impervious areas (IA). Taking this approach identifies the best-case scenario for pollutant load reduction, useful for evaluating if a given TMDL is even theoretically achievable within the current regulatory framework.

Finally, a parcel-based analysis was layered on top of the four BMP scenarios to assess how three different potential RDA scenarios would impact TMDL attainability in the Mashapaug Pond watershed. The analysis concludes that the Phosphorus TMDL can be met for Mashapaug Pond under two scenarios, which both assume a 54% phosphorus load reduction from the entire Spectacle Pond watershed:

- implementing bioretention BMPs for stormwater management for all areas currently regulated under NPDES *and* if EPA[10] or RIDEM expands the scope of its stormwater permitting program to also manage runoff from all residential, commercial, and industrial parcels larger than 2.5 acres via installation of bioretention BMPs.
- implementing infiltration BMPs for stormwater management for all areas currently regulated under NPDES *and* if EPA[11] or RIDEM expands the scope of its stormwater permitting program to also manage runoff from all residential, commercial, and industrial parcels via installation of infiltration BMPs.

However, there is no realistic scenario in which the Mashapaug Pond 2011 fecal coliform TMDL is attainable with current technology, regardless of which land uses are included or excluded from an RDA process.

2.2. Study Area

The Mashapaug Pond watershed [RI006017L-06, USGS HUC 01090004] is located in the Pawtuxet River basin, within an area locally known as Reservoir Triangle of Providence, Rhode Island. Mashapaug Pond has a long history of development along its banks dating back as early as 1636. Mashapaug Pond, situated in the southwest quadrant of Providence, is now bounded by the city of Cranston on the west, Narragansett Avenue to the east and Sinclair Avenue to the south. It is the largest freshwater lake in Providence.

The Pond's surface area is approximately 31 hectares (77 acres) with an average depth of about 3 meters (9.8 feet). Its sources of fresh water are inflow from Spectacle Pond, ground water, and stormwater. The Mashapaug Pond physical watershed, including Tongue Pond and Spectacle Pond, encompasses

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[9] RIDEM (2015)

[10] EPA (2012). Fact Sheet for the General Permit For Designated Discharges in the Charles River Watershed in Milford, Bellingham and Franklin Massachusetts. RD Fact Sheet, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.

[11] EPA (2012). Fact Sheet for the General Permit For Designated Discharges in the Charles River Watershed in Milford, Bellingham and Franklin Massachusetts. RD Fact Sheet, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.

approximately 308 hectares (762 acres) of urban land with a ratio of approximately 2 acres of residential use to 1 acre of industrial use. The watershed surrounding Mashapaug Pond is highly urbanized[12] and essentially fully developed at the present time. Land uses in the storm drain contributing areas[13] adjacent to the Pond range from 75.4 to 100% industrial. Land uses in the direct runoff draining areas[14] range from 11.1% to 95.1% industrial.

The Mashapaug Pond watershed has an impervious cover of 61%.[15] Impervious cover is defined as land surface areas, such as roofs and roads, that force water to run off land surfaces, rather than infiltrating into the soil. Runoff from urban activities, including industry and transportation, fertilization, domestic, wildlife waste, and atmospheric deposition has, and continues to, seriously degrade water quality in Mashapaug Pond. Degraded water quality impairs fish habitat and the use of Mashapaug Pond for contact[16] and non-contact recreation.[17] Urban runoff contains elevated concentrations of phosphorus which can cause excessive algae growth and potentially toxic algal blooms, loss of dissolved oxygen that results in fish kills, and loss of bio-diversity. Excess algal levels are also detrimental to the esthetic value of Mashapaug Pond resulting in color, clarity, and odor problems caused by living and decomposing algae.

2.3. Pollutants of Concern

The *State of Rhode Island 2014 303(d) List, List of Impaired Waters FINAL* identifies Mashapaug Pond (Waterbody ID Number RI0006017L-06) as impaired by excess algal growth, dissolved oxygen, phosphorous (total), PCB in fish tissue, and fecal coliform.[18] The *2014 303(d) List of Impaired Waters* identifies Mashapaug Pond as a Category 5 waterbody, meaning it is impaired/threatened for designated use(s) by a pollutant(s) and requires a TMDL. Inputs of water into Mashapaug Pond include precipitation, storm sewer drainage, direct overland runoff, and ground water. Mashapaug Pond is fed by groundwater discharging into the bottom and edges of the pond. The Pond has one tributary, Mashapaug Brook, that enters from Spectacle Pond.

Under existing conditions, the water quality standards for dissolved oxygen and phosphorus are not met in Mashapaug Pond. Average total phosphorus levels ranged from 30–50 ug/l during the summer of

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[12] The area surrounding Mashapaug Pond is entirely urban. *Final TMDL Mashapaug Pond, RI* at 6.

[13] Six storm drains discharge directly into the Pond. *Final TMDL Mashapaug Pond, RI* at 6.

[14] The areas immediately adjacent to the Pond shore where no sewers or storm drains exist are assumed to drain directly into the Pond. *Final TMDL Mashapaug Pond, RI* at 6.

[15] A level where stormwater impacts are expected. RI DEM, *Rhode Island Statewide TMDL for Bacteria Impaired Waters, Mashapaug Pond Watershed Summary*, at 7 (Jun. 2011) http://www.dem.ri.gov/programs/benviron/water/quality/swbpdf/mashpaug.pdf.

[16] Recreational activities in which there is prolonged and intimate contact by the human body with the water, involving considerable risk of ingesting water, such as swimming, diving, water skiing and surfing are primary contact recreational activities. *See* Rule 7 of Rhode Island's Water Quality Regulations, *Definitions*, R.I. Code R. 25-16-25:7.

[17] Recreational activities in which there is minimal contact by the human body with the water, and the probability of ingestion of the water is minimal, such as boating and fishing are secondary contact recreational activities. *See* Rule 7 of Rhode Island's Water Quality Regulations, *Definitions*, R.I. Code R. 25-16-25:7.

[18] RIDEM. 2007. Final Total Maximum Daily Load for Dissolved Oxygen and Phosphorus, Mashapaug Pond, Rhode Island.

2001[19] in violation of the state's water quality standards. Although the sources of phosphorus in runoff from storm drains and direct overland flow are nonpoint in nature, they are regulated as point sources and are considered controllable. In order to meet phosphorus reduction targets for these stormwater sources and to reduce wet weather fecal coliform concentrations, a combination of upland and end of pipe control structures to treat and reduce runoff volumes, land use management, and conservation efforts and source reduction within the watershed is recommended.

2.4. Regulatory Background

2.4.1. TMDL Process

As per EPA[20], a TMDL is the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

Pollutant sources are characterized as either point sources that receive a wasteload allocation (WLA), or nonpoint sources that receive a load allocation (LA). For purposes of assigning WLAs, point sources include all sources subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program, e.g. wastewater treatment facilities, some stormwater discharges and concentrated animal feeding operations (CAFOs). For purposes of assigning LAs, nonpoint sources include all remaining sources of the pollutant as well as natural background sources. TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.

The objective of a TMDL is to determine the loading capacity of the waterbody and to allocate that load among different pollutant sources so that the appropriate control actions can be taken and water quality standards achieved. The TMDL process is important for improving water quality because it serves as a link in the chain between water quality standards and implementation of control actions designed to attain those standards.

TMDLs are developed using a range of techniques, from simple mass balance calculations to complex water quality modeling approaches. The degree of analysis varies based on a variety of factors including the waterbody type, complexity of flow conditions and pollutant causing the impairment.

All contributing sources of the pollutants (point and nonpoint sources) are identified, and they are allocated a portion of the allowable load that usually contemplates a reduction in their pollution discharge in order to help solve the problem. Natural background sources, seasonal variations and a margin of safety are all taken into account in the allocations.

It is important to note that, throughout the remainder of this document, a distinction will be made between the terms 'total maximum daily load', which will be used to refer to the numeric load target for

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[19] Field monitoring was conducted by EPA contractor, ESS during 2001 to collect water quality data for the TMDL. *Final TMDL Mashapaug Pond, RI* at vii.

[20] https://www.epa.gov/tmdl/overview-total-maximum-daily-loads-tmdls

a given pollutant, and ‘TMDL’, which will be used to refer to the actual document generated by EPA that defines and describes the total maximum daily load.

2.4.2. Existing TMDLs

Mashapaug Pond Phosphorus TMDL

In 2007 a TMDL was developed for Mashapaug Pond to address excessive phosphorous loading. As per the 2007 TMDL, an outfall pipe from Spectacle Pond to Mashapaug Pond is responsible for a considerable portion of the annual phosphorus load to Mashapaug. A TMDL has also ben developed for Spectacle Pond for phosphorus, and the load contribution from Spectacle Pond to Mashapaug has been directly measured via water quality samples. The TMDL process resulted in the designation of a total maximum annual phosphorus load of 237 lbs. for Mashapaug Pond, a 54% reduction from current conditions.

Mashapaug Pond Fecal Coliform TMDL

In 2011 a TMDL was developed for Mashapaug Pond to address excessive fecal coliform loading. The TMDL identified a required percentage reduction in fecal coliform loading of 92% based on observed concentrations in the water body.

2.4.3. Role of RDA

Under the Clean Water Act “Residual Designation Authority” (RDA) found in § 402(p)(2)(E) of the Clean Water Act, and 40 C.F.R. § 122.26(a)(9)(i)(C) and (D), EPA can require permits for new and existing stormwater discharges that contribute to a water quality violation or are a significant contributor of pollutants to waters of the United States. RDA has been used to issue NPDES permits to control unregulated discharges—including discharges from wastewater treatment facilities and MS4 communities—to include requirements for pollutant reduction consistent with the wasteload allocations of a TMDL. Within TMDLs, two major waste sources are generally defined, and allocations set: 1) a wasteload allocation (WLA), which is generally defined as the sum of the pollutant load discharged from all “discrete conveyances” contributing to the impairment, such as discharge pipes or ditches and is regulated under a NPDES permit; and 2) a load allocation (LA), which is the sum of the remaining sources such as runoff, groundwater and atmospheric deposition that are more diffuse and not subject to regulation under a NPDES permit. This division occasionally causes confusion as certain classes of stormwater are regulated under the various stormwater permits (i.e., MS4, industrial stormwater, and construction stormwater) that were previously considered non-point sources. But, because they come under a permit, they become part of the WLA; nearly identical stormwater sources in non-MS4 areas are not regulated and remain in the LA and are not typically subject to an NPDES permit.

Since 2008, EPA Region 1 has exercised RDA in watersheds in Maine, Massachusetts, and Vermont where existing programs were not adequately addressing stormwater. In these instances, RDA was used to address sources of pollution not covered under existing NPDES programs such as communities outside of the MS4 jurisdiction, and large unregulated impervious areas such as malls and shopping centers.

This approach is the centerpiece of a stormwater management pilot program that EPA and MADEP are implementing in Milford, Bellingham and Franklin, Massachusetts. Similar stormwater management programs are being implemented in impaired streams in South Burlington, Vermont and in Long Creek and around South Portland, Maine. Those programs grew from residual designation determinations requiring stormwater controls on previously unregulated discharges and provide a third regional model for the designation and permitting of stormwater discharges to impaired waters, a significant environmental concern in New England[3]. In these cases, the TMDLs address severe water quality impairments resulting from nutrients and bacteria in stormwater. At the time of the establishment of the TMDLs, NPDES stormwater permitting addressed only discharges from Municipal Separate Storm Sewer Systems ("MS4s"), limited industrial activity sectors, and construction activities disturbing one or more acres of land. In these cases, EPA has taken the position that the existing permitting regime is not sufficiently comprehensive to achieve the necessary cuts in WLAs and that new strategies are needed to implement the TMDL. As such, EPA has expanded the scope of its stormwater permitting program in these instances by including large impervious areas primarily in commercial and industrial use to which TMDLs attribute significant pollutant loads through the use of RDA.

2.4.4. Unregulated Properties and Designated Discharge

In a similar manner, EPA is using the definition of "designated discharge" in the proposed final designation of the RDA general permit for the Charles River watershed in Milford, Bellingham and Franklin Massachusetts. EPA applies the designated discharge determination to cover discharges that flow directly into surface waters and its tributaries through MS4 systems or other private or public conveyance systems. Specifically, local state and federal government properties that discharge wholly into an MS4 owned and operated by the government unit need not be included. Those discharges are already being addressed by the government unit under its MS4 permit. However, a nongovernment property that discharges into an MS4 system must be counted. In the instance of the Charles River, EPA defines designated discharge as those properties typically with a commercial land use designation with two or more acres of impervious surfaces located: (1) in the watershed; (2) in whole or in part in the municipalities; and (3) on a single lot or two or more contiguous lots. The following impervious surfaces are not included: Any impervious surfaces associated solely with any of the following land uses:

a. Sporting and recreational camps;
b. Recreational vehicle parks and campsites;
c. Manufactured housing communities;
d. Detached single-family homes located on individual lots;
e. Stand-alone multi-family houses with four or fewer units; and
f. Any property owned by a local, state or federal government unit where the property discharges wholly into an MS4 system operated by that local, state or federal government unit that has a valid NPDES permit.

2.4.5. Small MS4 General Permit Updates 2017

Aspects of this analysis are intended to be consistent (in part) with recent advancements in NPDES permitting by EPA. Elements of the 2017 updates to the *NH Small MS4 General Permit* include requirements for BMPs to be optimized for pollutant removal, retrofit inventory and priority ranking to reduce discharges, and Pollutant Source Identification Reporting. It could be expected that future MS4 requirements for these Rhode Island communities could be subject to similar requirements and these analyses could satisfy some permit elements.

Specifically, *Appendix H Requirements Related to Discharges to Certain Water Quality Limited Waterbodies* add new requirements for Discharges to water quality limited waterbodies and their tributaries. *Part I, 1.a Additional or Enhanced BMPs.i.2* refers to the requirement for adoption/amendment of the permittee's ordinance or other regulatory mechanism shall include a requirement that new development and redevelopment stormwater management BMPs be optimized for [pollutant]nitrogen removal; retrofit inventory and priority ranking to reduce nitrogen discharges. *Part I, 1.b Nitrogen Source Identification Report* - *requires within four years of the permit effective date the permittee shall complete a Nitrogen Source Identification Report. The report shall include the following elements: 1. Calculation of total MS4 area draining to the water quality limited water segments or their tributaries, incorporating updated mapping of the MS4 and catchment delineations produced pursuant to Part 2.3.4.6;2. All screening and monitoring results pursuant to Part 2.3.4.7.d., targeting the receiving water segment(s); 3. Impervious area and DCIA for the target catchment; 4. Identification, delineation and prioritization of potential catchments with high nitrogen loading;5. Identification of potential retrofit opportunities or opportunities for the installation of structural BMPs during redevelopment*.

3. Methods

3.1. Land Use Assessment

In order to perform the pollutant load analysis and waste load allocation, detailed land use data from a 2011 Rhode Island GIS dataset[21] was generalized to fit into categories for which pollutant load export rates are available.

Table 1 lists the detailed land uses and resultant categorization into more generalized land uses. Figures 1 and 2 show the land use, impervious cover, and soil type distribution for the Mashapaug Pond watershed. Lands classified as 'Forest' and 'Water' were excluded from pollutant load reduction calculations.

Table 1 - Land use category generalization

Original RIGIS Detailed Land Use	Converted to…for PLA	Converted to…for RDA
Cropland (tillable)	Agriculture	RDA – Agriculture
Orchards, Groves, Nurseries	Agriculture	RDA – Agriculture
Pasture (agricultural not suitable for tillage)	Agriculture	RDA – Agriculture
Idle Agriculture (abandoned fields and orchards)	Open Land	RDA – Open Space
Cemeteries	Open Land	RDA – Open Space
Developed Recreation (all recreation)	Open Land	RDA – Open Space
Power Lines (100' or more width)	Open Land	RDA – Open Space
Transitional Areas (urban open)	Open Land	RDA – Open Space
Vacant Land	Open Land	RDA – Open Space
Brushland (shrub and brush areas, reforestation)	Forest	RDA – Forest
Deciduous Forest (>80% hardwood)	Forest	RDA – Forest
Mixed Forest	Forest	RDA – Forest
High Density Residential (<1/8 acre lots)	High Density Residential	RDA - Residential
Medium High Density Residential (1/4 to 1/8 acre	High Density Residential	RDA – Residential
Medium Density Residential (1 to 1/4 acre lots)	Medium Density	RDA – Residential
Medium Low Density Residential (1 to 2 acres	Medium Density	RDA – Residential
Low Density Residential (>2 acre lots)	Low Density Residential	RDA – Residential
Commercial (sale of products and services)	Commercial and Industrial	RDA – Commercial
Commercial/Industrial Mixed	Commercial and Industrial	RDA – Industrial
Industrial (manufacturing, design, assembly, etc.)	Commercial and Industrial	RDA – Industrial
Institutional (schools, hospitals, churches, etc.)	Commercial and Industrial	MS4
Other Transportation (terminals, docks, etc.)	Commercial and Industrial	MS4
Airports (and associated facilities)	Commercial and Industrial	MS4
Waste Disposal (landfills, junkyards, etc.)	Commercial and Industrial	MS4
Water and Sewage Treatment	Commercial and Industrial	MS4
Roads (divided highways > 200' plus related	Highway	MS4
Water	Water	Water
Wetland	Water	Water

[21] http://www.rigis.org/datasets/land-use-and-land-cover-2011

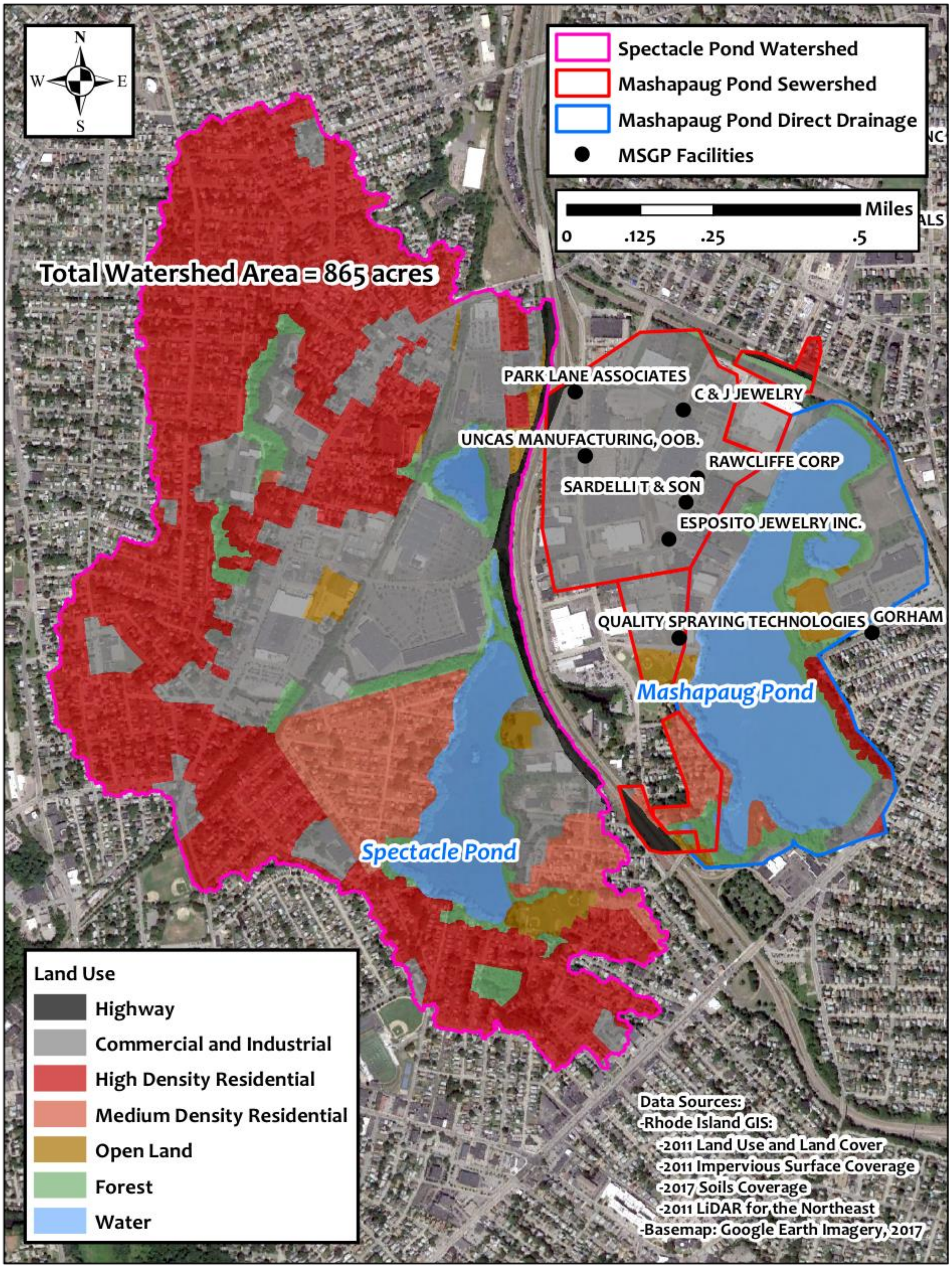

Figure 1 - Land Use in the Mashapaug Pond Watershed

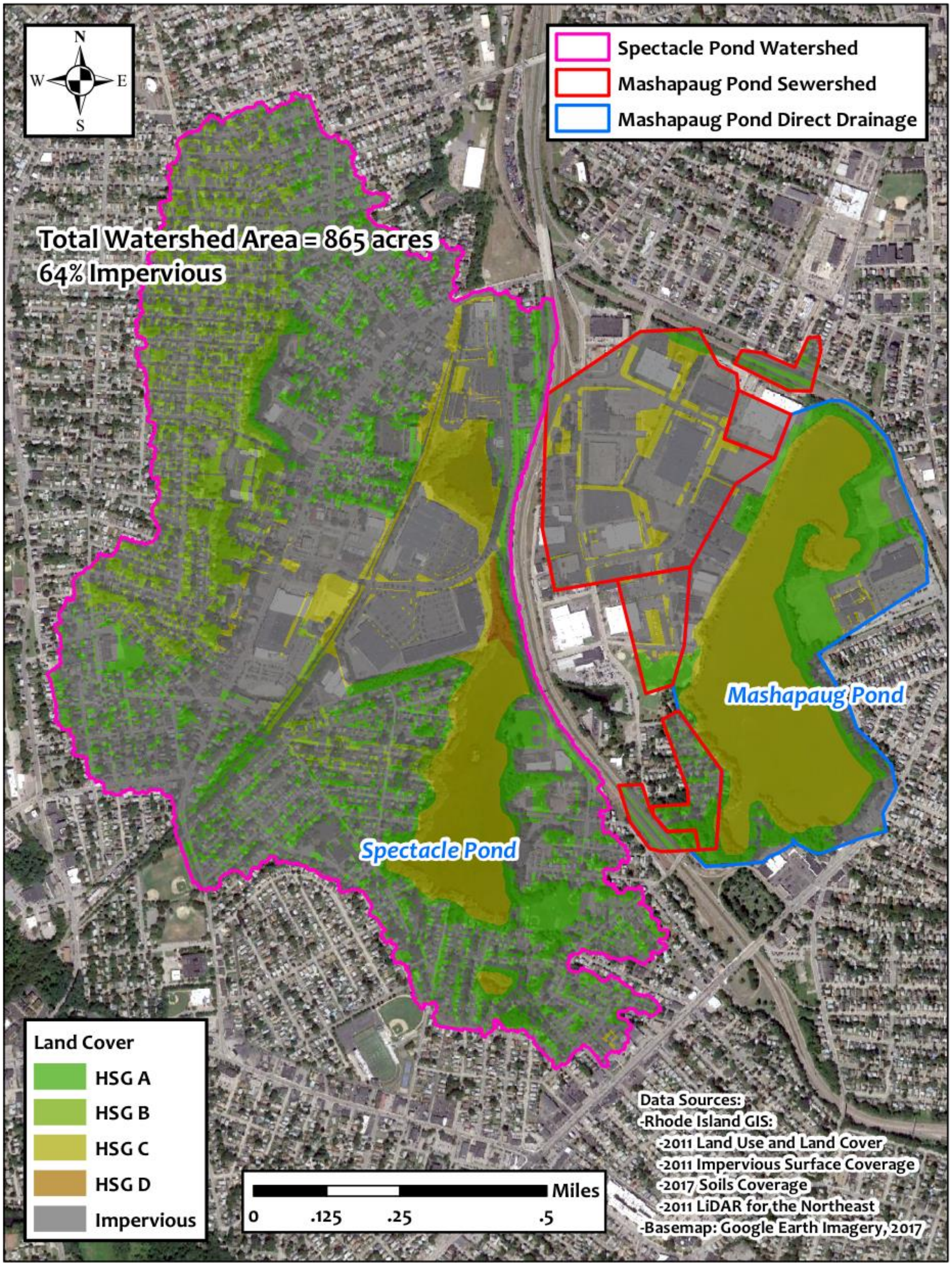

Figure 2 – Impervious Cover and Soil Type in the Mashapaug Pond Watershed

3.2. Pollutant Load Analysis Modeling Approach

The volume and quality of stormwater runoff generated from each major land use within the study watershed was characterized through the use of modeling of hydrologic response units (HRUs). HRUs are idealized catchments, 1 acre in size, which represent a land use cover, one of four hydrologic soil groups (HSG) and an imperviousness condition, either 100% impervious or 100% pervious. HRUs can be used as sub-elements to represent the various combinations of land use, land cover, imperviousness, and soil type within a watershed.

Each HRU was modeled in the EPA Stormwater Management Model (SWMM)[22] as a subcatchment. Subcatchments are defined as hydrologic units of land whose topography and drainage system elements direct surface runoff to a single discharge point. SWMM calculates estimated rates at which rainfall infiltrates into the upper soil zone of a subcatchment's pervious area. Infiltration is estimated for each HRU using the Curve Number (CN) Method. The CN Method is adopted from the NRCS[23] (SCS) and assumes that the total infiltration capacity of a soil can be found from the soil's tabulated Curve Number. During a rain event this capacity is depleted as a function of the cumulative rainfall and remaining capacity. The input parameters for this method are the Curve Number and the time it takes a fully saturated soil to completely dry (used to compute the recovery of infiltration capacity during dry periods). Curve numbers were assigned to HRUs based on the soil type and impervious cover.

After the stormwater runoff volumes were determined by HRU analysis, the pollutant load analysis was conducted. This was accomplished by using event mean concentrations (EMCs), the flow weighted average concentration of a pollutant throughout a storm event. EMCs for phosphorous, nitrogen, total suspended solids, and fecal coliform bacteria were available from a variety of sources[24,25,26,27] for a wide range of land uses and are listed in Table 2. Pollutant load export rates (PLERs) are the mass of pollutant load that is expected to be produced by a specific land use and soil type combination for a given period of time. PLERs were developed by combining the EMCs with the computed runoff volume for each HRU and specific land use type for fecal coliform to determine colonies per acre per year for each major land use / land cover combination (Table 3). PLERs for phosphorus were developed previously using this method in prior efforts and studies and published in the recent MS4 permit.[7]

Table 2 - Event Mean Concentration (EMC) values for water quality modeling[24]

Land Use Category	Cover Type	Event Mean Concentration (EMC) Total Phosphorus (mg/L)		Total Nitrogen (mg/L)	Total Suspended Solids (mg/L)		FC Bacteria (col/100mL)	
Residential	Pervious (Lawn)	0.414	a,f,g,l,m	Buildup/ Washoff functions used for these land uses	171	a,m	4700	a
	Roof	0.1	a,f,g,l,m		28	a,l	2400	a,l
	Other Impervious	0.81	a,f,l,m		178	a	1900	a
Commercial, Services	Pervious	0.414	a,f,g,l,m		171	a,m	4700	a
	Roof	0.152	a,f,g,l,m		14	a,l,m	1100	l

[22] EPA (2010b)
[23] NRCS (1986)
[24] Roseen, R. et al (2015)
[25] Steuer et al (1996)
[26] Pitt, R. National Stormwater Quality Database v1.1. Summary Table.
[27] Claytor & Schueler (1996)

	Other Impervious	0.26	a,f,g,l,m			64	a,l,m	3350	a,l
Institutional, Government	Pervious	0.24	h,k			29.5	h,k		
	Roof	0.24	h,k			29.5	h,k		
	Other Impervious	0.24	h,k			29.5	h,k		
Industrial	Pervious	0.414	a,f,g,l,m			171	a,m	4700	a
	Roof	0.08	l			17	l	5800	l
	Other Impervious	0.65	l			228	l	2500	l
Transportation, Communications, and Utilities	Road	0.54	a,f,g,l,m	1.51	a,m	248	a,l	2400	a
	Freeway	0.36	d,h,k,m	2.58	d,h,k,m	87	d,h,k,m		
	Right-of-Way	0.54	a,f,g,l,m	1.51	a,m	248	a,l	2400	a
	Utilities	0.2	h	1.2	h	20.7	h		
	Rail	0.13	c	1.63	c	97	c		
Industrial and Commercial Complexes	Pervious	0.414	a,f,g,l,m	Buildup/ Washoff functions used for these land uses		171	a,m	4700	a
	Roof	0.116				16		3450	
	Parking	0.46				146		2925	
Mixed Developed Uses		0.29	e,h,j,k,m	2.48	e,h,j,k,m	103	e,h,j,k,m	4600	k
Outdoor & Other Urban and Built-up Land		0.12	h,i,m	1.36	h,i,m	27.3	h,i,m		
Agriculture		0.53	b,d,h,i,m	2.85	b,d,h,i,m	80	b,d,h,i,m		
Transitional		0.31	k	1.33	k	48.5	k	7200	k
Forest		0.15	b,d,h,j,m	1.4	b,d,h,j,k,m	52	b,d,h,j,k,m	7200	k
Wetlands		0.16	d,h,m	1.36	d,h,m	9.6	d,h,m		
Barren		0.13	c	1.63	c	97	c		

[a] Steuer et al (1996); [b] Line, D.E. et al (2002); [c] Los Angeles County Stormwater Monitoring Report: 1998-1999; [d] Harper, H.H. (1998); [e] Guerard, P., and Weiss, W.B. (1995); [f] Bannerman et al (1992); [g] Waschbusch et al (2000) [h] CH2MHill Technical Memo. Urban Stormwater Pollutant Assessment, NC DENR 2001.; [I] Adamus and Bergman (1995); [j] Results of the Nationwide Urban Runoff Program (NURP). Volume 1 – Final Report; [k] Pitt, R. National Stormwater Quality Database v1.1. Summary Table.; [l] Claytor & Shueler (1996). Design of Stormwater Filtering Systems; [m] New Hampshire Stormwater Manual, Appendix D.

Table 3 – Fecal Coliform Event Mean Concentrations (EMCs) and Pollutant Load Export Rates

		Fecal Coliform EMCs	Average Annual Runoff	Fecal Coliform
Land Use	Land Cover	col/L	L/acre	col/acre/yr
Agriculture	A	72,000	246,052	1.77E+10
	B	72,000	635,408	4.57E+10
	C	72,000	1,070,731	7.71E+10
	D	72,000	1,343,821	9.68E+10
	Impervious	72,000	4,085,541	2.94E+11
Commercial and Industrial	A	47,000	246,052	1.16E+10
	B	47,000	635,408	2.99E+10
	C	47,000	1,070,731	5.03E+10
	D	47,000	1,343,821	6.32E+10
	Impervious	29,250	4,085,541	1.20E+11
Forest	A	72,000	246,052	1.77E+10
	B	72,000	635,408	4.57E+10
	C	72,000	1,070,731	7.71E+10
	D	72,000	1,343,821	9.68E+10
	Impervious	72,000	4,085,541	2.94E+11
High Density Residential	A	47,000	246,052	1.16E+10
	B	47,000	635,408	2.99E+10
	C	47,000	1,070,731	5.03E+10
	D	47,000	1,343,821	6.32E+10
	Impervious	21,500	4,085,541	8.78E+10
Low Density Residential	A	47,000	246,052	1.16E+10
	B	47,000	635,408	2.99E+10
	C	47,000	1,070,731	5.03E+10
	D	47,000	1,343,821	6.32E+10
	Impervious	21,500	4,085,541	8.78E+10
Medium Density Residential	A	47,000	246,052	1.16E+10
	B	47,000	635,408	2.99E+10
	C	47,000	1,070,731	5.03E+10
	D	47,000	1,343,821	6.32E+10
	Impervious	21,500	4,085,541	8.78E+10
Highway	A	47,000	246,052	1.16E+10
	B	47,000	635,408	2.99E+10
	C	47,000	1,070,731	5.03E+10
	D	47,000	1,343,821	6.32E+10
	Impervious	24,000	4,085,541	9.81E+10
Open Land	A	72,000	246,052	1.77E+10
	B	72,000	635,408	4.57E+10
	C	72,000	1,070,731	7.71E+10
	D	72,000	1,343,821	9.68E+10
	Impervious	72,000	4,085,541	2.94E+11

3.3. Calculating Total Maximum Daily Load based on TMDL Data

The fecal coliform TMDL documents for Mashapaug Pond do not give an actual total maximum daily load (TMDL), rather they reference the water quality standards. For these analyses, the TMDL target for fecal coliform for the Mashapaug Pond watershed was calculated by formulas (see Formula 2 below) in the Rhode Island Statewide TMDL for Bacteria Impaired Waters[8]. This enables the conversion of a water quality standard into a total bacterial load. As detailed in the 2011 RI Statewide TMDL, Appendix M, for lakes, ponds, or estuarine waters, the loading capacity is derived by multiplying the average daily water outflow by the allowable bacteria concentration. Average daily water outflow is obtained by dividing the basin volume by the flushing time of that basin. Flushing time is the mean time that a parcel of water will spend in a particular lake or pond before it is replaced by water from outside the system.

The following formula for determining total maximum daily loads for bacteria in freshwater rivers and streams is given in the Rhode Island Statewide TMDL for Bacteria Impaired Waters, Appendix M[8]:

Formula 2: Fecal Coliform Freshwater Lakes and Ponds Daily Loads

$$TMDL\left(\frac{10^9\ colonies}{day}\right) = average\,daily\ outflow\left(\frac{m^3}{day}\right) \times WQS\left(\frac{colonies}{100mL}\right) \times 10\left(\frac{100mL}{L}\right) \times 1000\left(\frac{L}{m^3}\right) \div 10^9$$

Where: $average\ daily\ outflow\left(\frac{m^3}{day}\right) = \frac{Volume(m^3)}{Flushing\ Time(days)}$

Average daily outflow is given as 0.077 m^3/s in the 2007 phosphorus TMDL for Mashapaug Pond[18].

According to the Rhode Island Statewide TMDL for Bacteria Impaired Waters, Appendix M[8] the Water Quality Standard (WQS) for Fecal Coliform is 200 MPN / 100mL (geometric mean).

3.4. Assessing TMDL Attainability

TMDLs define and allocate two major waste sources: 1) a wasteload allocation (WLA), which is generally defined as the sum of the pollutant load discharged from all “discrete conveyances” contributing to the impairment, such as discharge pipes or ditches and is regulated under a NPDES permit; and 2) a load allocation (LA), which is the sum of the remaining sources such as runoff, groundwater and atmospheric deposition that are more diffuse and not subject to regulation under a NPDES permit. This division occasionally causes confusion as certain classes of stormwater are regulated under the various stormwater permits (i.e., MS4, industrial stormwater, and construction stormwater) that were previously considered non-point sources. But, because they come under a permit, they become part of the WLA; nearly identical stormwater sources in non-MS4 areas are not regulated and remain in the LA and are not typically subject to an NPDES permit.

TMDL attainability was assessed for the Mashapaug Pond watershed by applying several BMP efficiency scenarios to the results of the pollutant load analysis and also by performing a parcel-based pollutant loading assessment. The parcel-based assessment demonstrates which land use types must be included in an RDA scheme in order to facilitate attainment of total maximum daily loading goals.

3.4.1 BMP Efficiency Scenarios

The pollutant load reduction potential for each watershed was assessed assuming that new development, redevelopment, or installation of stormwater best management practice (BMP) retrofits in all runoff-producing areas would provide treatment for the 1" water quality volume (WQV). This represents a conservative assessment given that site-specific feasibility for stormwater management was not considered. Taking this approach identifies the best-case scenario for pollutant load reduction, useful for evaluating if a given TMDL is even theoretically achievable within the current regulatory framework.

The following 4 load reductions scenarios were analyzed for a 1" water quality volume:

1. '**Maximum Potential Load Reduction'** - This scenario applies estimated load reductions based on the EPA 2010 BMP performance curves for bioretention, assuming all areas would be managed by the most effective BMP with the greatest load reduction potential regardless of site-specific feasibility. This scenario represents the highest tier of pollutant removal and was only applied to phosphorous load reductions because bacteria removal performance was not provided for within EPA 2010.
2. **'High Load Reduction'** - This scenario applies estimated load reductions based on the 2010 Rhode Island SWM for infiltration practices, assuming all areas would be managed by the most effective BMP with the greatest load reduction potential regardless of site-specific feasibility. This scenario represents the second highest tier of pollutant removal, using the highest published removal efficiencies within the state manual.
3. **'Moderate Load Reduction'** - This scenario applies estimated load reductions based on the 2010 Rhode Island SWM for infiltration practices, assuming all areas would be managed by BMPs of intermediate effectiveness regardless of site-specific feasibility. This scenario represents the third highest tier of pollutant removal, using intermediate published removal efficiencies within the state manual.
4. **'Minimum Load Reduction'** - This scenario applies estimated load reductions based on the 2010 Rhode Island SWM for dry detention. This scenario represents the lowest tier of pollutant removal, using the lowest published removal efficiencies within the state manual which represents the past standard of practice.

3.4.2 Parcel-Based Analysis

As discussed in detail in 'Section 2.4.3. Role of RDA', government-owned properties that drain to an MS4 are regulated under NPDES, however residential, commercial, industrial, agricultural, and open space properties are not. However, EPA has the authority to use residual designation to permit other un-regulated sources. For this reason a parcel-based pollutant loading analysis was performed for the Mashapaug Pond watershed to determine the minimum parcel area for which RDA could be applied to achieve the required load reductions. The analysis examined the role of parcel size and land use as it relates to pollutant loading. This was done for the purpose of determining the minimum parcel size threshold needed to achieve the required load reductions and for which stormwater management would be required. This analysis can also be used to determine the “optimal” parcel size to achieve the greatest reduction for the lowest cost.

Figure 4 and Figure 5 illustrate the cumulative pollutant load by parcel size and land use for phosphorous and fecal coliform. This was developed by GIS analysis, overlaying parcel data with the results of the pollutant loading analysis described in Section 3.2. The results of this were analyzed to assess the contribution of a specific land use as a function of parcel size. This was followed by an iterative spreadsheet analysis examining BMP scenarios and a range of parcel area thresholds to determine how inclusion of different parcel sizes in various land use combinations could be implemented under RDA.

The following 3 RDA parcel area thresholds represent different approaches based on parcel lot size that EPA could take using its residual designation authority. Each was analyzed to determine the feasibility for TMDL attainability of each:

1. **All Parcels:** Regulating all parcels within residential, commercial, and industrial areas, and excluding all other parcels.

2. **Parcel Areas >1 Acre:** Regulating all parcels larger than 1-acre for residential, commercial, and industrial land use types.

3. **Parcel Areas > 2.5 Acres:** Regulating all parcels larger than 2.5-acres for residential, commercial, and industrial land use types.

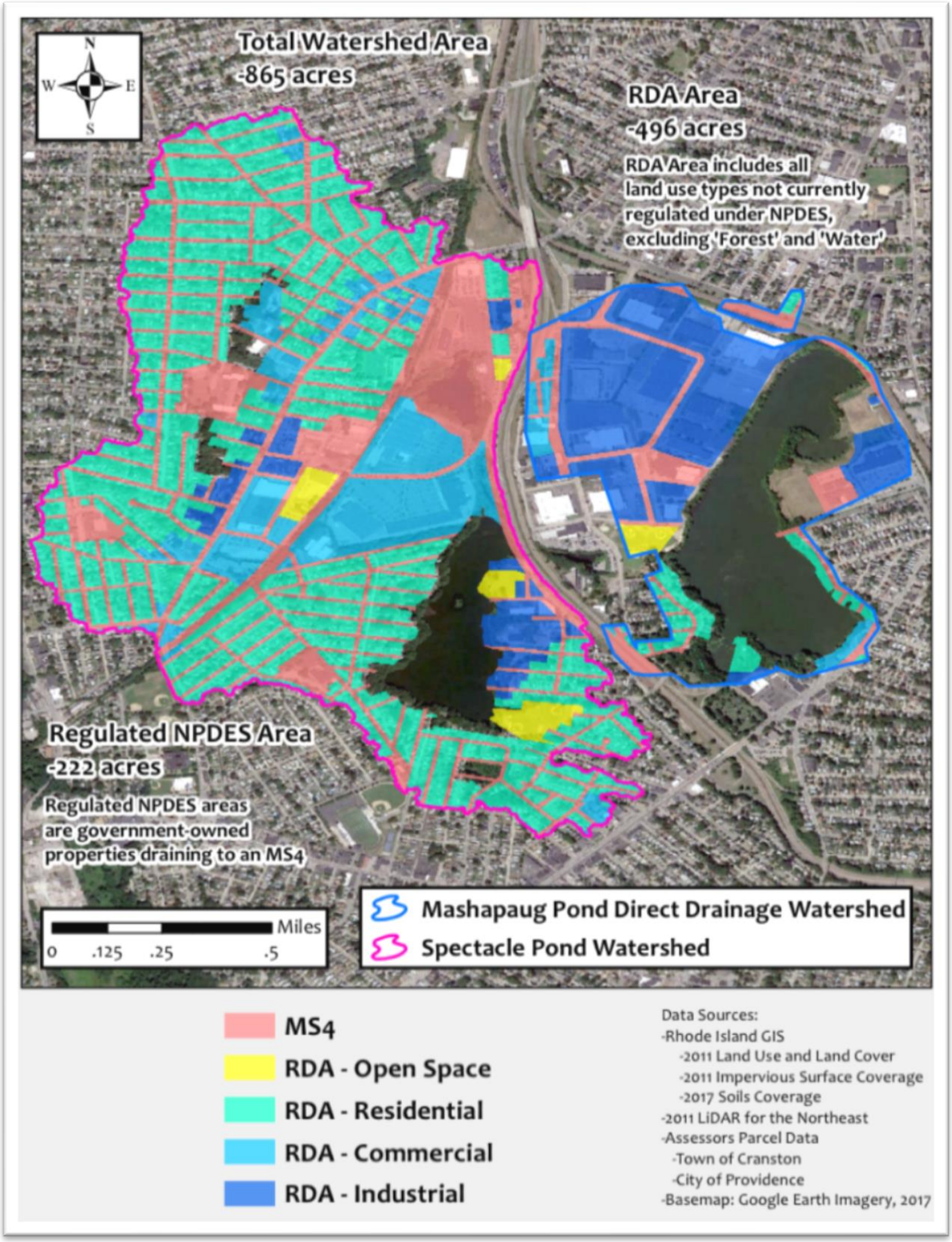

Figure 3 - Areas within the Mashapaug Pond Watershed Regulated under NPDES

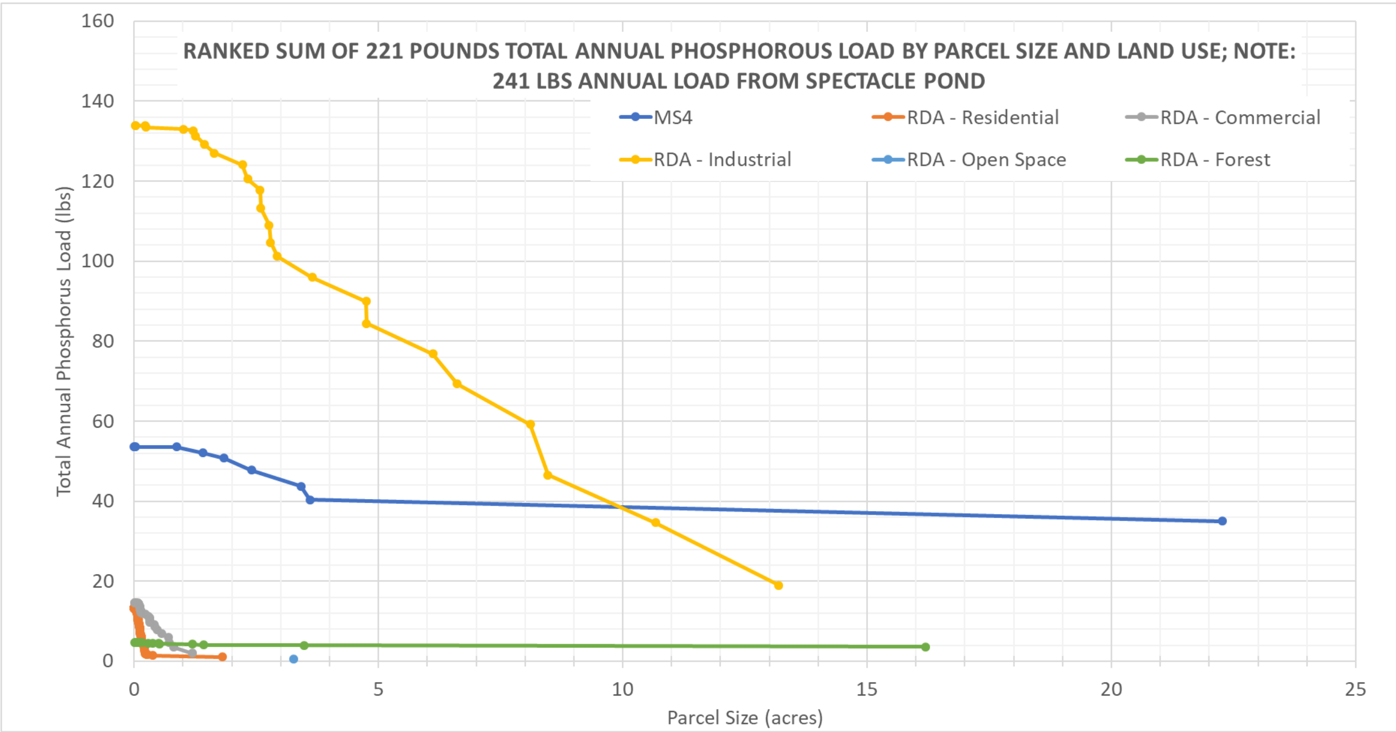

Figure 4 – Cumulative Total Annual Phosphorus Load by Parcel Size and Land Use[28]

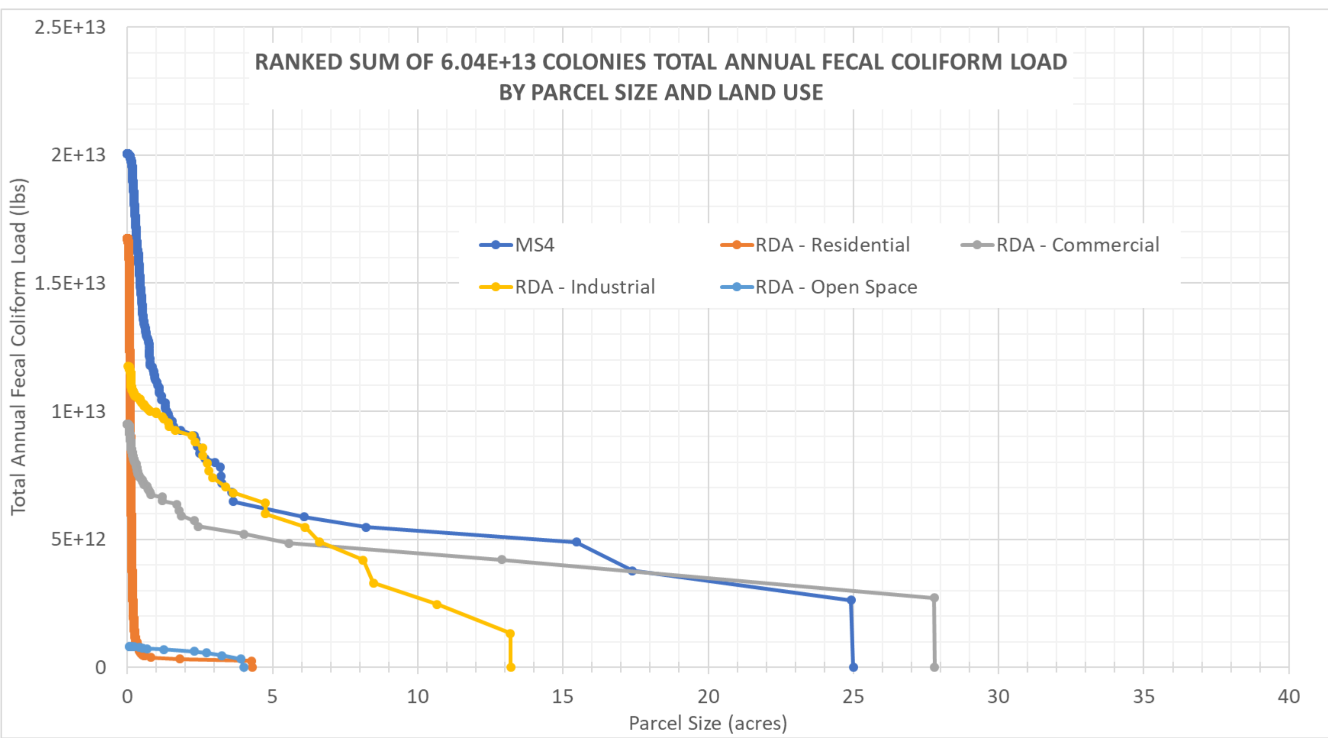

Figure 5 – Cumulative Total Annual Fecal Coliform Load by Parcel Size and Land Use

[28] MS4 represents government-owned properties that drain to an MS4 and regulated under NPDES, RDA represents residential, commercial, industrial, agricultural, and open space land uses that could be regulated under RDA

4. Results

4.1. Pollutant Load Analysis

Loads for phosphorus and fecal coliform were calculated by land use for the Mashapaug Pond watershed. The estimated loads shown in Tables 4 and 5 are for wet weather runoff and do not include contributions from point sources such as wastewater treatment facilities, industrial discharges, illicit discharges, leaking sewers, septic systems or groundwater and atmospheric deposition.

For Tables 4 and 5, Column 1 (Land Use) lists the various land uses within each watershed area; Column 2 (Area (acres)) gives the area covered by each land use within the watershed; Column 3 (% of Total Area) gives the percentage of the total watershed area covered by each land use; Column 4 (% Impervious) gives the percentage of the area of each land use that is covered by an impervious surface; Column 5 (Annual Phosphorus Load (lbs)) gives the total annual phosphorus load from the area covered by each land use; Finally, Column 6 (% of Total Load) gives the percentage of the total pollutant load for the watershed that is derived from each land use.

Table 4 and Figure 6 presents the phosphorous load for Mashapaug Pond watershed as detailed in the Phosphorous TMDL.

Table 4 - Mashapaug Pond Phosphorus Loading Summary by Land Use

Land Use	Area (acres)	% of Total Area	% Impervious	Annual Phosphorus Load (lbs)	% of Total Load
Highway	4	2%	78%	4	2%
Residential	17	7%	59%	21	10%
Commercial / Industrial	127	50%	80%	184	86%
Open Land	9	4%	5%	1	1%
Forest	20	8%	4%	4	2%
Water	75	30%	0%	0	0%
Total	252	-	44%	214	-

Table 5 and Figure 7 present the fecal coliform loading for Mashapaug Pond watershed only, also as detailed within the Bacterial TMDL.

Table 5 - Mashapaug Pond and Spectacle Pond Fecal Coliform Loading Summary by Land Use

Land Use	Area (acres)	% of Total Area	% Impervious	Annual Fecal Coliform Load (CFUs)	% of Total Load
Highway	14	2%	71%	1.00E+12	2%
Residential	368	43%	68%	2.41E+13	41%
Commercial / Industrial	292	34%	82%	3.02E+13	51%
Open Land	23	3%	12%	1.41E+12	2%
Forest	51	6%	8%	2.83E+12	5%
Water	117	14%	0%	0.00E+00	0%
Total	865	-	64%	5.96E+13	-

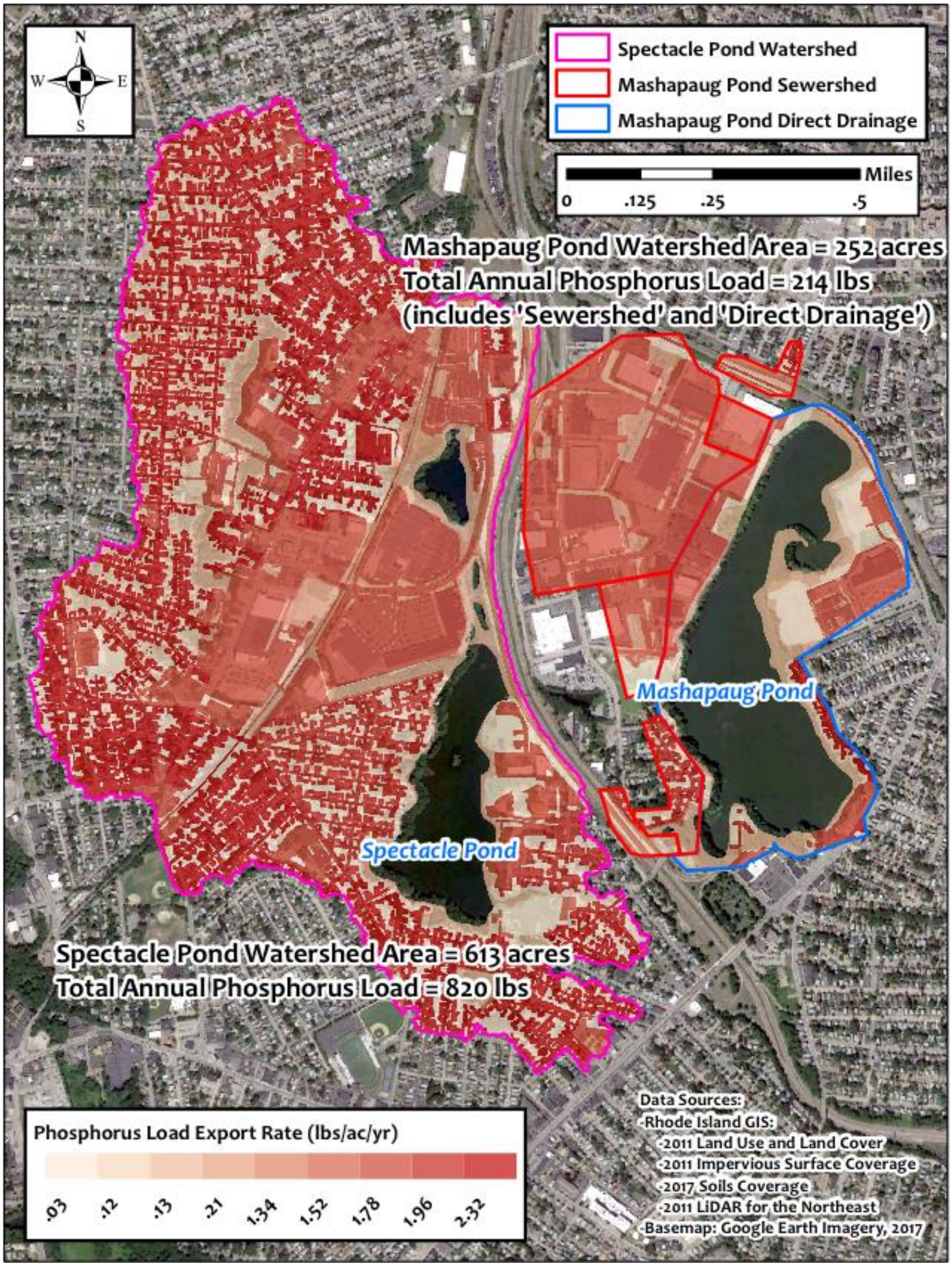

Figure 6 - Phosphorus Loading in the Mashapaug and Spectacle Pond Watersheds

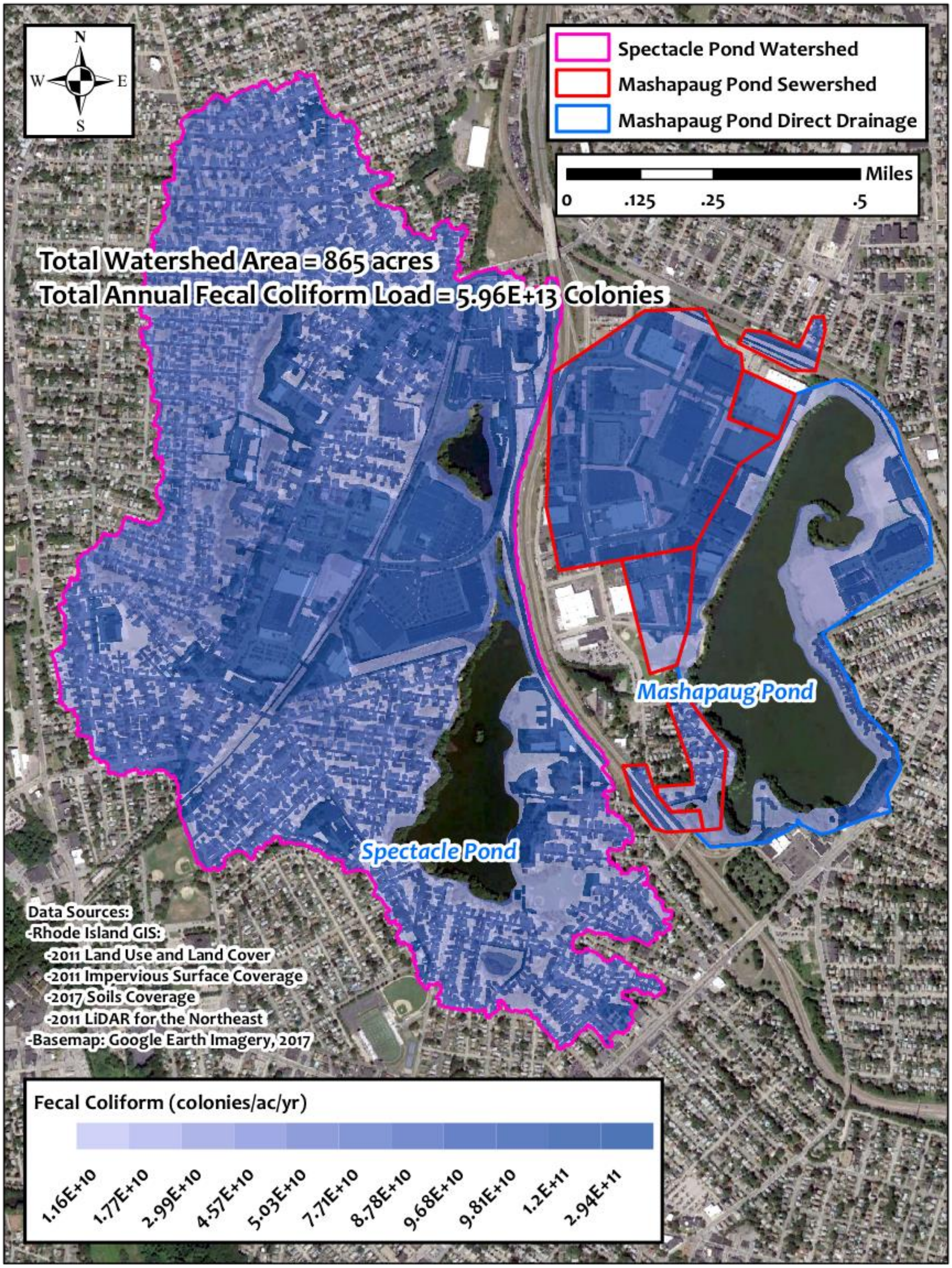

Figure 7 - Fecal Coliform Loading in the Mashapaug Pond Watershed

4.2. Total Maximum Daily Load Calculations for Mashapaug Pond

The total maximum daily and annual fecal coliform load for Mashapug Pond was determined via Formula 2 using applicable water quality standards and the SWMM-derived average daily flow to yield the following:

Total Maximum Daily Load= [0.077 m^3/s] x [2000 MPN / 1L] x [86,400 sec/day] x [1000 L/m^3]

=1.33E+10 colonies per day

Total Maximum Annual Load (Target Load) = [1.33E+10 colonies/day x 365 days/year]

= 4.84E+12 colonies per year

4.3. Comparison / Combination of PLA and TMDL Results

4.3.1 Phosphorus

Table 6 shows a comparison of the TMDL and the pollutant load analysis (PLA) for phosphorous for Mashapaug Pond. For Mashapaug Pond, a total phosphorous load reduction of 275 lbs. (54%) is required for the TMDL. The existing annual load is 511 lbs. versus the 546 as calculated by the PLA indicating the load may be higher than indicated by the TMDL. As noted in the TMDL[29], “Because loads associated with groundwater and atmospheric deposition cannot be easily reduced, a higher percentage of the load reduction must come from the remaining sources. Therefore, a nutrient load reduction of 62% from all storm drains and direct overland runoff areas as well as the base flow from Spectacle Pond was required in order to meet the water quality standard.”

The Mashapaug Pond TMDL estimates annual groundwater and atmospheric loading to be 35 lbs. and 55 lbs., respectively. Estimates for groundwater loading were derived from observations of flow rates and nutrient concentrations from a 2001 field survey and do not include baseflow from Spectacle Pond. Wet and dry atmospheric deposition rates from previous studies were applied to Mashapaug Pond to generate an estimate of the annual contribution in Mashapaug.

Table 6 - Mashapaug Pond Phosphorus TMDL and PLA Summary

	Area	Impervious	Current Direct Runoff Load	Current Spectacle Pond Load	Current Nonpoint Source Load	Current Annual Load	Required Load Reduction	TMDL (Annual)
	acres	%	lbs	lbs	lbs	lbs	%	lbs
TMDL	762*	61%	179	241	90	511	54%	237
PLA	865	64%	214	241**	90**	546	-	-

*Excludes water surface area

**Phosphorus loads from Spectacle Pond and nonpoint sources (groundwater underflow, atmospheric deposition) taken from Mashapaug Pond TMDL estimates[29]

[29] RIDEM, 2007a

4.3.2 Bacteria

Importantly, the Mashapaug Pond TMDL[8] does not specify a percent reduction to meet the Target Load for fecal coliform. However, using the PLA estimate for annual load, we calculate a 92% reduction will be necessary to meet the specified TMDL. Table 7 shows a comparison of the TMDL to the estimated current load calculated through the pollutant load analysis (PLA) described above.

Table 7 – Mashapaug Pond Fecal Coliform TMDL and PLA Summary

Flow	Water Quality Standard	Total Maximum Daily Load	Total Maximum Annual Load	TMDL Required Reduction	PLA Current Annual Load	PLA Estimated % Reduction
m^3/s	colonies / L	colonies	colonies	%	colonies	%
0.077	2,000	1.33E+10	4.84E+12	-	5.96E+13	92%

4.4. BMP Efficiency Scenarios

The pollutant removal efficiencies from the EPA 2010[4] and the Rhode Island Stormwater Manual[30] for a range of BMPs were applied to each watershed in a number of combinations to determine an upper and lower bound for pollutant load reduction feasibility.

Performance estimates for each BMP category, TMDL, and watershed are summarized in Table 8 and Table 9 on the following page. For each water body, those scenarios which achieve the TMDL are highlighted in green, and those that do not are highlighted in red.

Table 8 - Mashapaug Pond Phosphorus Loading Reduction Potential Summary (includes Spectacle Pond contribution of 241 lbs. annually) ; green and red represent TMDL attainability and non-attainability respectively.

Scenario	Current Annual Load (lbs)	BMP % Removal Efficiency for Applicable Land Uses*	% Total Reduction	Potential Load Reduction (lbs)	New Annual Load (lbs)	Residual Annual Load* (lbs)
Maximum: EPA 1" WQV Bioretention BMPs	455	76%	75%	343	112	(125)
High: RISWM Infiltration BMPs	455	65%	64%	293	162	(75)
Moderate: RISWM Bioretention BMPs	455	30%	30%	135	320	83
Minimum: RISWM Dry Detention BMPs	455	20%	20%	90	365	128

*Note: Negative values are shown in parentheses, e.g. (125) is 125 pounds below the required load. The total maximum annual load is 237 lbs. of phosphorous, an 84% reduction

[30] RIDEM (2015)

Table 9 - Mashapaug Pond Fecal Coliform Loading Reduction Potential Summary; green and red represent TMDL attainability and non-attainability respectively.

Scenario	Current Annual Load (colonies)	BMP % Removal Efficiency for Applicable Land Uses*	% Total Reduction	Potential Load Reduction (colonies)	New Annual Load (colonies)	Residual Annual Load* (colonies)
High: RISWM Infiltration BMPs	5.96E+13	95%	90%	5.39E+13	5.67E+12	8.33E+11
Moderate: RISWM Bioretention BMPs	5.96E+13	70%	67%	3.97E+13	1.99E+13	1.50E+13
Minimum: RISWM Dry Detention BMPs	5.96E+13	35%	33%	1.99E+13	3.97E+13	3.49E+13

*BMPs applied to LU Types: Highway, Residential, Commercial / Industrial, Agricultural, and Open Land. LU Types Forest, and Water are excluded.
*Note: The total maximum annual load is 4.84E+12 colonies of Fecal Coliform, a 92% reduction

4.5. Parcel-Based Pollutant Loading Analysis

Parcel area thresholds (3) for which stormwater management would be required (all parcels, >1 acres, and >2.5 acre, as described above) were examined in combination with BMP efficiency scenarios to determine how excluding different land use types or parcel sizes from an RDA scheme would impact TMDL attainability. Figure 4 and Figure 5 demonstrate cumulative pollutant load as a function of parcel size based on land use.

For Mashapaug Pond, the 'maximum potential load reduction' BMP scenario is capable of achieving the phosphorus TMDL with stormwater management applied to parcels >2.5 acres. These results are summarized in Table 10, below. In Tables 10 and 11, green cells represent scenarios which achieve a given TMDL and red cells represent scenarios which do not achieve a given TMDL.

Table 10 - Unmanaged Phosphorus Load by Scenario; Total Maximum Daily Load is set at 237 lbs.; green and red represent TMDL attainability and non-attainability respectively.

Mashapaug Pond Unmanaged Phosphorus Load	RDA Parcel Area Threshold		
	All	>1 Acre	2.5> Acre
BMP Efficiency Scenarios	lbs.	lbs.	lbs.
100% Removal	116	142	160
Bioretention BMPs	199	219	233
Infiltration BMPs	237	254	266

When considering RDA scenarios, none of those assessed in this analysis were capable of meeting the TMDL for fecal coliform, even assuming 100% pollutant removal efficiency. These results are summarized in Table 11, below.

Table 11 - Unmanaged Fecal Coliform Load by Scenario; Total Maximum Daily Load is 4.84E+12 CFUs; green and red represent TMDL attainability and non-attainability respectively.

Mashapaug Unmanaged Fecal Coliform Load	**RDA Parcel Area Threshold**		
	All	>1 Acre	>2.5 Acres
BMP Efficiency Scenarios	colonies	colonies	colonies
100% Removal	2.12E+12	2.32E+13	2.61E+13
Infiltration BMPs	5.02E+12	2.50E+13	2.78E+13

5. Discussion and Conclusion

5.1. Assessing TMDL Attainability

The pollutant load reduction potential for each watershed was assessed assuming that new development, redevelopment, or installation of stormwater best management practice (BMP) retrofits in all runoff-producing areas would provide treatment for the 1" water quality volume (WQV). This analysis determined that the Phosphorus TMDL can be met for Mashapaug Pond by implementing the maximum potential load reduction for all areas currently covered and not covered under the NPDES program. Phosphorous attainability can be achieved by management of industrial, commercial, and residential parcels larger than 1 acre with the best available BMP technology (bioretention systems).

A tremendous 58% reduction in pollutant load could be achieved for fecal coliform however TMDL attainability does not appear to be possible at this point in time. Fecal coliform reductions would require industrial parcels larger than 1 acre to be managed with the best available BMP technology (infiltration systems). It is important to recognize that the significant bacterial load reduction would still bring tremendous benefits. It is possible that bacterial reduction requirements could be achieved with an improved understanding of the system through monitoring and modeling. Future study will include additional surface water quality investigations of sources, future monitoring data, improved understanding of bacteria dynamics in relation to nutrient load reduction, and advances in technology for treatment. Bacteria concentrations and pollutant load export rates are far more varied and less well understood than more common nutrients.

For the purposes of this analysis, it was assumed (as was done in the Upper Charles RDA provisional permit) that government-owned properties that drain to an MS4 are regulated under NPDES, and residential, commercial, industrial, agricultural, and open space properties are not. This analysis assumed that EPA would exercise the authority for use of residual designation to regulate industrial, commercial, and residential properties > 1 acre. A parcel-based pollutant loading analysis identified that regulation of a minimum parcel area of 1 acre by RDA could achieve the required load reductions.

With respect to phosphorous, parcel areas >1 acre encompasses only 1% of all residential parcels, 3% of commercial parcels, and 84% of industrial parcels (23 total parcels) and reduces the existing load by 53% (243 lbs. TP) of the existing load in the Mashapaug Pond watershed. In contrast, a target area of >2.5 acres encompass no residential parcels, no commercial parcels, and 56% of all industrial parcels (14 total parcels) and manages (removes) 50% (229 lbs. TP).

With respect to fecal coliform in Mashapaug Pond watershed, management of parcel areas >1 acre reduces the existing load by 58% (3.51E+13 Fecal Coliform CFUs). In contrast, a target area of >2.5 acres would remove 54% of the existing load (3.24E+13 Fecal Coliform CFUs).

5.2. TMDL Implementation

The water quality volume refers to a runoff capture volume that will provide treatment of 90% of the average annual runoff, typically equivalent to 1-inch of runoff from impervious areas. The use of a WQV design criteria is intended to provide treatment for the majority of stormwater contaminants in a cost-effective manner. For example, a 1" rainfall is far smaller than even a 1-

year 24-hr storm event equal of 2.6”.[31] The WQV design is based in part on the first-flush phenomenon where contaminant concentrations are highest in the beginning of storm runoff and becomes progressively cleaner as the contaminant load is exhausted during the wash-off process from impervious areas. In practice, the first-flush phenomenon varies by contaminant and in some instances smaller capture depths of 0.25” can be used to capture and treat the majority of nitrogen. This is an oft used approach for sizing retrofit BMPs in existing developed areas where there may be less opportunity for stormwater management for the 1” WQV. For this reason the use of the 1” WQV is a conservative assumption for water quality treatment and TMDL attainability.

The pollutant removal efficiencies from the EPA (2010)[4] and the Rhode Island Stormwater Manual (RISWM)[32] for a range of BMPs were applied to each watershed in 4 scenarios (maximum, high, moderate, and minimum) to determine upper and lower bounds for pollutant load reduction attainability. This represents a conservative assessment given that site-specific feasibility for stormwater management was not considered, it is unlikely that stormwater management (SWM) would be required for all impervious areas (IA). Taking this approach identified the best-case scenario for pollutant load reduction, useful for evaluating if a given TMDL is even theoretically achievable within the current regulatory framework.

The iterative spreadsheet study conducted for the parcel-based analysis is useful for determining potential RDA approaches based on parcel size. The detailed results from the parcel-based analysis are included in Appendix D. The results include a ranked-sum analysis, plotting phosphorus load against parcel size for each land use type. Each curve on the chart represents a different land use type, and each shows what percentage of the total phosphorus load for the land use type would be managed by including all parcels above a certain size in an RDA designation. For example, if all residential parcels greater than 5 acres in size were compelled to manage 100% of their stormwater runoff under RDA, this would account for roughly 22% of the total Phosphorus load contribution from residential areas in the Mashapaug Pond watershed.

5.3. Assumptions and Limitations

One major assumption lies with the treatment of the phosphorus load from Spectacle Pond in the parcel-based analysis. Rather than include the watershed area that drains to Spectacle Pond in the analysis, the load from Spectacle (derived from field data collected as part of the original TMDL development for Mashapaug) was treated as a point source contribution. The spreadsheet tool (as shown in Appendix D) applies a uniform 54% reduction to this load because this is the target reduction identified in the TMDL for the entire Mashapaug Pond watershed. Varying this assumed reduction percentage will impact the TMDL attainability results for the various RDA scenarios described above. Importantly, the fecal coliform analysis presented above includes the entire Spectacle Pond watershed because no estimate for the point source contribution from Spectacle to Mashapaug Pond was available in the bacteria TMDL.

In order to perform the parcel-based RDA scenario analysis, it was necessary to determine which land use types from the existing 2011 RIGIS dataset[21] should be included within the MS4 area. Typically, only government-owned properties are considered to be a part of the NPDES permit

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[31] A 1-yr 24-hour storm depth is equal to 2.62 inches for Lincoln, MA, Northeast Regional Climate Center, 2012.
[32] RIDEM (2015)

for an MS4. Recognizing this, the following land use types were grouped in order to determine the extent of the watershed area which had already been accounted for by NPDES: Institutional (schools, hospitals, churches, etc.); Other Transportation (terminals, docks, etc.); Airports (and associated facilities); Waste Disposal (landfills, junkyards, etc.); Water and Sewage Treatment; Roads (divided highways > 200' plus related facilities). While this categorization scheme is likely to be fairly representative of the MS4 area, it is almost certain that some areas have been included or excluded erroneously (such as churches, which are grouped with 'institutional' but are not government-owned properties). Errors like this are unavoidable without spending considerable effort manually ruling individual parcels in/out of a given land use category, but may have a small impact on the pollutant load estimates for each land use category within the parcel-based analysis. Curve numbers were assigned to HRUs based on the soil type and impervious cover. For pervious subcatchments, the land use condition was assumed to be open space in good condition: grass cover on 75% or more of the area.

Along the same lines, in the process of assigning a land use type to each parcel for the RDA scenario analysis, many parcels were found to be spanning multiple land use types. In these cases, whichever land use type covered the greatest amount of a parcel's area was assigned to that parcel. However, this generalization process might have led to either an over- or underestimation of pollutant load contributions from a given land use type, though it is reasonable to assume that this would balance out overall.

The parcel datasets obtained from the Towns of Cranston and Providence contained duplicate entries for many parcels. In automating the elimination of these duplicates, it is possible that non-duplicate parcels were also removed, which would impact the final pollutant load estimates. However, the impact from this is expected to be very minor.

The pollutant loading analysis lumped roadways in with different land use types. Roads were separated from each land use type and added to the 'MS4' category for the parcel-based analysis. This is because the land-use data did not separate, for example, residential streets from residential property areas, so these areas were assigned a phosphorus load export rate appropriate for impervious residential areas. However, residential streets would be included in the current NPDES permit for a city, so it was important to reflect this in the RDA scenario analysis. Overall, the total Phosphorus load export rate for the watershed remains unchanged between the two approaches with the exception of small differences.

Second, it is useful to memorialize the rationale for choosing parcel-size rather than the impervious area within a parcel as the independent variable in the parcel-based analysis. This choice was largely made with ease of implementation in mind. Impervious coverages are constantly changing in urban areas, and this could present challenges for identifying which properties are in or out of the RDA designation. This also opens the door for property owners to remove small amounts of impervious cover to get under a threshold value, as well as for litigation which could challenge a property's inclusion based on use of outdated spatial data (the most recent geospatial impervious cover dataset available for the areas is from 2011). For these reasons, it was determined that the management process would be simpler if an RDA designation was based on parcel size, a fixed value, rather than impervious area within a parcel. Tracking of impervious area would continue to be part of any such analysis.

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APPENDICES

Appendix A: Expert Witness Resume, Publications Authored in Previous 10 years, Expert Witness Experience

Appendix B: Literature Sources for Pollutant Load Export Rates

Appendix C: EPA SWMM Model Documentation for Bacterial HRU Analysis

Appendix D: Parcel-Based RDA Scenario Spreadsheet Tool Results

7. Appendix A: Expert Witness Resume, Publications Authored in Previous 10 years, Expert Witness Experience

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EDUCATION

Ph.D., Civil- Water Resources Engineering, University of New Hampshire, Durham, NH, 2002

M.S., Environmental Science and Engineering, Colorado School of Mines, Golden, CO, 1998

PROFESSIONAL EXPERIENCE

Waterstone Engineering, Owner, Stratham, NH, 2016-Present
Horsley Witten Group, Practice Leader, Newburyport, MA, 2015- 2016
Geosyntec Consultants, Inc., Associate, Acton, MA, 2012 – 2015
University of New Hampshire, Research Assistant Professor, Durham, NH, 2007 – 2012
UNH Stormwater Center, Director, Durham, New Hampshire, 2004 – 2012
University of New Hampshire, Research Project Engineer III, Durham, NH, 2001 - 2007
The Bioengineering Group, Inc., Salem, MA, 2001 - 2004

REGISTRATIONS AND CERTIFICATIONS

Registered Professional Engineer, NH No. 12215, ME No. PE15125, MA No. 333
Diplomate of Water Resources Engineering, American Academy of Water Resources Eng., No. 00556

CAREER SUMMARY

Dr. Roseen provides many years of experience in water resources investigations and most recently, led a project team in the development of an Integrated Plan for nutrient management for stormwater and wastewater. This plan has received provisional approval by EPA and would be one of the first in the nation. Rob is a recognized industry leader in green infrastructure and watershed management, and the recipient of 2010 and 2016 Environmental Merit Awards by the US Environmental Protection Agency Region 1. He consults nationally and locally on stormwater management and planning and directed the University of New Hampshire Stormwater Center for 10 years and is deeply versed in the practice, policy, and planning of stormwater management. Rob has over 20 years of experience in the investigation, design, testing, and implementation of innovative approaches to stormwater management. Rob has led the technical analysis of dozens of nutrient and contaminant studies examining surface water pathways, system performance, management strategies, and system optimization.

Dr. Roseen provides Clean Water Act expert consultation, analysis, modeling, advice, reports and testimony in regard to compliance with Construction General Permits, Municipal Separate Storm Sewer System (MS4) Permits, and Multi Sector General Permits.

He also served as Research Assistant Professor for five years. His areas of expertise include water resources engineering, stormwater management (including low impact development design), and porous pavements. He also possesses additional expertise in water resource engineering including hydrology and hydraulics evaluations, stream restoration and enhancement alternatives, dam removal assessment, groundwater investigations, nutrient and TMDL studies, remote sensing, and GIS applications.

Dr. Roseen has taught classes on Stormwater Management and Design, Fluid Mechanics, and Hydrologic Monitoring and lectures frequently on these subjects. He is frequently called upon as an expert on stormwater management locally, regionally, and nationally.

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Recent activities include chairing the ASCE EWRI 2016 International Low Impact Development Conference, an annual event that draws participants from around the world to discuss advances in water resources engineering, and participating until 2017 as a Control Group member for the ASCE Urban Water Resources Research Council (UWRRC). He has also served on the ASCE Task Committee on Guidelines for Certification of Manufactured Stormwater BMPs, EWRI Permeable Pavement Technical Committee, and the Hydrology, Hydraulics, and Water Quality Committee of the Transportation Research Board. Dr. Roseen has been the author or co-author of over two dozen professional publications on the topics of stormwater runoff, mitigation measures, best management practices (BMPs), etc. He has also been the recipient of several awards and other honors for his work, including the 2010 Outstanding Civil Engineering Achievement Award from the New Hampshire Chapter of the American Society of Civil Engineers, and an Environmental Merit Award from the EPA. He has extensive experience working with local, state, and regional agencies and participates on a national level for USEPA Headquarters, WEF, and the White Council on Environmental Quality on urban retrofit innovations and next generation LID/GI technology and financing solutions.

SELECT EXPERT WITNESS EXPERIENCE

Construction General Permit (CGP), and Clean Water Act Expert Services

Dr. Roseen is currently providing expert consultation, analysis, modeling, advice, reports and testimony in regards to construction general permit compliance, erosion and sedimentation control, and monitoring. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities. This service is being provided for the plaintiff for one (1) case of significant size geographically and in project scope.

Municipal Separate Storm Sewer System (MS4) Permit and Clean Water Act Expert Services

A team lead by Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MS4 violations under the Clean Water Act. Such services include sworn to written or oral expert testimony regarding such matters in Court, and site and facility inspections. This service is being provided for the plaintiff for two (2) cases of significant size geographically and in project scope.

Multi Sector General Permit (MSGP), Stormwater Pollution Prevention Plan, and Clean Water Act Expert Services

A team lead by Dr. Roseen is currently providing expert consultation, analysis, modelling, advice, reports and testimony regarding stormwater discharges in regards to MSGP under the Clean Water Act. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of defendants' facilities. This service is being provided for the plaintiff for over ten (10) separate cases in the northeastern United States.

Multi Sector General Permit (MSGP) and Clean Water Act Expert Services

A team lead by Dr. Roseen provided expert consultation, analysis, modelling, advice, reports and testimony regarding the operations of a scrap metal and automotive recycling facility in relation to Multi Sector General Permit, Safe Drinking Water Act, and National Water Quality Criteria violations of the Clean Water

Act. Such services include sworn to written or oral expert testimony regarding such matters in Court, and on-site inspections of facilities. This service was provided for a single location in the northeastern United States.

Expert Study and Testimony for Erosion and Sediment Control Litigation

A team lead by Dr. Roseen is currently providing expert study and testimony in defense of an undisclosed Federal Client in a $25-million-dollar lawsuit from a private entity. The plaintiff alleges impacts from upstream channel erosion and sediment transport. The efforts examine urban runoff and off-site impacts to a downstream channel and subsequent erosion and sediment transport into the downstream storm sewer system.

Expert Testimony for HB 1295 an Act Establishing a Commission to Study Issues Relating to Stormwater, and Commission Member for NH Legislature, January 2008.

Dr. Roseen participated as a lead member of the NH Stormwater Commission, House Bill 1295. The SW commission was comprised of experts in the field and stakeholders. The Commission provided recommendations to the legislature.

Expert Testimony for HB 648 NH Flood Commission, January 2008.

Dr. Roseen has provided expert testimony to numerous commissions including the NH Legislative Flood Commission. House Bill 648 developed a comprehensive flood management plan for the state of New Hampshire that considers possible measures for minimizing flood impacts on communities and individual properties and to consider issues associated with flood abatement.

Expert Review of Stormwater Management for Proposed Mystic Woods, Groton, CT

Dr. Roseen expert testimony and review of at the request of Hawthorne Partners for the stormwater management strategy for the proposed Mystic Woods Development in Groton, CT. Review was based on the practice requirements of 2004 Connecticut Stormwater Quality Manual. Review included assessment of both quantity management through infiltration (and recharge) and detention, and water quality treatment through the use of bioretention and infiltration for rooftop runoff, and detention and treatment with subsurface gravel wetlands for roadways, parking areas and impervious surfaces runoff. Design and potential impacts were assessed for the combination of strategies incorporating treatment trains (sequential treatment strategies) as a tool for minimizing off-site impacts and changes to predevelopment hydrologic and water quality conditions.

Expert Testimony and Review of YMCA Westport/Weston Stormwater Management

Dr. Roseen provided review and expert testimony of documents presented on behalf of the proposed development. Potential impacts and impairment from the proposed stormwater management was evaluated for Poplar Plains Brook, Lee's Pond, and the Saugatuck Estuary. Considerations included: treatment mechanisms for nitrogen removal to impaired waters, recommendations for water quality monitoring information from which to base the assessment. It appears from the limited water quality monitoring available, review of Connecticut water quality standards for Class C impaired waters, and USEPA 303D Impaired Waters requirements.

Expert Testimony on Stormwater Issues Before The Nashua Planning Board For Proposed Commercial Development, Nashua, New Hampshire, December 2005.

Dr. Roseen provided testimony and review of the stormwater treatment strategy performance for a proposed facility. In particular he examined a variety of issues of concern for the proposed activities with regards to stormwater, increased traffic counts, and estimated contaminant loading to receiving waters within the Water Supply Protection District.

Participation in National Expert Meeting by the White House Council on Environmental Quality and Environmental Protection Agency

Dr. Roseen participated in a national meeting of experts entitled "Municipal Stormwater Infrastructure: Going from Grey to Green". This meeting purpose was to engage stakeholders in developing options and solutions that result in wider implementation of green infrastructure practices to manage municipal stormwater.

SELECT OTHER PROJECTS

Integrated Permitting for MS4 and Wastewater:

Dr. Roseen is currently leading the stormwater engineering component for a large 5 firm engineering team and an integrated planning steering committee beginning in 2016. The integrated planning effort is the first in the northeastern United States for a municipally funded effort. This project seeks to develop an integrated plan for stormwater, wastewater, and nonpoint sources for a phosphorous TMDL.

Dr. Roseen lead a team from 2013-2015 that developed the foundation for an Integrated Plan for three coastal communities in the seacoast region of New Hampshire. The goal of the plan is to help these communities meet new, more stringent wastewater and stormwater permit requirements for nutrients, improve water quality in the Squamscott River and Great Bay, and support the economic viability of the participating communities. The Plan provides the communities with the necessary information to make long-term financial commitments and planning decisions and to communicate to the public essential information that was developed jointly.

MS4 Regulatory Program Experience: Dr. Roseen lead a team from 2012-2013 with the City of Rochester, New Hampshire as part of a 3-year stormwater engineering contract to provide services to support their MS4 operations and planning. A diverse array of services were provided including nutrient management planning for stormwater and wastewater, stormwater ordinance and planning regulations development, stormwater master planning, MS4 auditing for the 2003 permit, planning and preparation for the 2013 Draft MS4 permit, assistance with developing funding mechanisms to support the municipal program, stream restoration, asset inventory and assessment for drainage infrastructure, operations and management plan preparation, and GIS database development, to name a few.

Phase III Stormwater Master Plan and GIS Updates, Framingham, Ma: Dr. Roseen was the Project Manager for the development of a stormwater master plan for select sub-basins in the Town of Framingham. This project included a field program to collect data on over 1,000 stormwater structures and associated conveyances, as well as in-depth QA/QC of field data using GIS tools, integration of field data into the Town's geodatabase, the development of a hydraulic and hydrologic model of the stormwater system, the performance of a water quality assessment including a pollutant loading analysis, and recommendations based on the condition assessment and modeling exercises based on GIS data and modeling results to develop a Stormwater Master Plan that identifies priority projects based on schedules, capital costs, feasibility, and permitting.

Long Creek Watershed Management Team: Dr. Roseen was a recipient of an Environmental Merit Award as a participating member in the Long Creek Watershed Management Team that was awarded by the US Environmental Protection Agency Region 1 in 2010. This involved the development of the Watershed Management Plan. Rob has collaborated with the Maine Department of Environmental Protection, the Department of Transportation, and the LCWMD in the implementation, monitoring, and maintenance of LID management measures including bioretention, gravel wetlands, tree filters, and the first installation of a high-use state roadway using porous asphalt in the northeastern United States.

Water Integration for the Squamscott Exeter (WISE), (2013-2015), National Estuarine Research Reserve—Science Collaborative. Dr. Roseen was the lead author and Project Director and Principal Investigator for this two-year, $449,484 project.

UNH Stormwater Center 2004-2012. The program tested over 30 BMPs with total funding in excess of $3 million.

Community Based Planning for Climate Change in New Hampshire, National Estuarine Research Reserve—Science Collaborative. Dr. Roseen was the lead stormwater enginnering investigator for this two-year, $683,472 project.

Green Infrastructure for Sustainable Coastal Communities, National Estuarine Research Reserve—Science Collaborative. Dr. Roseen is lead author and the lead science investigator for this two-year, $589,838 project.

Great Bay Municipal Bioretention Program, *New Hampshire Department of Environmental Services*. Dr. Roseen managed this two-year, $140,000 project.

Berry Brook Watershed Restoration, *Aquatic Resource Mitigation Fund of the NHDES and US Army Corps of Engineers*. Dr. Roseen managed this two-year, $400,000 project that investigated wetland and stream restoration, buffer development, and LID retrofits.

Berry Brook Watershed Management Plan Implementation, Phase I Water Quality BMPs, *New Hampshire Department of Environmental Services.* Dr. Roseen managed this two-year, $145,000 project.

Evaluation and Optimization of the Effectiveness of Stormwater Control Measures for Nitrogen Removal, *USEPA Region 1*. Dr. Roseen managed this two-year, $190,000 project.

Assessing the Risk of 100-year Freshwater Floods in the Lamprey River Watershed of New Hampshire Resulting from Changes in Climate and Land Use, *Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET).* Dr. Roseen served as Co-Investigator for a two-year, $177,815.

SELECT PEER REVIEWED PUBLICATIONS

Roseen, Robert M., Todd V. Janeski, Michael Simpson, James H. Houle, Jeff Gunderson, and Thomas P. Ballestero. "Economic and Adaptation Benefits of Low Impact Development." Low Impact Development Technology (2015): 74.

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PROFESSIONAL AFFILIATIONS

- Management Committee, Piscataqua Region Estuary Partnership, since 2015
- Expert Panel, Long Creek Watershed Management District, since 2014.

- USEPA Headquarters, Urban Retrofit Innovation Roundtable, Next Generation LID/GI Technology and Financing Solutions, The National Experience, Selected participant, April 2012
- Urban Water Resources Research Council, Control Group Member, American Society of Civil Engineers, 2012-2017.
- Water Quality Standards Advisory Committee, Piscataqua Region Estuary Program, since 2010
- Technical Advisory Committee, Piscataqua Region Estuary Partnership, since 2009
- American Academy of Water Resources Engineers, Member since May, 2010
- ASCE EWRI-WERF Task Committee on Guidelines for Certification of Manufactured Stormwater BMPs-Subgroup Chair, Member since 2007
- Science and Technical Advisory Committee, American Rivers, Washington, DC, since 2011
- Board of External Reviewers, Washington State Stormwater Technology Assessment Program, 2010-2014
- Board of Directors, The Low Impact Development Center, Beltsville, Maryland, 2009-2015
- Board of Directors, The NH Coastal Protection Partnership, 2008-2012

HONORS AND AWARDS

- Environmental Merit Award, as project lead for the Water Integration for Squamscott Exeter (WISE) in coastal New Hampshire, awarded by the US Environmental Protection Agency, Region 1, 2016.
- Environmental Merit Award, as participating member in the New Hampshire Climate Adaption Workgroup, awarded by the US Environmental Protection Agency, Region 1, 2015
- In 2010, received the prestigious certification as a Diplomate by the American Academy of Water Resources Engineers (D. WRE), to certify competence in water resources specialization for 1) advanced stormwater management, and 2) design and execution of experiments, data analysis, and interpretation.
- 2010 Outstanding Civil Engineering Achievement Award, New Hampshire ASCE, Project Title: State Street Utilities Replacement and Street Revitalization, Portsmouth, New Hampshire, Design Team Member and Lead for Low Impact Development
- Environmental Merit Award, as participating member in the Long Creek Watershed Management Team, awarded US Environmental Protection Agency, Region 1, 2010
- Letter of Commendation from Commissioner Burack of the New Hampshire Department of Environmental Services for School Street School Stormwater Retrofit Project, September 2010

8. Appendix B: Literature Sources for Pollutant Load Export Rates

Table 12 - PLER Sources

Land Use	Land Cover	Nitrogen PLER Source	Phosphorus PLER Source	Fecal Coliform EMC Source	Enterococci EMC Source
Agriculture	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015[24], App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015[24], App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Commercial and Industrial	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Industrial and Commercial Comp.	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Forest	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Forest	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Forest	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
High Density Residential	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Residential	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Low Density Residential	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Residential	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Medium Density Residential	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Residential	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Highway	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Developed Pervious	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015, App. B, Table 3-5; Transportation	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
Open Land	Pervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015[24], App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24
	Impervious	EPA, 2017; Table 2-2	EPA, 2017; Table 2-1	WISE, 2015[24], App. B, Table 3-5; Transitional	[Fecal Coliform] x [1.12] ; ratio from USGS, 2002, Tables 22-24

9. Appendix C: EPA SWMM Model Documentation for Bacterial HRU Analysis

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.012)
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 *********************************************************
 NOTE: The summary statistics displayed in this report are
 based on results found at every computational time step,
 not just on results from each reporting time step.
 *********************************************************

 ****************
 Analysis Options
 ****************
 Flow Units .......................... CFS
 Process Models:
   Rainfall/Runoff ................  YES
   RDII ................................  NO
   Snowmelt .........................  YES
   Groundwater ....................  NO
   Flow Routing ...................  NO
   Water Quality ................... YES
 Infiltration Method ............. CURVENUMBER
 Starting Date ......................  01/01/2000 00:00:00
 Ending Date .......................  12/30/2013 23:59:00
 Antecedent Dry Days ......... 0.0
 Report Time Step ...............  01:00:00
 Wet Time Step ..................  00:01:00
 Dry Time Step .................... 00:05:00


 **************************          Volume         Depth
```

Runoff Quantity Continuity	acre-feet	inches
**************************	-------------	------------
Initial Snow Cover	0.000	0.000
Total Precipitation	282.546	678.110
Evaporation Loss	27.520	66.049
Infiltration Loss	169.563	406.951
Surface Runoff	83.767	201.041
Snow Removed	0.000	0.000
Final Snow Cover	1.690	4.056
Final Storage	0.007	0.017
Continuity Error (%)	-0.001	

**************************	Volume	Volume
Flow Routing Continuity	acre-feet	10^6 gal
**************************	-----------	------------
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	83.767	27.297
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	83.767	27.297
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

****

Subcatchment Runoff Summary
****

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
IMP.CN98	678.11	0.00	117.99	0.00	556.45	15.11	1.68	0.821
PERV.A.CN39	678.11	0.00	34.54	605.93	33.47	0.91	0.35	0.049
PERV.B.CN61	678.11	0.00	50.28	537.15	86.51	2.35	0.64	0.128
PERV.C.CN74	678.11	0.00	60.67	467.56	145.71	3.96	0.75	0.215
PERV.D.CN80	678.11	0.00	66.77	424.11	183.07	4.97	0.77	0.270

Analysis begun on: Thu May 10 09:08:57 2018
Analysis ended on: Thu May 10 09:09:56 2018
Total elapsed time: 00:00:59

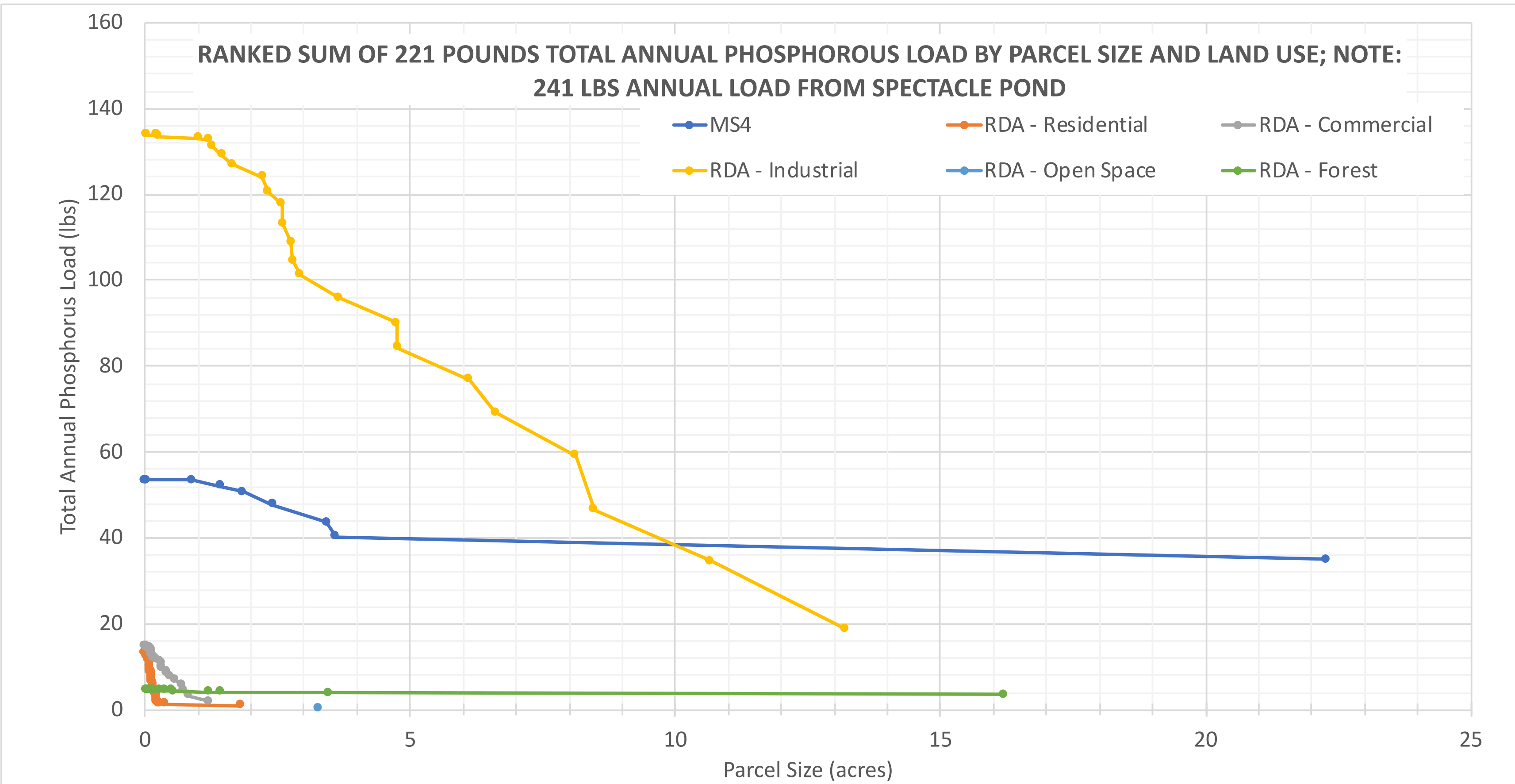
10. Appendix D: Parcel-Based RDA Scenario Spreadsheet Tool Results

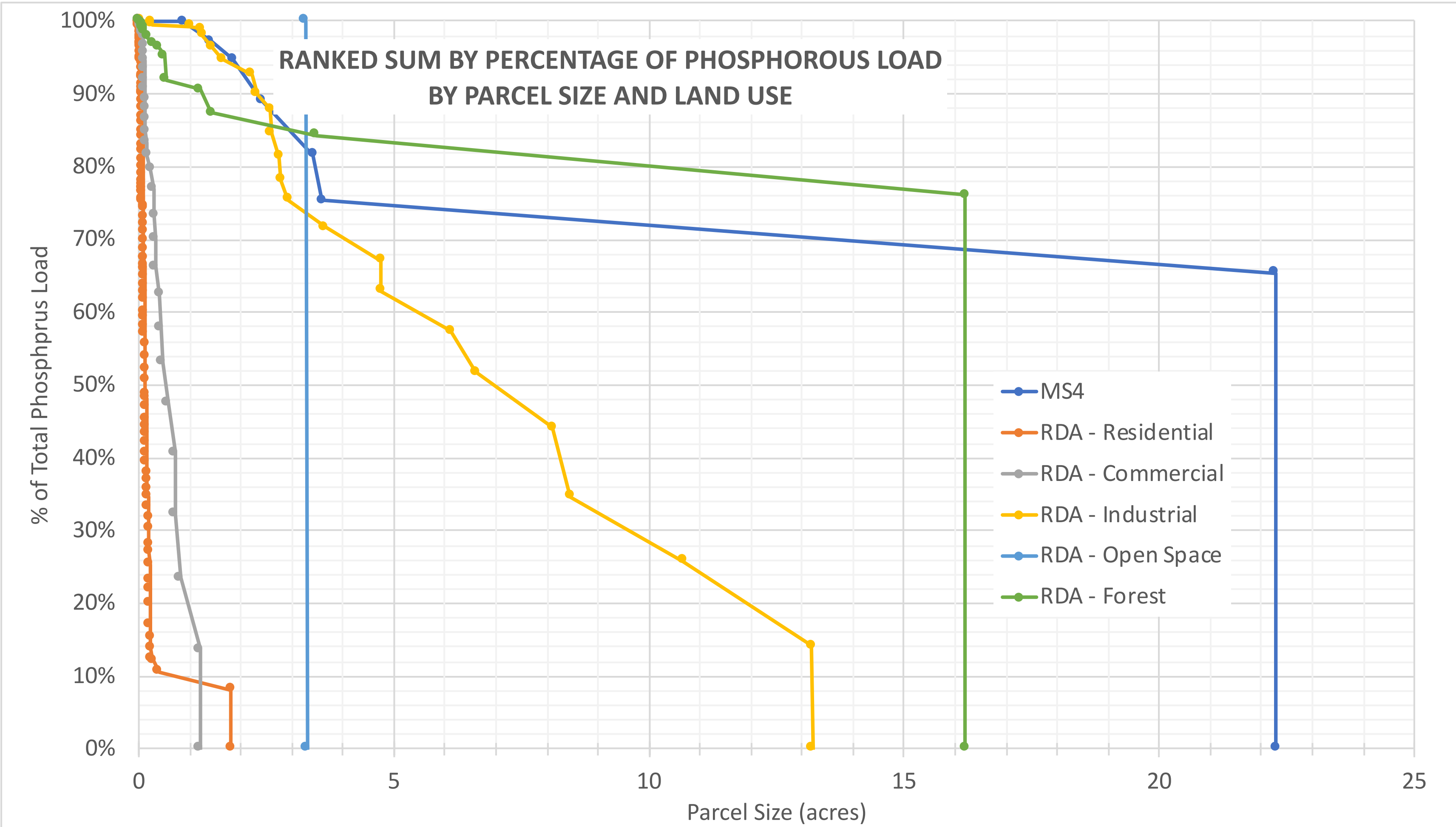
							Scenario 1: Regulating All Non-MS4 Residential, Commercial, and Industrial Parcels					
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency		Infiltration BMPs; 65% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	10	35.9	53.6	0.0	10	100%	53.6	100%	40.7	76%	34.8	65%
RDA - Residential	122	12.8	13.2	0.0	122	100%	13.2	100%	10.1	76%	8.6	65%
RDA - Commercial	36	8.9	14.7	0.0	36	100%	14.7	100%	11.2	76%	9.5	65%
RDA - Industrial	25	91.6	134.0	0.0	25	100%	134.0	100%	101.8	76%	87.1	65%
RDA - Open Space	1	3.3	0.5	9999.0	0	0%	0.0	0%	0.0	0%	0.0	0%
Forest	20	24.9	4.7	9999.0	0	0%	0.0	0%	0.0	0%	0.0	0%
Spectacle Pond	3259	613.0	241.0	54%	-	-	130.1	54%	98.9	41%	84.6	35%
Total	**3473**	**790.3**	**461.6**		**193**	**90%**	**345.6**	75%	**262.7**	57%	**224.6**	49%
Unmanaged Load			**0.0**				**116.0**		**199.0**		**237.0**	
TMDL Requirement			237				237		237		237	
% of TMDL			0%				51%		16%		0%	

							Scenario 2: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >1 acres					
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency		Infiltration BMPs; 65% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	10	35.9	53.6	0.0	10	100%	53.6	100%	40.7	76%	34.8	65%
RDA - Residential	122	12.8	13.2	1.0	1	1%	1.1	8%	0.8	6%	0.7	5%
RDA - Commercial	36	8.9	14.7	1.0	1	3%	2.0	14%	1.5	10%	1.3	9%
RDA - Industrial	25	91.6	134.0	1.0	21	84%	133.0	99%	101.1	75%	86.5	65%
RDA - Open Space	1	3.3	0.5	9999.0	0	0%	0.0	0%	0.0	0%	0.0	0%
Forest	20	24.9	4.7	9999.0	0	0%	0.0	0%	0.0	0%	0.0	0%
Spectacle Pond	3259	613.0	241.0	54%	-	-	130.1	54%	98.9	41%	84.6	35%
Total	**3473**	**790.3**	**461.6**		**33**	**15%**	**319.8**	69%	**243.1**	53%	**207.9**	45%
Unmanaged Load			**0.0**				**141.8**		**218.6**		**253.8**	
TMDL Requirement			237				237		237		237	
% of TMDL			0%				40%		8%		-7%	

							Scenario 3: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >2.5 acres					
	# Parcels	Area (acres)	Total Phosphorus Load (lbs)	Minimum Parcel Size to Regulate (acres)	# Parcels Regulated	% Parcels Regulated	100% Removal		Bioretention BMPs; 76% Removal Efficiency		Infiltration BMPs; 65% Removal Efficiency	
							Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load	Managed Phosphorus Load (lbs)	% of Total Load
MS4	10	35.9	53.6	0.0	10	100%	53.6	100%	40.7	76%	34.8	65%
RDA - Residential	122	12.8	13.2	2.5	0	0%	0.0	0%	0.0	0%	0.0	0%
RDA - Commercial	36	8.9	14.7	2.5	0	0%	0.0	0%	0.0	0%	0.0	0%
RDA - Industrial	25	91.6	134.0	2.5	14	56%	117.8	88%	89.5	67%	76.6	57%
RDA - Open Space	1	3.3	0.5	9999.0	0	0%	0.0	0%	0.0	0%	0.0	0%
Forest	20	24.9	4.7	9999.0	0	0%	0.0	0%	0.0	0%	0.0	0%
Spectacle Pond	3259	613.0	241.0	54%	-	-	130.1	54%	98.9	41%	84.6	35%
Total	**3473**	**790.3**	**461.6**		**24**	**11%**	**301.5**	65%	**229.2**	50%	**196.0**	42%
Unmanaged Load			**0.0**				**160.1**		**232.5**		**265.7**	
TMDL Requirement			237				237		237		237	
% of TMDL			0%				32%		2%		-12%	

Parcel Stats	Total		MS4		Residential		Commercial		Industrial		Open Space		Forest	
	Area (acres)	Phosphorus Load (lbs)	Area (acres)	Phosphorus Load (lbs)	Area (acres)	Phosphorus Load (lbs)	Area (acres)	Phosphorus Load (lbs)	Area (acres)	Phosphorus Load (lbs)	Area (acres)	Phosphorus Load (lbs)	Area (acres)	Phosphorus Load (lbs)
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.05	3.26	0.50	0.02	0.00
Q1	0.06	0.03	0.24	0.34	0.03	0.02	0.09	0.06	1.26	2.09	3.26	0.50	0.07	0.01
Median	0.11	0.13	1.63	2.25	0.08	0.10	0.13	0.21	2.59	4.24	3.26	0.50	0.11	0.01
Average	1.19	1.03	3.59	5.36	0.10	0.11	0.25	0.41	3.66	5.36	3.26	0.50	1.95	0.22
Q3	0.25	0.27	3.16	3.86	0.13	0.16	0.32	0.56	4.76	7.54	3.26	0.50	0.53	0.07
Max	79.50	35.04	22.27	35.04	1.81	1.07	1.19	2.01	13.19	18.98	3.26	0.50	16.20	3.55



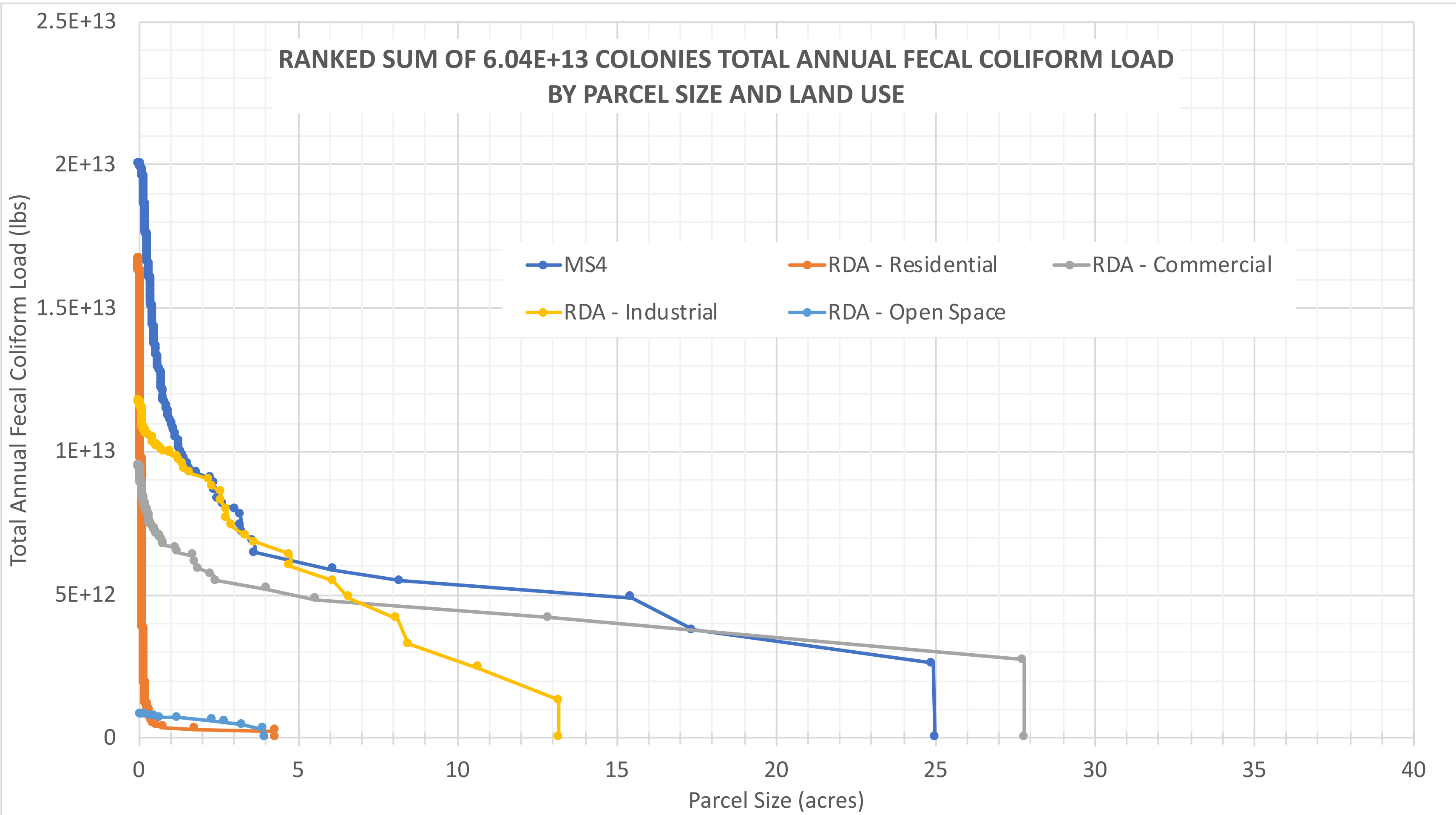

RANKED SUM BY PERCENTAGE OF PHOSPHOROUS LOAD
BY PARCEL SIZE AND LAND USE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% of Total Phosphprus Load
0
5
10
15
20
25
Parcel Size (acres)
MS4
RDA - Residential
RDA - Commercial
RDA - Industrial
RDA - Open Space
RDA - Forest

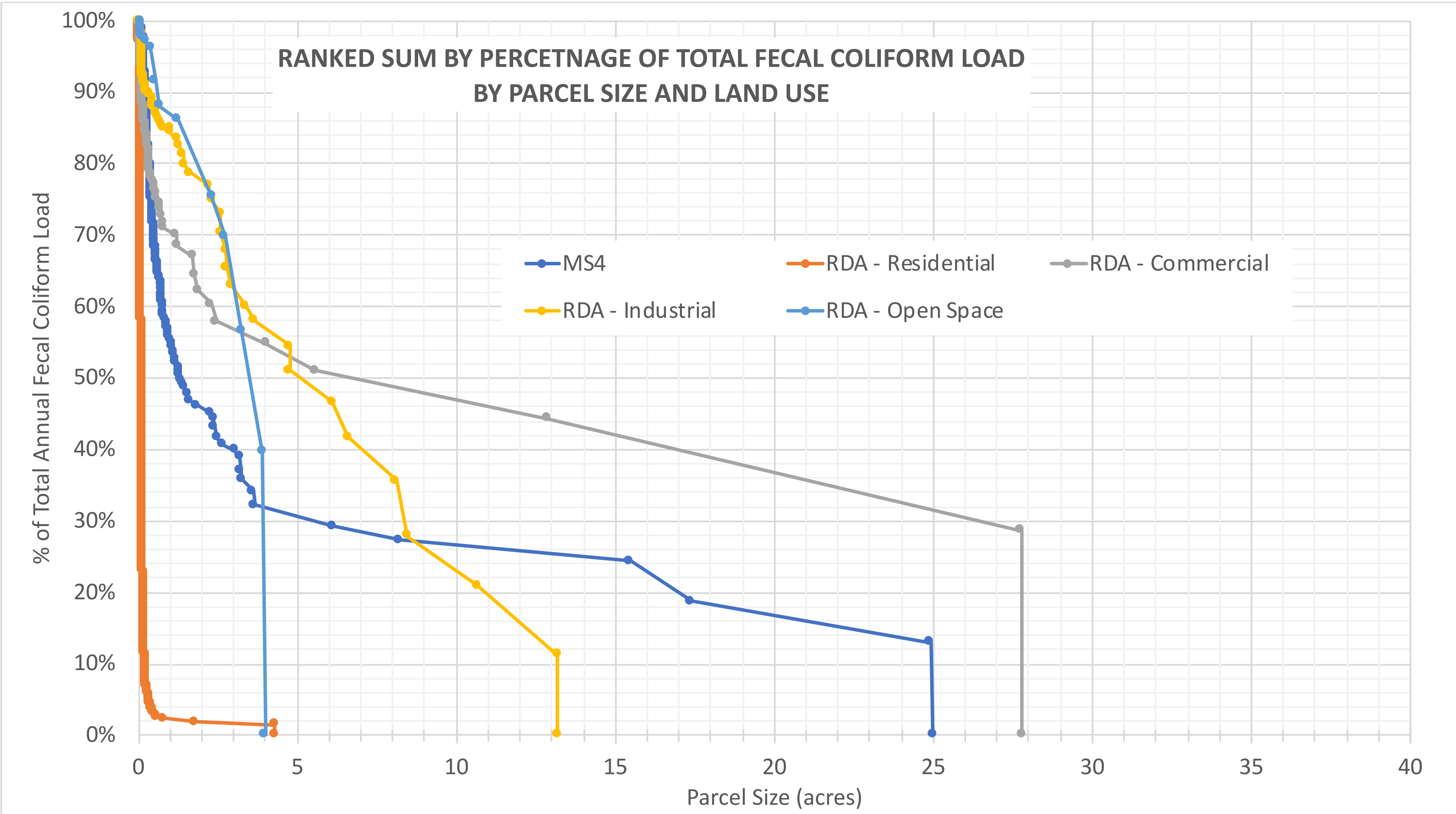
							Scenario 1: Regulating All Non-MS4 Residential, Commercial, and Industrial Parcels			
		Area	Total	Minimum Parcel Size to	# Parcels	% Parcels	100% Removal		Infiltration BMPs; 95% Removal Efficiency	
	# Parcels	(acres)	Fecal Coliform Load (colonies)	Regulate (acres)	Regulated	Regulated	Managed Fecal Coliform Load (colonies)	% of Total Load	Managed Fecal Coliform Load (colonies)	% of Total Load
MS4*	364	222.0	2.01E+13	0.0	364	100%	2.01E+13	100%	1.91E+13	95%
RDA - Residential	2682	276.0	1.67E+13	0.0	2682	100%	1.67E+13	100%	1.59E+13	95%
RDA - Commercial	184	89.0	9.49E+12	0.0	184	100%	9.49E+12	100%	9.02E+12	95%
RDA - Industrial	136	115.0	1.17E+13	0.0	136	100%	1.17E+13	100%	1.12E+13	95%
RDA - Open Space	18	16.1	8.18E+11	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	89	38.5	1.30E+12	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**3473**	**756.7**	**6.02E+13**		**3366**	**97%**	**5.80E+13**	96%	**5.51E+13**	92%
Unmanaged Load**			**0.00E+00**				**2.12E+12**		**5.02E+12**	
TMDL Requirement			4.84E+12				4.84E+12		4.84E+12	
% of TMDL			0%				56%		-4%	

							Scenario 2: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >1 acres			
		Area	Total	Minimum Parcel Size to	# Parcels	% Parcels	100% Removal		Infiltration BMPs; 95% Removal Efficiency	
	# Parcels	(acres)	Fecal Coliform Load (colonies)	Regulate (acres)	Regulated	Regulated	Managed Fecal Coliform Load (colonies)	% of Total Load	Managed Fecal Coliform Load (colonies)	% of Total Load
MS4*	364	222.0	2.01E+13	0.0	364	100%	2.01E+13	100%	1.91E+13	95%
RDA - Residential	2682	276.0	1.67E+13	1.0	2	0%	3.20E+11	2%	3.04E+11	2%
RDA - Commercial	184	89.0	9.49E+12	1.0	11	6%	6.64E+12	70%	6.31E+12	66%
RDA - Industrial	136	115.0	1.17E+13	1.0	24	18%	9.97E+12	85%	9.47E+12	81%
RDA - Open Space	18	16.1	8.18E+11	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	89	38.5	1.30E+12	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**3473**	**756.7**	**6.02E+13**		**401**	**12%**	**3.70E+13**	61%	**3.51E+13**	58%
Unmanaged Load**			**0.00E+00**				**2.32E+13**		**2.50E+13**	
TMDL Requirement			4.84E+12				4.84E+12		4.84E+12	
% of TMDL			0%				-379%		-417%	

							Scenario 3: Regulating Non-MS4 Residential, Commercial, and Industrial Parcels >2.5 acres			
		Area	Total	Minimum Parcel Size to	# Parcels	% Parcels	100% Removal		Infiltration BMPs; 95% Removal Efficiency	
	# Parcels	(acres)	Fecal Coliform Load (colonies)	Regulate (acres)	Regulated	Regulated	Managed Fecal Coliform Load (colonies)	% of Total Load	Managed Fecal Coliform Load (colonies)	% of Total Load
MS4*	364	222.0	2.01E+13	0.0	364	100%	2.01E+13	100%	1.91E+13	95%
RDA - Residential	2682	276.0	1.67E+13	2.5	1	0%	2.48E+11	1%	2.36E+11	1%
RDA - Commercial	184	89.0	9.49E+12	2.5	4	2%	5.20E+12	55%	4.94E+12	52%
RDA - Industrial	136	115.0	1.17E+13	2.5	15	11%	8.58E+12	73%	8.15E+12	69%
RDA - Open Space	18	16.1	8.18E+11	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Forest	89	38.5	1.30E+12	9999.0	0	0%	0.00E+00	0%	0.00E+00	0%
Total	**3473**	**756.7**	**6.02E+13**		**384**	**11%**	**3.41E+13**	57%	**3.24E+13**	54%
Unmanaged Load**			**0.00E+00**				**2.61E+13**		**2.78E+13**	
TMDL Requirement			4.84E+12				4.84E+12		4.84E+12	
% of TMDL			0%				-439%		-474%	

	Total		MS4		Residential		Commercial		Industrial		Open Space		Forest	
Parcel Stats	Area (acres)	Fecal Coliform Load (colonies)	Area (acres)	Fecal Coliform Load (colonies)	Area (acres)	Fecal Coliform Load (colonies)	Area (acres)	Fecal Coliform Load (colonies)	Area (acres)	Fecal Coliform Load (colonies)	Area (acres)	Fecal Coliform Load (colonies)	Area (acres)	Fecal Coliform Load (colonies)
Min	0.00	0.00E+00	0.00	3.60E+04	0.00	8.12E+03	0.00	2.04E+08	0.03	9.52E+08	0.08	1.47E+09	0.01	0.00E+00
Q1	0.07	4.12E+09	0.17	1.43E+10	0.07	3.89E+09	0.07	7.39E+09	0.11	9.81E+09	0.09	2.79E+09	0.06	1.15E+09
Median	0.10	6.39E+09	0.27	2.34E+10	0.09	5.87E+09	0.11	1.08E+10	0.12	1.37E+10	0.18	5.85E+09	0.08	2.34E+09
Average	0.25	1.73E+10	0.61	5.51E+10	0.10	6.24E+09	0.48	5.16E+10	0.85	8.64E+10	0.90	4.54E+10	0.61	1.45E+10
Q3	0.14	9.70E+09	0.45	4.21E+10	0.12	7.85E+09	0.19	2.23E+10	0.37	3.41E+10	1.11	4.37E+10	0.13	5.64E+09
Max	79.50	2.72E+12	24.91	2.62E+12	4.28	2.48E+11	27.78	2.72E+12	13.19	1.33E+12	3.91	3.25E+11	16.20	4.17E+11





RANKED SUM BY PERCETNAGE OF TOTAL FECAL COLIFORM LOAD
BY PARCEL SIZE AND LAND USE
MS4
RDA - Residential
RDA - Commercial
RDA - Industrial
RDA - Open Space
% of Total Annual Fecal Coliform Load
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
5
10
15
20
25
30
35
40
Parcel Size (acres)