Potential and Quantification of Street Sweeping Pollutant Reductions towards addressing TMDL WLAs for MS4 Compliance

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Abstract

Municipal separate storm sewer system (MS4) permittees face costly obligations to reduce pollutant loadings needed to achieve waste load allocations (WLAs) and meet total maximum daily loads (TMDLs). Street sweeping is potentially an effective BMP since streets exist throughout urban watersheds, often are directly connected to the storm sewer, and are found to contain an abundance of contaminants. Although pollutant removal from street sweeping has been evaluated for decades, an understanding of the impact on water quality in receiving streams is elusive. Due to numerous variables, the large number of samples necessary to measure impact in receiving streams may never be obtained. In response, modeled pollutant removal efficiencies based on frequency of sweeping have been recommended to the Chesapeake Bay Program, but these results are suspect. Alternatively, the amount of swept material has emerged as a method to quantify reductions.

A sampling study was conducted to measure pollutants in swept material. The study identified the fraction of material susceptible to transport in runoff based on timing of sweeping in relation to runoff events. Based on observed pollutant concentration associations with particle size, the study results in estimates of pollutant concentrations for the fraction of material susceptible to downstream transport, dependent on duration since the last rainfall and type of surface swept, whether the area is a streets or a parking lot. Pollutant loadings and required reductions to achieve the Chesapeake Bay WLAs for various land use sample areas are computed for an average year. Modeled removal efficiencies and results from the sampling study were employed to assess impacts from street sweeping. Modeled efficiencies predict significantly lower impact than measurements of pollutants susceptible to runoff in swept material. Modeled loadings are inconsistent with measurements of swept materials and the rigorous sweeping frequency required for modeled removal efficiency credit appears to be unnecessary.

Potential and Quantification of Street Sweeping Pollutant Reductions towards addressing TMDL WLAs for MS4 Compliance

Lee Franklin Hixon, Jr., P.E.

General Audience Abstract

Many localities, state agencies and other public entities that own storm sewer systems are increasingly required to reduce pollutants discharged from their systems to surface waters as a result of programs stemming from the Clean Water Act. Traditional stormwater management practices, such as retention ponds, appear limited towards providing the total pollutant reductions necessary due to physical constraints, opportunity and cost. Street sweeping is potentially an effective alternative practice since streets exist throughout urban watersheds, often are directly connected to the storm sewer, are found to contain an abundance of contaminants and can be cost effective. Although pollutant removal from street sweeping has been evaluated for decades, an understanding of the pollutants removed from stormwater is elusive. Past studies suggest the large number of samples necessary to measure impact from sweeping in receiving streams may never be obtained. In response, pollutant removal estimates have been made using computer models, but modeled results are suspect since they cannot be calibrated. Alternatively, a measure of swept material has emerged as a method to quantify pollutant reductions.

A sampling study was conducted to measure pollutants in swept material. Results identify the fraction of swept material washed from the swept surface dependent on timing of sweeping in relation to the duration since the last rainfall. Based on observed pollutant concentration associations with particle size, the study results in estimates of concentrations for the fraction of material susceptible to downstream transport, dependent on duration since the last rainfall and type of surface swept, whether the area is a streets or a parking lot. Application of the results are compared to modeled removal efficiencies towards achieving regulatory compliance within various land use sample areas. Modeled efficiencies predict significantly lower impact than measurements of pollutants susceptible to runoff in swept material. Rigorous sweeping frequency required for modeled removal efficiency credit appears to be unnecessary.

Dedication

This dissertation is dedicated to my ethereal daughter, Kamryn Lee Hixon, and my parents, Stacy and Dennis Seaman.

In memory, this dissertation is also dedicated to those temporarily lost in Room 206 Norris Hall on April 16, 2007, including Dr. G.V. Loganathan, Brian Roy Bluhm, Matthew Gregory Gwaltney, Jeremy Michael Herbstritt, Jarrett Lee Lane, Partahi Mamora Halomoan Lumbantoruan, Daniel Patrick O'Neil, Juan Ramón Ortiz-Ortiz, Julia Kathleen Pryde, and Waleed Mohamed Shaala.

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In addition to Randy, I am also grateful for the time and input from my other prestigious committee members, including Dr. David Sample, Dr. Adil Godrej, and Dr. Tom Walski. In particular, I'd like to express gratitude for Tom's continued support. I met Dr. Walski as an undergraduate student at Wilkes University when he served as a senior project advisor. The experience was invaluable to me, as Tom freely gave of his time and expertise, helping me to develop an understanding of what it meant to conduct research and analyze the results in a meaningful way. Tom also served on my master's thesis committee and grilled me on that one, as well. I'll certainly follow his lead if I find myself in the same position one day.

Finally, I want to acknowledge the support and patience of my family. As somewhat of a fishing and beach bum in my early twenties, I hadn't given much reason for my parents to cosign on a student loan for me when I suddenly decided to leave my hometown of Pensacola, Florida, to move to Wilkes-Barre, Pennsylvania, to go to school (and follow a girl). Yet, after a well-prepared presentation on their living room floor, they agreed. Despite the time it has taken to get to this point, my parents have continued to encourage and support me. I am grateful for their support in all my endeavors. In 2012, I was blessed with a daughter, Kamryn Lee Hixon. She has been the upmost motivation to complete this dissertation. As she has grown, she has also been patient and supportive. Now, at six years old, she is excited I am nearing completion of this dissertation and that I will have more time to play dolls. I can't wait!

Table of Contents

List of Tables

List of Figures

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Chapter 1: Introduction

1.1 Background

Urban runoff is a significant contributor of pollutant loadings to surface waters in the United States. Water quality standards established by the 1972 amendments to the Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA), require states to assess surface water quality to determine if water quality standards are present, generally defined as “fishable” and “swimmable.” When standards are not met, Section 303(d) of the CWA requires the calculation of the maximum amount of the pollutant impairing the waterbody that can be assimilated and still have the waterbody meet water quality standards, known as the total maximum daily load (TMDL). TMDL development requires the identification of the pollutant(s) of concern (POCs) causing the impairment and subsequent development of waste load allocations (WLAs). WLAs designate the portion of the TMDL allocated to National Pollutant Discharge Elimination System (NPDES) regulated point source discharges within the watershed, including municipal separate storm sewer systems (MS4s). Over half of assessed waters in the United States have been designated as impaired, with the POCs most often identified as pathogens, sediment or nutrients (USEPA 2017). Costs to address WLAs are significant, with estimates for Virginia’s regulated MS4s to address the Chesapeake Bay TMDL ranging from $9.4 to $11.5 billion (VSFC 2011).

NPDES permits have traditionally required MS4 permittees to address permit conditions to a standard defined as the maximum extent practicable (MEP). The subjective standard allows for compliance flexibility; but can become problematic for permit holders due to the provision of the CWA that allows for citizen enforcement, resulting in litigation (Taylor and Cazenas 2010). Ambiguity is also a concern for the permittee in regards to compliance expectations of the Environmental Protection Agency (EPA) or state agency delegated to implement and enforce the NPDES permit program. With more recent assignment of numerical values associated with WLAs, compliance expectations have effectively shifted from the qualitative MEP standard to demonstrating quantifiable POC reductions (Leisenring et al 2014, VDEQ 2013). This shift is explicitly demonstrated with the total suspended solids (TSS), total phosphorus (TP), and total nitrogen (TN) numeric POC reductions required to address the Chesapeake Bay TMDL in Virginia's General MS4 Permit (VAC 2018).

Inherently, impaired surface waters have watersheds that can encompass significant portions, or the entirety, of an MS4 service area. This creates challenges for MS4 operators when identifying and implementing best management practices (BMPs) to achieve the magnitude of pollutant reductions to achieve WLAs. BMPs to reduce stormwater pollutants can be characterized as either structural or nonstructural (source) controls. The former have traditionally been implemented to address stormwater management at the site scale to comply with NPDES regulations associated with land development. As a result, structural BMPs have been heavily studied, resulting in the assignment of pollutant removal efficiencies to assess performance, with efficiencies based on measures at the inflow and outflow of the BMP. However, relative to the greater watershed-scale, application of structural BMPs may not be practical to address WLAs due to the relatively small drainage areas to structural BMPs (Ouwejan et al. 2007) and limited opportunity in built-out areas common to those served by MS4s (SPU 2012). Structural BMPs alone cannot achieve water quality goals, necessitating source controls to yield major reductions in pollutant loadings (Ports 2009).

Although the potential for source controls to improve water quality has been recognized (Murphey and Lokey 1999; Taylor and Wong 2002; Bateman 2005, HEC 2006; Sansalone and Rooney 2007; Gupton and Lennon 2013; Lien 2013), studies to quantify impacts to water quality resulting from these controls are limited and sparsely available in the literature (Taylor and Wong 2002; Taylor and Cazenas 2010; NCHRP 2013). An exception is street sweeping, which has been extensively studied to understand the practices impact on surface waters, most notably with the Nationwide Urban Runoff Program (NURP) studies (USEPA 1983). However, there remains little available evidence to quantify the extent to which street sweeping can improve stormwater quality (Allison et al. 1998; Walker and Wong 1999; Rochfort et al. 2009; Kang et al. 2009; Sutherland 2011; Sorenson 2012; Schueler et al. 2016). This is due to the high variability in stormwater-quality loads which requires a large number of water samples to detect any significant change due to street sweeping (Selbig and Bannerman 2007). Difficulties can also be attributed to inaccuracies in sampling methods, and the lag effect of sediment transport in the storm sewer between storms (Law et al. 2008). The inability to quantify reductions from source controls in receiving streams is problematic for MS4s seeking to employ controls towards achieving numerical WLAs. In-lieu of measuring impacts directly in receiving streams, other methods have emerged, supported with models and direct measures of swept material.

1.2 Literature Review

This Section includes a condensed literature review focused on key components of this dissertation. Additional detail is provided within Chapters 3 - 5.

1.2.1 Streets as a Pollutant Source

Particle size distribution (PSD) of collected street surface material provides insight on the fraction readily available for transport in runoff (Pitt 1979; Pitt 1981; Pitt 1985; Sansalone 2007; Rochfort 2009; Horwatich and Bannerman 2009). PSD typically exhibits a lognormal distribution, described by the median to reduce the influence of extreme observations. Median particle size on the street surface typically ranges from 150 – 350 µm, higher on streets in poor condition where breakdown of the street itself could contribute larger particles (Pitt 1979; Pitt and Shawley 1981). The majority of particles on the street surface are < 1,000 µm, with reported ranges from 29 – 58% of the particle size fraction < 250 (Pitt 1979; Pitt and Shawley 1981; Breault et al. 2005; Horawatich and Bannerman 2009; SPU 2012; Gastaldini and Silva 2013).

Loadings after a rainfall event can vary due to factors such as the energy of the previous rain, traffic volumes and street conditions (Pitt 1979). The slope of the surface can also impact loadings, with higher loadings associate with smaller gradients (Gastaldini and Silva 2013). Accumulation rates for street solids and pollutants increase at a faster rate in the initial day or two after cleaning, decreasing significantly after the first few days (Sartor and Boyd 1972; Pitt 1979; Pitt 1981; Sorenson 2012). The accumulation rate of materials on the surface is highly variable and may be impacted by factors such as adjacent land use, street surface type and condition, season and climate (Pitt 1985; Pitt and Shawley 2001; Sorenson 2012). Limited studies quantifying loading rates in the first few days after rainfall find a range of 11 lbs/curb-mile (Horwatich and Bannerman 2009) to approximately 50 lbs/curb-mile (Breault et al. 2005; Pitt and Shawley 1981).

Pollutants on the street surface are mostly associated with the smaller particles (Sartor and Boyd 1972; Vaze and Chiew 2004; Horwatich and Bannerman 2009). However, the median particle size associated with contaminants is several hundred microns, indicating larger particles also represent a significant portion of pollutant loadings on the street surface (Pitt 1979). Leaf litter on the street surface can also be a significant source of nutrients in stormwater from residential areas (Selbig 2016).

Few particles > 1,000 µm are washed from the street surface during runoff events (Sartor and Boyd 1972; Horwatich and Bannerman 2009; Winston and Hunt 2016), with Horwatich and Bannerman (2009) finding 63% and 77% of highway runoff particles to be < 250 µm and be < 500 µm, respectively. Greater rainfall intensity transports greater sediment loads (Sartor and Boyd 1972; Pitt 1985; Walker and Wong 1999; Gastaldini and Silva 2013). The magnitude of transported material is also dependent on the street loading, and therefore the duration since the previous rainfall (Pitt and Shawley 1981; Furumai et al. 2001). A study with downstream monitoring by Pitt and Shawley (1981) finds most of the runoff yield to be from streets for storm events < 0.7 inches.

1.2.2 Potential of Street Sweeping to Reduce Loadings

Transportation related imperviousness (parking lots and streets) is often directly connected to storm sewers and can be a significant fraction of the total imperviousness (Schueler 1994; Lee 2003), implying areas available to sweeping could contribute a significant fraction of pollutants. However, reductions from sweeping are dependent on the frequency of sweeping, precipitation patterns, and street material accumulation (Sutherland and Jelen 1997). The removal efficiencies of the sweepers employed also impact removal. The ability of a mechanical broom, regenerative-air or vacuum-assisted sweeper to collect particles from the street surface has improved as technology has advanced. Whereas early studies found sweepers to be ineffective at collecting smaller particles (Sartor and Boyd 1972), more recent studies find effectiveness at collection of large fractions of the fine particles associated with pollutants (Pitt and Shawley 1981; Breault et al. 2005; Sutherland 2011; Sorenson 2012). These advancements in sweeper technology that have the ability to significantly reduce pollutants to surface waters (USEPA 2006; Rochfort et al. 2009; Selbig 2016).

Ideally, quantification of reductions towards achieving WLAs would be based on measures to assess water quality pre- and post-sweeping at the downstream outfall. However, previous studies have found this difficult due to variables impacting stormwater-quality loads (Pitt 1985; Zariello et al. 2002; Selbig and Bannerman 2007; Law et al. 2008). As a result, little statistically significant information is available (HEC 2006; Schilling 2005). The potential for sweeping to impact water quality has been demonstrated in a recent study by Selbig et al. (2016) with a paired basin approach for a small residential area that found reductions in downstream sampling in excess of 80% and 70% for TP and TN, respectively, in the fall months as a result of aggressive street cleaning. Measures in the receiving street gutter by Weston Solutions (2010) from a swept and unswept street also observed significant TSS reductions of 74% and 85% for a mechanical and vacuum sweeper, respectively.

1.2.3 Quantifying Pollutant Reductions from Sweeping for Regulatory Compliance

MS4s face challenges to assess BMP performance in a manner consistent with numeric WLAs that are based on application of various assumptions and watershed-scale hydrologic models combined with water quality models (Borah et al. 2019). WLAs can vary significantly dependent on the model employed (Borah et al. 2006; Wallace et al. 2018; Mohamoud and Zhang 2019). In regards to street sweeping, transportation land cover is typically not explicitly modeled, instead aggregated with urban runoff (Wu et al. 1998). As a result of these challenges and the limited information to quantify impact from sweeping to measures downstream, methods have emerged that either rely on pollutant removal efficiencies resulting from a modeling application, or (2) direct measure of swept material.

Pollutant removal efficiencies based on frequency of sweeping were previously incorporated into state guidance documents for MS4s within the Chesapeake Bay TMDL watershed (MDE 2014; VDEQ 2015). The removal efficiencies were based on a conceptual model by Law et al. (2008) that applied various impact factors to estimate reductions. Subsequently, Schueler et al. (2016) presents findings of an expert panel recommending replacement of the Law et al. (2008) model based removal efficiencies with modest removal efficiencies resulting from a continuous simulation watershed model. The use of a modeling application is deemed necessary by the panel due to the lack of statistically significant measures in receiving streams quantifying the impact of sweeping.

The use of modeled removal efficiencies to quantify sweeping reductions raises concerns based on the sources of model input, functions employed, and the lack of calibration. Model data and functions for street material loading, accumulation, and washoff are mostly based on data early studies by the National Urban Runoff Program (NURP) studies described by USEPA (1983) that have been later questioned due to sampling techniques (Sutherland and Jelen 1997; Kang 2009; Winston and Hunt 2017). Pitt et al. (2005) finds unreasonable modeled loading predictions using a common loading function if not based on direct measures and also cites concerns with the wash-off function typically used and modified by models. The ability to estimate loadings without direct measure is also questioned by (Kim et al. (2006) and Breault et al. (2005).

State guidance documents within the Chesapeake Bay TMDL watershed also included a method to quantify reductions from sweeping based on measure of the swept material (MDE 2014; VDEQ 2015). The method was based on the collected mass of material, then translated to pollutant reductions resulting from measures of material from the street surface by Law et al. (2008). Driven by NPDES compliance, others have implemented similar methods, with TSS quantifications either based on the entire mass collected (Breault et al 2005; EOA 2007) or the fraction of collected material susceptible to transport in runoff (SPU 2012, Bateman 2012). For quantification of other POCs, concentrations have been measured based on recovered material (EOA 2007; Bateman 2012) and constituency measured on the street surface (Law et al. 2008; MDE 2014; VDEQ 2015).

1.3 Research Objectives

The research goal is to examine the potential of street sweeping as a practice for addressing quantifiable WLAs. In the absence of the ability to quantify impacts to water quality from street sweeping with long-term water quality monitoring in receiving waters, the research goals seeks to build from knowledge obtained from the peer-reviewed literature to provide insight towards answering the following research questions:

- Can relatively easily obtained measures of swept material be defensibly translatable to POC reductions towards WLAs at regulated MS4 outfalls?
- Can street sweeping provide an appreciable amount of POC reductions towards achieving WLAs?

To address the research questions, the following objectives are proposed:

1. *Objective 1:* Conduct a comprehensive literature review of the state of the practice for assessing water quality benefits from street sweeping to guide the approach for addressing each research questions.
2. *Objective 2:* Develop and implement a sampling program that results in analytical examination and assessment of swept material in context to characterization of pollutant reduction towards achieving WLAs.
3. *Objective #3:* Evaluate areas within typical MS4 watersheds, representing various land uses, to estimate the potential impact of street sweeping to achieve POC reductions in context to those required by TMDL WLAs.

1.4 Organization of Dissertation

The remainder of this dissertation is organized as follows:

- ✓ **Chapter 2** - *State of the Practice: Assessing Water Quality Benefits from Street Sweeping*

  This paper addresses research objective 1, describing a comprehensive review of the literature on street sweeping studies impact to water quality. The paper includes compilation of relevant data towards gaining understanding of loadings and wash-off of pollutants from the street surface. As the result of the inability to quantify reductions in receiving streams from past studies, the paper also describes alternative methods emerging for quantifying pollutant reductions towards achieving NPDES compliance with WLAs.

- ✓ **Chapter 3 -** *Characterization of Street Sweeping Material for addressing Total Maximum Daily Load Waste Load Allocations*

  This paper addresses research objective 2, presenting the analysis and assessment of 58 samples of swept material collected from six MS4 permitees in Virginia. Assessment of results leads to estimates of mass of POCs removed for total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP), dependent on duration since rainfall and type of surface swept.

- ✓ **Chapter 4 -** *Quantifying Street Sweeping Pollutant Reductions towards achieving Total Maximum Daily Load Waste Load Allocations*

  This paper addresses research objective 3, presenting characterization of pollutant reductions achieved with street sweeping based on both modeled pollutant removal efficiencies and direct measure of collected material. Characterization is applied in context to loadings and required reductions generated for four sample areas representing various land uses with an MS4 regulated city. Quantification of pollutant reductions predicted from modeled removal efficiencies are significantly less than those resulting from the measure of pollutants susceptible to runoff in swept material. The difference between the methods finds the modeled removal efficiencies to characterize sweeping as having modest impact to water quality; while the direct measure method indicates high potential impact towards achieving WLAs, especially in the in non-commercial land use sample areas.

- ✓ **Chapter 5 -** *Conclusions*

  A summary of the outcomes addressing each objective is discussed based on the findings of the research. The broader impact and suggested future work based on research findings is also provided.

Chapter 2: State of the Practice: Assessing Water Quality Benefits from Street Sweeping

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2.1 Abstract

Municipal separate storm sewer system (MS4) permittees face costly obligations to reduce pollutant of concern (POC) loadings for achieving waste load allocations (WLAs) assigned from total maximum daily loads (TMDLs). Due to the magnitude of reductions necessary to achieve WLAs at a watershed-scale, implementation of nonstructural best management practices (BMPs) that can be applied to large areas within the watershed appears necessary. Street sweeping serves as an example since streets exist throughout urban watersheds, often are directly connected to the storm sewer, and are found to contain an abundance of contaminants. Although pollutant removal from street sweeping has been evaluated for decades, an understanding of the impact on water quality in receiving streams is elusive. A current review of rigorous street sweeping studies, in the context of application towards WLAs, suggests that impacts are potentially significant in reducing downstream pollutant loads. Due to few adequate sampling studies, lack of feasible methodologies, and perhaps inability to evaluate impacts downstream from street sweeping altogether, alternative methods have emerged to quantify POC reductions as measures of effectiveness required for regulatory compliance.

2.2 Introduction

Urban runoff is a significant contributor of pollutant loadings to surface waters in the United States. Water quality standards established by the 1972 amendments to the Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA), require states to assess surface water quality to determine if water quality standards are present, generally defined as “fishable” and “swimmable.” When standards are not met, Section 303(d) of the CWA requires the calculation of the maximum amount of the pollutant impairing the waterbody that can be assimilated and still meet water quality standards, known as the total maximum daily load

(TMDL). TMDL development requires the identification of the pollutants of concern (POCs) causing the impairment and subsequent development of waste load allocations (WLAs). WLAs designate the portion of the TMDL allocated to National Pollutant Discharge Elimination System (NPDES) regulated point source discharges within the watershed, including municipal separate storm sewer systems (MS4s). Over half of assessed waters in the United States have been designated as impaired, with the POCs most often identified as pathogens, sediment or nutrients (USEPA 2017). Costs to address WLAs are significant, with estimates for Virginia's regulated MS4s to address the Chesapeake Bay TMDL ranging from \$9.4 to \$11.5 billion (VSFC 2011).

Structural and nonstructural best management practices (BMPs) can be used to reduce discharge of POCs in stormwater runoff to surface waters, the latter also known as source controls. In context to WLAs, structural BMPs can be limited in application since they may be ineffective at removal of dissolved nutrients and require available space for installation (Selbig 2016). Raje et al. (2013) comments that structural BMPs are also poorly maintained, noting that structural BMPs can become pollutant sources due to leaching and resuspension of pollutants in runoff. Ouwejan et al. (2007) find pollutant removal from structural BMPs is also limited due to the relatively small contributing drainage area and upper limits on physical contaminant removal, stating that significant load reductions can only be achieved through implementing source controls. A similar conclusion is made by Selbig (2016) as result of a study that found source control of leaves resulted in reductions in both total and dissolved phosphorus and nitrogen. Perspective is provided in Figure 2-1 that illustrates the area necessary to be treated by structural BMPs for achieving the Chesapeake Bay TMDL WLA for total phosphorus (TP) in Hopewell, Virginia. As BMP removal efficiency increases, the total area that requires treatment decreases.

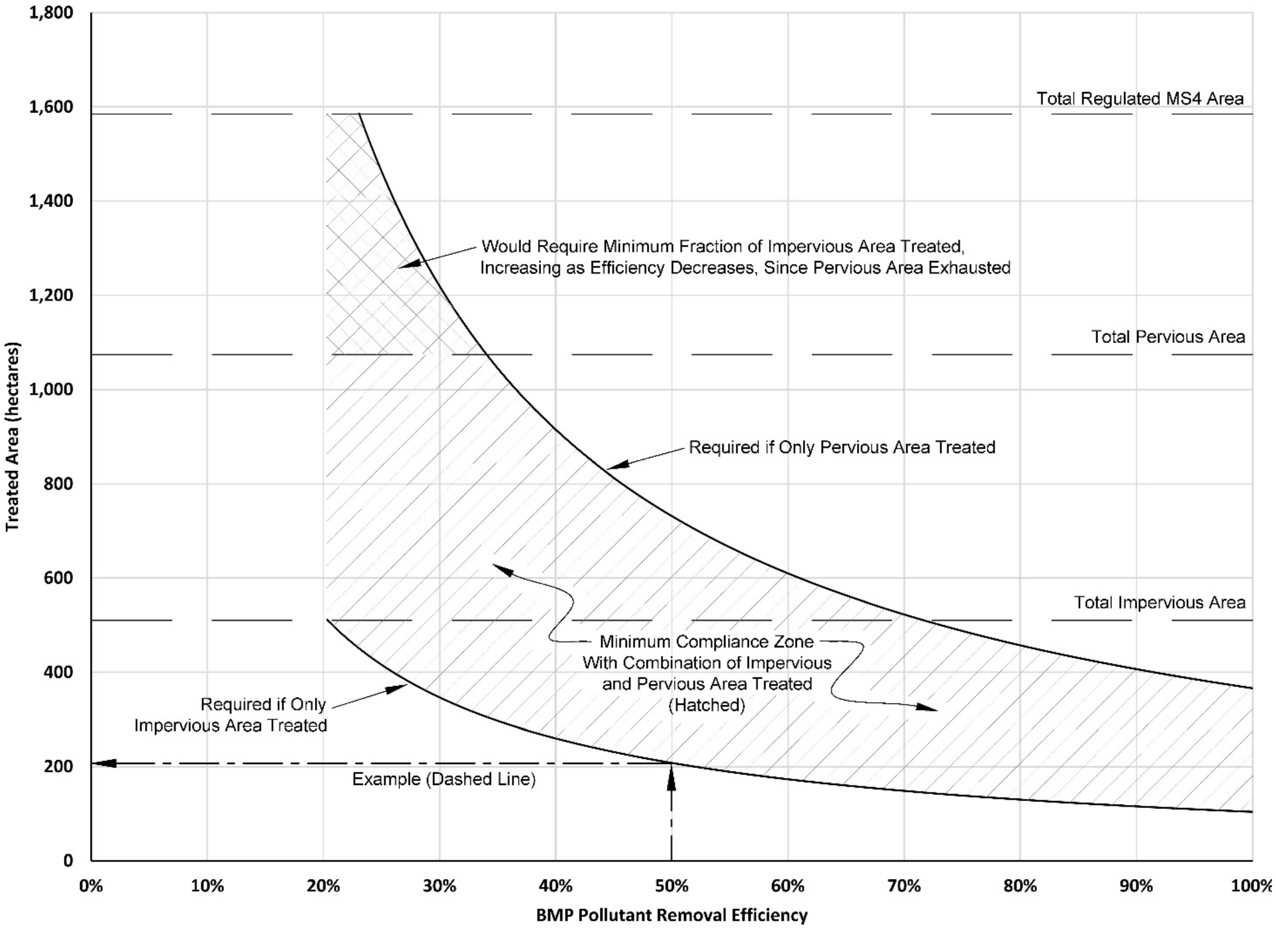

Figure 2-1. Treated area using structural BMPs to achieve 205 kg/yr of TP reduction required for the Chesapeake Bay TMDL for Hopewell, Virginia. Loading rates are 4.349 and 1.236 lbs/ha for impervious and pervious, respectively (VAC 2013). Land cover data is from EEE Consulting (2015).

The figure illustrates that a significant fraction of the MS4's regulated area would require treatment to achieve the required TP reductions, despite BMP removal efficiency. For example, about 200 of the City's 511 hectares of impervious area (40%) would require treatment by structural BMPs with a 50% TP removal efficiency to achieve minimum compliance with the WLA. The required area for treatment if only pervious area was treated is also shown and would be higher since TP loading from pervious cover is approximately 30% less than loadings from impervious cover (VAC 2013). It would likely be difficult to identify structural BMP opportunities to treat the necessary fraction of existing area, suggesting the potential importance for inclusion of source controls as part of a strategy to achieve WLAs.

2.3 Nonstructural BMPs and Regulatory Compliance

NPDES permits have traditionally required MS4 permittees to address permit conditions to a standard defined as the maximum extent practicable (MEP). The subjective standard allows for compliance flexibility; but can become problematic for permit holders due to the provision of the CWA that allows for citizen enforcement, resulting in litigation (Taylor and Cazenas 2010). Ambiguity is also a concern for the permittee in regards to compliance expectations of the Environmental Protection Agency (EPA) or state agency delegated to implement and enforce the NPDES permit program. With the assignment of numerical values associated with most WLAs, compliance expectations have effectively shifted from the qualitative MEP standard to a quantifiable POC reductions. This shift is explicitly demonstrated with the total suspended solids (TSS), TP, and total nitrogen (TN) numeric POC reductions to address the Chesapeake Bay TMDL in Virginia's General MS4 Permit (VAC 2013). Whereas structural BMPs have been studied extensively, resulting in established removal efficiencies to quantify POC reductions, nonstructural practices have been assessed by their implementation to the MEP. However, structural BMPs alone cannot achieve water quality goals, necessitating source controls to yield major reductions in pollutant loadings (Ports 2009).

Potential for nonstructural BMPs towards addressing WLAs has been recognized, yet there has been little development and implementation of these source controls to address TMDLs (Taylor and Cazenas 2010). Potential is demonstrated by Selbig (2016), finding significant reductions for total and dissolved phosphorus and nitrogen from runoff as a result of leaf removal from streets. Bateman (2005) suggests municipalities analyze and evaluate each stormwater program element regarding the degree to which the associated activity can be related to POC load reduction. A draft effort by USEPA (2011) illustrates an attempt to quantify reductions from nonstructural practices using available studies and best professional judgment, but the effort was not completed. In an effort to quantify reductions, Murphy and Lokey (1999) developed a spreadsheet model using a Monte Carlo style simulation module to accommodate the uncertainty in published removal efficiencies and other solicited efficiency data for nonstructural BMPs included in the City of Phoenix's MS4 program. The model applied a physical and operational efficiency to each of the City's BMPs, including policies, standards, guidelines and operational procedures. Results found the cumulative load reductions of the nonstructural BMPs were significant, ranging between 30 – 51% of a baseline estimate. However, long-term monitoring is necessary to validate improvement resulting from implementation of nonstructural BMPs (Lien 2013).

In contrast to most source controls, street sweeping has been extensively studied to understand the practices impact on surface waters, most notably with the Nationwide Urban Runoff Program (NURP) studies (USEPA 1983). These early studies concluded that street sweeping was largely ineffective at reducing the event mean concentration (EMC) of pollutants in urban runoff. However, subsequent studies suggest reevaluation of the NURP conclusion is necessary due to improved experimental designs, limited samples (Kang 2009), sampling techniques (Sutherland 1997; Winston and Hunt 2016), and advancements in sweeper technology that have the ability to significantly reduce pollutants to surface waters (USEPA 2006; Rochfort et al. 2009; Selbig 2016). Many conclude there is little available evidence to quantify the extent to which street sweeping can improve stormwater quality (Allison et al. 1998; Walker and Wong 1999; Rochfort et al. 2009; Kang et al. 2009; Sutherland 2011; Sorenson 2012; Schueler et al. 2016). This paper reviews the wealth of literature on the practice of street sweeping and its potential to improve water quality, specifically in the context of regulatory compliance.

2.4 Pollutant Loadings on the Street Surface

An understanding of the constituency of material on the road surface can assist with understanding the potential for water quality benefit from street sweeping. In early studies, Sartor and Boyd (1972) collected street surface material for analysis by hand sweeping and then hose flushing test areas. Subsequent studies collected street surface material with industrial vacuums by vacuuming strips across the street section, allowing for simplified collection of many random dry samples (Pitt 1979; Pitt and Shawley 1981; Pitt 1985; Sorenson 2012). The latter method is reported to remove more than 99% of the particulates from the street surface (Pitt & Shawley1981; Pitt et al. 2005). Particle size distribution (PSD) of collected street surface material provides insight on the fraction readily available for transport in runoff (Pitt 1979; Pitt 1981; Pitt 1985; Sansalone 2007; Rochfort 2009; Horwatich and Bannerman 2009). PSD typically exhibits a lognormal distribution, described by the median to reduce the influence of extreme observations. Median particle size on the street surface typically ranges from 150 – 350 µm, higher on streets in poor condition where breakdown of the street itself could contribute larger particles (Pitt 1979; Pitt and Shawley 1981). Median particle size can also increase in the winter and spring due to treatment applications (Horwatich and Bannerman 2009). Winston and Hunt (2016) found PSD in road runoff not impacted by traffic volume nor underlying soil type. A summary of reported information in Table 2-1 finds fine and medium particle sizes comprise approximately 80% of the particles on the street surface, with roughly 30-50% less than 250 µm, the maximum particle size sometimes associated with TSS in stormwater runoff (Law et al. 2008; Taylor 2002). However, this association may not be completely representative since larger particles can become resuspended during increased flows (Smith 2002) and TSS can represent around 30% of suspended-sediment > 250 µm (Selbig and Bannerman 2011). A review of the literature did not find studies that consider the breakdown of larger particles to smaller particles on street surfaces over time, potentially occurring due to impact from traffic.

Table 2-1. Percentage (%) of street surface material per particle size range, microns.

Study	**Fine**			**Medium**			**Coarse**
	0-36	**36-63**	**63-125**	**125-250**	**250-500**	**500-1,000**	**> 1,000**
Pitt (1979); Good Condition	25		18	15	13	11	18
Pitt (1979); Poor Condition	18		15	13	15	16	23
Pitt & Shawley (1981)	48.5			51.5			
Breault (2005)[a]	3.5		5.5	22	69[b]		
Horwatich and Bannerman (2009) Swept Streets [c]	13		12	18	24	14	18
Horwatich and Bannerman (2009) Unswept Streets [c]	7		8	15	25	18	27
SPU (2009) Unswept [a]	12		17		71		
SPU (2009) Swept [a]	13		19		68		
Gastaldini and Silva (2013)	3.0		28.0		69.0		

[a] Average of multiple sites.
[b] Percentage represents fraction up to 2,000 µm. Larger than 2,000 µm averaged 14.5%.
[c] Does not add to 100% since extrapolated from graphs.

Another metric for evaluation of material on the street surface is the loading. The surface loading is characterized as the initial loading, occurring immediately after street cleaning (rain or sweeping), and in terms of accumulation of the loading between cleaning events. Loading on the street surface is typically characterized as mass per curb length, considered an effective measurement for estimation of loadings and reductions (Pitt and Shawley 1981). Initial loadings can vary due to factors such as the energy of the previous rain, traffic volumes and street conditions (Pitt 1979). Gastaldini and Silva (2013) suggests street gradient impacts the loading whereas loadings were found to be higher on a street with a lesser slope, despite higher traffic volume on the steeper street. Street loadings are found to vary widely, as illustrated in Table 2-2.

Table 2-2. Example ranges for reported street surface loadings, representing total solids.

Study	Street Loading (grams/curb-meter)*
Sartor and Boyd 1972	282 – 986 (290 – 3,500)
Pitt 1981	14 – 846 (50 – 3,000)
Pitt (1985) Pre-swept	< 28 – 197 (<100 – 700)
Horwatich and Bannerman (2009) Swept Streets	45 – 137 (159 – 486)
Horwatich and Bannerman (2009) Unswept Streets	40 – 419 (142 – 1,488)
MAWMP (Anchorage) (2011) Pre-swept	6 – 1,085 (20 - 3,850)
Sorenson (2012)	28 – 705 (100 – 2,500), > 5000 (winter)

* Loading provided as lbs/curb-mile in parentheses.

The accumulation rate of the street loading is defined as the deposited dirt minus removal of material from rain, street sweeping, wind and vehicle turbulence (Pitt 1985). The deposited material is mostly attributed to local soil erosion, vehicle emissions and wear, and minor contribution from street surface erosion (Pitt and Shawley 1981). Apparent influence of nearby soils is shown by Charters et al. (2015), finding PSD in runoff from various urban surface types similar to the PSD of a source of nearby wind-blown soils. The source appears as an influence since previous studies had shown variation in PSD among varied urban surface types. The accumulation rate of materials on the surface is highly variable and may be impacted by factors such as adjacent land use, street surface type and condition, season and climate (Pitt 1985; Pitt and Shawley 2001; Sorenson 2012). Schueler et al. (2016) conclude sediment accumulation may vary per road type, but not enough studies have provided comparative statistics.

Accumulation rates for street solids and pollutants increase at a faster rate in the initial day or two after cleaning (Sartor and Boyd 1972; Pitt 1979; Pitt 1981; Sorenson 2012). This is demonstrated, for example, by comparison of results from Pitt (1979) and Pitt and Shawley (1981) in Table 2-3. Accumulation rates decrease significantly after the first few days with less variation between studies, perhaps as an equilibrium of material capacity is reached in balance with wind and vehicle turbulence transporting sediment to the adjacent area. Breault et al. (2005) evaluated accumulation rates in residential areas for 1-, 2- and 3-day intervals after street cleaning, finding an average accumulation of approximately 14 grams/curb-meter (50 lbs/curb-mile), comparable to Pitt and Shawley (1981). Measures by Horwatich and Bannerman (2009) found daily accumulation rates that were much smaller, with a median less than 3 grams/curb-meter (< 11 lbs/curb-mile) for the first four days after cleaning and 1 grams/curb-meter (< 4 lbs/curb-mile) between six and nine days. Accumulation was not observed after ten days, with the latter assumed to represent an equilibrium between accumulated material and material removed from the roadway by turbulence from vehicles and wind, known as fugitive dust and made up of particles < 20 µm (Pitt 1979). Due to limited sampling and the need to group accumulation days, detail of accumulation value is lost; however, the trend of decreasing accumulation as days after street cleaning occurred was consistent with previous studies.

Table 2-3. Comparison of street material accumulation rates for two nearby studies in California.

Days since last cleaning	**Total Solids Accumulation Rate (grams/curb-meter/day)***	
	San Jose (Pitt 1979) (Averaged from 2 test areas)	**Castro Valley (Pitt & Shawley 1981) (Averaged from 3 test areas)**
2	5 (18)	17 (60)
4	5 (18)	10 (36)
5	4 (14)	6 (21)
7		5 (18)
10		5 (18)
20	4 (14)	4 (14)
30	4 (14)	3 (11)
55	3 (11)	1 (4)

* Approximate accumulation rate provided as lbs/curb-mile/day in parentheses.

Pollutants on the street surface are mostly associated with the smaller particles (Sartor and Boyd 1972; Vaze and Chiew 2004; Horwatich and Bannerman 2009), with pollutant concentrations typically increasing as particle size decreases (Breault et al. 2005; Pitt 1979; Pitt and Shawley 1981; Pitt 1985). Vaze and Chiew find 85% of pollutants are attached to particles < 300 µm. It is theorized that the association of pollutants with smaller particles is due to the larger specific surface area, allowing contaminants to adhere more easily compared to larger particles (EOA 2007). However, the median particle size associated with contaminants is several hundred microns, indicating larger particles also represent a significant portion of pollutant loadings on the street surface (Pitt 1979). A summary of Waschbusch et al. (1999) by Schueler et al. (2016) found 50% of TP by mass of street solids to be in particles > 250 µm. Sampling of pollutants dissolved from street material by Gastaldini and Silva (2013) provides insight since some forms of phosphorus and nitrogen can adhere to the particles transported downstream by runoff. The sampling, performed to quantify pollutants related to sediments of different sizes, found the highest phosphate loads associated with particles > 500 µm and < 63 µm. Nitrate was most heavily associated with particles ranging from 63 – 250 µm. Leaf litter on the street surface can also be a significant source of nutrients in stormwater from residential areas (Selbig 2016); but an inconsequential nutrient source from highways (Winston and Hunt 2016).

2.5 Downstream Transport of Street Loading

Transport of the street loadings through runoff is impacted by the intensity and magnitude of rainfall, with greater rainfall intensity transporting greater sediment loads (Sartor and Boyd 1972; Pitt 1985; Walker and Wong 1999; Gastaldini and Silva 2013). As would be expected, smaller particles are more easily washed off the street (Pitt 1979; Pitt 1985; Furumai et al. 2001; Horwatich and Bannerman 2009; Kang et al. 2009; Winston and Hunt 2016). An early effort to observe how contaminants are flushed from streets by Sartor and Boyd (1972) simulated rainfall at 0.2 and 0.8 in/hr. intensities and sampled wash-off at 15 minute intervals. Results found initial runoff dirty, becoming cleaner over time, and approaching a maximum washoff of contaminants after about one hour during the smaller intensity simulation for all particle size ranges. With the more intense storm, maximum accumulations occurred at 15 minutes for particles < 840 µm and at an hour for larger particles. The mass accumulation of the particles < 840 µm was roughly five and twenty times greater than that of the coarser particles (840 – 2,000 µm) for the smaller intensity and more intense simulation, respectively. Although there was wash-off of larger particles, fine and medium sized particles represent a majority of the particles transported from the road surface, with loadings increasing with increased simulated rainfall intensity. For comparison, mean particle size in runoff samples from street surfaces has recently been reported to vary between 8 – 167 µm (Winston and Hunt 2016; Selbig 2015; Charters 2015).

Downstream runoff sampling by Horwatich and Bannerman (2009) found that concentrations in runoff exhibit a lognormal distribution with a median of 63% of highway runoff particles to be < 250 µm across five sites and a median of 77% of the particles to be < 500 µm. Less than 10% were over 1,000 µm, indicating few particles greater than this size are transported downstream. Winston and Hunt (2016) found similar results from edge-of-pavement runoff samples from highways in North Carolina, finding a median d_{90} of 428 µm and few particles over 1,000 µm for samples from conventional paved highways. Correlation tests found PSDs negatively correlated to rainfall duration and positively correlated to peak hourly rainfall intensity and average rainfall intensity. No correlation was found to peak 5-minute rainfall intensity, antecedent dry period or rainfall depth. The tests appear to align with the Sartor and Boyd (1972) findings for the time to maximum wash-off accumulations per particle size relationship with rainfall intensity.

The magnitude of transported material is also dependent on the street loading (Pitt and Shawley 1981). This is supported with regression models developed from highway runoff samples by Irish et al. (1998) that found as the antecedent dry period increases, wash-off loadings increase and as intensity of the previous storm increases, the loading decreases. Furumai et al. (2001) found loads of nitrate and total phosphorus in runoff are also dependent on the duration of the dry period and the average traffic count during the dry period. Pitt and Shawley (1981) examined the potential impact of street runoff relative to the discharge from the downstream storm sewer outfalls in several residential urban test areas. The study, in a mostly low-density residential area, included rainfall and runoff monitoring compared with street surface particulate loading measurements before and after rain events. A relationship between the ratio of street surface loadings prior to the storm and runoff yields monitored in the creek downstream was dependent on runoff volumes. For smaller runoff events (volume ≤ approximately 18 mm across the 909-acre urban test area), most of the runoff yield is from the street surface, resulting in a ≥ 1 ratio of street loading to total loading at the outfall. The ratio became smaller as the runoff volume increased, implying loadings from other sources became more important as these surfaces became saturated. This also implies that street loadings may be the significant contributor to downstream pollutant loadings with the more frequent storm events.

2.6 Sweeper Performance

Sweeper types are classified as either a mechanical broom, regenerative-air or vacuum-assisted sweeper, each described in detail by Kang et al. (2009) and Sutherland (2011). Generally, mechanical sweepers are the most widely used, credited for their effectiveness in picking up larger materials, and are typically used for aesthetic purposes (Sartor and Boyd 1972; Pitt 1979; Pitt and Shawley 1981; Pitt 1985; Horwatich and Bannerman 2009; Weston Solutions 2010; Sorenson 2012). Regenerative air and vacuum assisted sweepers are more effective at picking up finer particles (Sartor and Boyd 1972; Pitt 1979; Pitt and Shawley 1981; Pitt 1985; Breault 2005; Horwatich and Bannerman 2009; Weston Solutions 2010). Sweeper performance is impacted by sweeper type, sweeping frequency, geographic region, adjacent land uses and methods for assigning effectiveness values (HEC 2006). Other factors that impact the effectiveness of street sweeping include roadway maintenance, traffic, weather, street condition and material, and curbing (Breault et al. 2005). The slope of the street can also affect performance (Weston Solutions 2010; Gastaldini and Silva 2013) and street parking that prohibits sweepers from accessing the high fraction of street material near the curb (Sartor and Boyd 1972; Sutherland 2011).

Sweeper performance has traditionally been defined as a percent removal efficiency of the material on the street surface. Removal efficiencies are determined using similar methods previously described for quantifying the material on the street surface before and after sweeping. These methods have been applied in-situ and in controlled test areas (Breault et al. 2005; Sutherland 2009). Controlled tests have typically resulted in higher removal efficiencies, perhaps due to pre- and post-sweeping surface sampling performed closer in time to the sweeping event instead of a one or two day span before and after sweeping for in-situ testing (Sutherland 2011). Removal efficiency has also improved as technology has improved, with early studies reporting overall loading reductions ranging from 25-50% for mechanical sweepers, but finding removal efficiencies for small particles relatively insignificant. Inefficiency to remove smaller particles was concerning since finer particles are associated with pollutant loadings (Sartor and Boyd 1972) and percent removal rates for total solids are consistent with removal rates for pollutants across the particle size ranges for a mechanical and regenerative-air sweeper (Pitt 1979).

Improved performance was reported with subsequent testing, finding removal rates for the smallest particles (< 45µm) averaged 52% for a mechanical sweeper and 67% for a regenerative-air sweeper (Pitt and Shawley 1981). More recent testing by Sorenson (2012) finds removal efficiencies ranging from about 50% for particles < 125 µm, about 80% for particles ranging from 125 µm – 2,000 µm, and 90% for the particles > 2,000 µm. Breault et al. (2005) applied a known mass of dirt obtained from the downstream catch basins to a cleaned test area. The catch basin material was dry sieved and reconstituted to proportions representative of vacuumed street dirt (less trash, leaves and other debris) with a mass expected to accumulate in a day or two applied to two test areas. Average removal efficiency, as a particle size weighted average, was 20 and 30% for a mechanical sweeper and 60 and 92% for a vacuum sweeper, with the lower value for the vacuum sweeper suggested to be due to high winds during the experiment. Results showed a 93% removal efficiency for particles between 63 – 125 µm and 81% efficiency for particles < 63 µm for the vacuum sweeper test under non-windy conditions. Performance testing of advanced technology sweepers described by Sutherland (2009) was based on controlled tests with application of material on the street surface prepared to represent PSD and loadings from previous studies. Results for overall pick-up efficiency averaged 97 and 94%

for regenerative-air and vacuum sweepers, respectively, with each sweeper type removing around 90% of particles < 250. Overall removal efficiency for mechanical sweepers tested averaged about 85%, also performing well with smaller particles.

Sutherland and Jelen (1997) express concern with methods for determining percent removal efficiency, specifically in regards to the pre- and post-sweeping measurements that remove 99% of the material from the street surface, as previously described. An alternative method is presented for computing effectiveness above a base residual on the street surface that cannot be removed by rain or sweeping. Base loading is estimated to be approximately 20% of the street loading by Zarriello et al. (2002), with Pitt (1979) estimating a base loading range of 30 grams/curb-meter (106 lbs/curb-mile) for streets in good condition to 300 grams/curb-meter (1,064 lbs/curb-mile) for streets in poor condition. Since removal efficiencies increase for all particle size ranges as the street loading increases, Pitt and Shawley (1981) argue the amount of street material removed (mass/curb length) is a more important performance indicator than removal efficiencies since more material is collected from a dirtier street than a clean street. As a result, quantification of reductions achieved from sweeping would be dependent on knowledge of the street loading at the time of sweeping and the sweeper's removal efficiency for the loading rate of the street. However, with the dynamic nature of street loadings, this approach is not feasible.

Law et al. (2008) presents a conceptual model for assigning POC removal efficiency to street sweeping based on various factors impacting efficiency. Impact of various factors are those identified from early studies, such as Pitt (1979). The model first applies a factor to reduce the street loading to an available loading for potential removal from sweeping, including a 28% reduction for fugitive dust loss from the street (Pitt 1979) and non-street area contributions (Waschbusch et al. 1999, Pitt and Bissonette 1984). A sweeper pick-up efficiency is then applied to the remaining available loading to determine the amount of material removed, which is then further reduced by 20% for obstructions such as parked cars. Employment of a vacuum sweeper with a weekly sweeping frequency, assigned a 60% pick-up efficiency, results in 31% removal efficiency for total solids. Nutrient reductions are determined in a similar manner after a discount fraction is applied based on the median stormwater EMCs for Chesapeake Bay communities, as found in the National Stormwater Quality Database (NSQD). Although the conceptual model allows for consideration of many factors impacting sweeper performance, assumptions for discount factors are heavily based on early studies. Although modification to factors in the model could be applied, direct measurement would not be feasible. For example, the model estimates a 10% discount to the available loading for treatment from fugitive dust, although Pitt (1979) found 90% of fugitive dust is less than 10 µm and during a duration of 10 days makes up approximately 1 grams/curb-meter (< 4 lbs/curb mile), a small fraction compared to the total street loading. Fugitive dust would also settle on non-street area, separately discounted. Reduction factors from available loadings for non-street area contributions could vary widely and overland flows have a very low yield of most pollutants when compared with directly connected parking lots or street surfaces (Pitt and Shawley 1981). Finally, although the desire to incorporate local data is understood, use of median EMCs from the NSQD may not be representative since the database is not unique to runoff from streets.

2.7 Evaluating Sweeping Impact on Water Quality

Although sweeper effectiveness is typically reported as a removal efficiency of the fraction of the loading removed from the street, this metric alone is insufficient for quantifying annual POC load reductions towards achieving a WLA since not all collected material would be transported to surface waters. A direct approach for evaluating POC reduction from street sweeping would include long term water quality measurement at the outfall to the receiving surface waters. Studies have attempted to assess water quality pre- and post-sweeping at the downstream outfall, but have had difficulty measuring differences in sediment and nutrient loadings (Pitt 1985; Zariello et al. 2002; Selbig and Bannerman 2007; Law et al. 2008). The high variability in stormwater-quality loads also requires a large number of water samples to detect any significant change due to street sweeping (Selbig and Bannerman 2007). Difficulties can also be attributed to inaccuracies in sampling methods, and the lag effect of sediment transport in the storm sewer between storms (Law et al. 2008). As a result, little statistically significant information is available regarding the impact of street sweeping on water quality (HEC 2006; Schilling 2005).

The contribution of pollutant laden runoff from non-street areas within a drainage basin, activities in the drainage area, and rainfall variables also contribute to difficulty measuring effectiveness downstream (Gastaldini and Silva 2013). Based on a study in a residential basin in the San Francisco Bay area, Pitt and Shawley (1981) concluded that a maximum of 20 percent of the total solids can be prevented from reaching receiving waters with very frequent street sweeping (3 passes per week). This performance is impacted by load contributions from non-street areas (street surfaces estimated to make up 15 to 20% of the urban area), the inability for sweepers to collect smaller particles, and due to the number of sweeping opportunities available between storms. However, Schueler (1994) notes transportation related imperviousness (parking lots and streets) is often directly connected to storm sewer and can be significant fraction of the total imperviousness. Schueler (1994) illustrates the significance with results of a study by the City of Olympia (1994) that found measured transport-related impervious cover at 11 residential, multi-family, and commercial areas to comprise of 62 to 70% of the total impervious cover. For a residential area in Colorado, Lee (2003) finds transportation-related land cover (streets and parking lots) to comprise 64% of the total impervious and greater than 97% of the directly connected impervious area.

Since WLAs typically specify annual reductions, quantification of POC reductions from street sweeping is heavily dependent on understanding impacts over time. POC reductions achieved over time are highly variable, depending on factors such as the street loading, the effectiveness of rainfall to wash off street loadings, sweeper efficiency, timing of sweeping between storms, and frequency of sweeping. Frequency of sweeping is the most significant factor and dependent on the resources available and appropriated to a street sweeping program. Optimal frequency and associated reductions would vary, dependent on precipitation patterns and street material accumulation (Sutherland and Jelen 1997). Figure 2-2 hypothetically illustrates the impact of some of these variables, comparing street material load and wash-off over time for a swept and unswept street surface. The figure utilizes accumulation rate results averaged from several areas presented by Pitt & Shawley (1981), previously presented in Table 2-3. The accumulation rates are represented as an increase in daily load dependent on the time since the street surface was last cleaned, whether by sweeping or rainfall. For illustrative purposes, the figure hypothetically assumes a 50% wash-off efficiency for the average rainfall, occurring at 5-day increments. Likewise, a sweeper pick-up efficiency of 50% is represented with sweeping occurring at the halfway point between the rainfall events (sweeping frequency of 5-days increments). Rainfall wash-off and sweeper pick-up reductions are based on the surface solids load on the street surface above the base loading at the time of occurrence, estimated by Zarriello et al. (2002) to be 20 percent.

The figure illustrates that street solids load remains lower over time with the sweeping scenario, represented as the area under the respective scenario curves. The swept scenario finds a 70% reduction of material (note 0.3X in Figure 2-2) washed off from the street surface with each rainfall event, compared to the unswept street. If sweeping were to occur closer in time after the previous rainfall event, more solids would be washed off the street with the subsequent storm since more time would have passed to allow for accumulation of street solids. If sweeping occurred closer in time to the subsequent rainfall event, the fraction of material wash-off reductions compared to the unswept scenario would decrease, since the available solids load at the time of the rainfall event would be less (the 0.3X hatched area would become smaller).

Although not explicitly illustrated in Figure 2-2, the relationship between the pick-up efficiency of the sweeper and wash-off efficiency of the average storm would also be critical for assessing reductions over time. For example, the fraction of reduction in material wash-off would increase as the sweeper’s pick-up efficiency exceeded the wash-off efficiency of the average rainfall. It is also noted that Figure 2-2 reflects an aggressive sweeping schedule and as sweeping frequency decreases, the reduction of materials over time would decrease. In context with WLAs, the reductions would be dependent on the annual fraction of material that would ultimately discharge at the outfall and the portion of total watershed area swept, especially the fraction directly connected to storm sewer. A smaller impact may result in low density areas where street runoff discharges to roadside swales; but a larger impact is likely as development density increases.

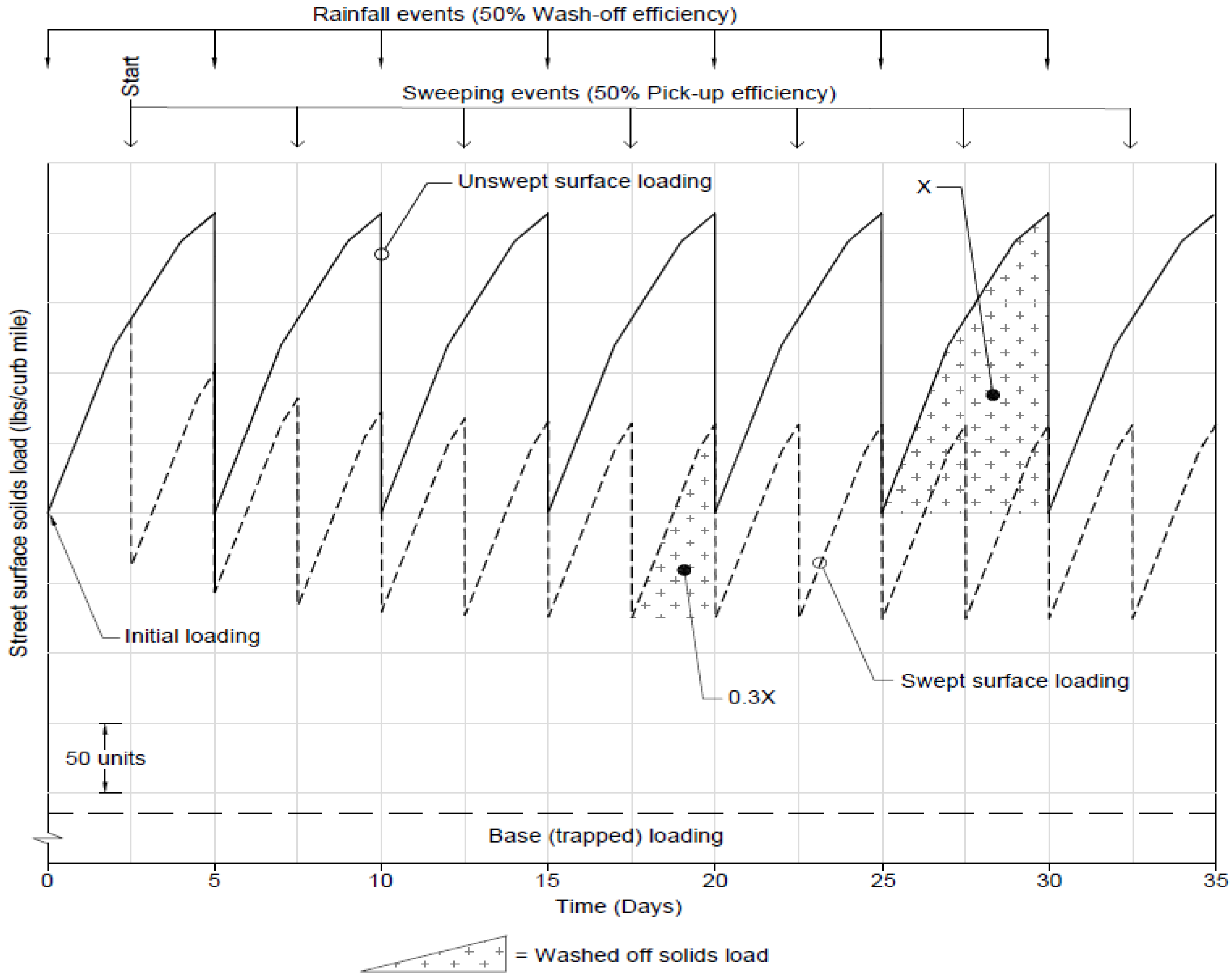

Figure 2-2. Hypothetical comparison of street surface solids load for swept versus unswept streets based on an average storm (50% wash-off efficiency) occurring every 5-days and sweeping (50% pick-up efficiency) at the midpoint between storms. The example uses accumulation rates from Pitt and Shawley (1981).

A modeling effort by Sutherland and Jelen (1993) predicts 80% TSS reductions from regenerative-air and vacuum sweepers with sweeping occurring every one to two weeks. Conversely, (Smith 2002) found no benefit from mechanical sweeping with sweeping occurring only a few times within a year. Weston Solutions (2010) suggests optimal reductions achieved with twice per week sweeping with a vacuum sweeper and once per week with a mechanical sweeper, based on maintaining consistent optimal removal efficiencies (i.e. efficiencies eventually decreased with increasing frequency). Since frequency impacts performance over time, methods to evaluate sweeping performance have varied pollutant reduction efficiencies dependent on frequency of sweeping to estimate pollutant reductions (Law et al. 2008).

In a paired basin approach, detection of differences is difficult due to limited number of observations and statistical conclusions due to regional and seasonal differences, random nature of meteorological conditions, high variability in storm water samples and measurement errors (Kang et al. 2009). However, a recent study by Selbig (2016) applied a paired basin design using nearby residential catchments of relatively small size (6.47 and 1.21ha). Implementing aggressive leaf removal in the test basin that included street sweeping, downstream sampling demonstrated significant reductions during the fall months for total and dissolved phosphorus of 84 and 83%, respectively. Total and dissolved nitrogen reductions during the fall month were of 74 and 71%, respectively. Results for the spring months found about half the reduction achieved in the fall and a 36% reduction in total phosphorus was observed in the summer.

Results presented by Weston Solutions (2010) from 90 runoff samples collected directly from the street gutter during the first flush of three storm events from an unswept site, a site swept with a vacuum sweeper and site swept with a mechanical sweeper. Compared to the unswept street, mean TSS concentrations in samples collected during the first flush, defined in the study as within an hour of flow in the gutter, were reduced by 74% and 85% for the street swept by a mechanical sweeper and the vacuum sweeper, respectively. Since samples were collected from only three storm events, results from the sampling study must be considered with caution. However, the study provides additional insight with measurement in the gutter instead of the downstream outfall, from which the larger watershed is also contributing runoff.

The lack of statistically significant studies measuring impacts at the outfall has led to the use of complex models, such as continuous simulation models. Model simulations often rely on functions based on information from the early NURP studies, such as the use of productivity coefficients by Horwatich and Bannerman (2009) derived from plots of before and after street cleaning loadings from previous studies, including Pitt (1985). Modeling is dependent on estimation of initial loadings, accumulation rate of loadings on the street surface (buildup), loading wash-off, and downstream transport of pollutants to surface waters. Most buildup models have been based on antecedent dry days, expressed as linear, power-law, exponential, or other functions of time. An example presented by Pitt (1979) computes the street loading (Y) at time x based on a deposition loading (ax), amount of material lost to the air (bx) and an initial storage loading (c) as:

$$Y = ax - bx^2 + c \tag{1}$$

Application of Equation 1 is ideally based on direct measurements over time, potentially resulting in unreasonable model predictions when values are obtained by trial and error during the model calibration process (Pitt et al. 2005). Without direct measurements, estimating the initial mass after a previous storm event and the pollutant accumulation for dry days is challenging (Kim et al. 2006). Breault et al. (2005) suggests additional information is needed on street material accumulation, recognizing most information is from the early studies. Instead of direct measurement, Kim et al. (2006) use rainfall, flow rate, and water quality data to develop a build-up model to indirectly estimate initial mass as the product of the final runoff concentration and the retained water (based on total rainfall and the runoff coefficient). Accumulated mass is determined by the washed off mass in the following event.

As previously discussed, the simulated wash-off testing by Sartor and Boyd (1972) found a maximum cumulative material that could be washed off (N_o) for a specific rainfall intensity (r) with mass of material flushed over time dependent on road surface condition, resulting in Equation 2. Equation 2 estimates the amount of material of a given particle size removed during time interval (t) by a rainfall intensity with a proportionality constant (k) based on the street surface characteristics.

$$N_c = N_o(1 - e^{-krt}) \tag{2}$$

Equation 2 is typically used and modified for studies to evaluate constituent wash-off (Furumai et al. 2001) and in many stormwater quality models for urban impervious runoff, including EPA’s Stormwater Management Model (SWMM), the United States Geological

Survey (USGS) Hydrologic Simulation Program – Fortran (HSPF), the Source Loading and Management Model for Windows (WinSLAMM) and others. However, Pitt et al. (2005) describes concern with the Sartor and Boyd (1972) wash-off equation, citing tests that showed observed quantities to be up to five times less than those predicted by the equation.

2.8 Quantifying Sweeping Effectiveness for Compliance

Quantification of pollutant loadings for TMDLs at a watershed-scale is formidable and subject to uncertainty, with WLAs resulting from models employed as part of the TMDL development (Reckhow 2003; Hantush 2009). The use of detailed modeling efforts to evaluate street sweeping in the context of a WLA causes concern due to lack of reliable data for calibration. Also of concern is the application of land use data for TMDL modeling that often do not include a roadway or transportation land use category, such as with the National Land Cover Database (NLCD). This results in street runoff being aggregated with urban runoff (Wu et al. 1998). Endreny and Thomas (2009) demonstrate modification to NLCD data that include reclassification of pixels with high accuracy vector roads, considering direct connectedness to surface waters, resulting in a significant increase in modeled pollutant loads. These results suggest higher loadings from street surfaces available for removal by street sweeping.

Due to difficulties with direct measurements, there are uncertainties with modeling applications and few feasible methods for quantifying POC reductions from street sweeping in surface waters. Simplified alternatives are emerging, driven by NPDES compliance for achieving WLAs. HEC (2006) proposes a modification to the City of Portland’s geographic information system (GIS) model for measuring effectiveness of nonstructural BMPs, including street sweeping, which would apply pollutant loads to grid units instead of effluent concentrations used to assess structural BMPs. Reduction in loads resulting from street sweeping would then be based on a percent removal of the pollutant load. A monitoring report by Seattle Public Utilities (SPU 2009) describes a mass balance approach that assumes the total mass of material collected from sweeping is equivalent to the reduction in sediment ultimately discharged to the receiving surface water. Similarly, Breault et al. (2005) converts the volume of swept material collected by the city to a mass based on an assumed average density of 2.0 g/cm^3 (Pitt et al. 2005). Assuming the particle-size distribution and chemistry of samples collected from the sweeper are representative of the city's street loadings, the mass is multiplied by the concentration of the constituent measured in swept material to estimate contaminants removed. EOA (2007) also estimates annual mass of POC load removal by multiplying the mean concentration of the pollutant found in swept samples by the dry mass of the collected volume of sweeper waste. The Municipality of Anchorage Watershed Management Program (MAWMP) reports based on a similar assumption, with supplemental information from a study measuring street loadings before and after street sweeping (MAWMP 2011). Results report removal efficiencies ranging from 67 – 99%, dependent on road type (curb and gutter or open channel). Although direct measurements are incorporated into these approaches, they are not representative of POC reductions towards achieving WLAs since they assume all particles collected by sweeping would be transported in runoff.

Several studies were reviewed that provide guidance to MS4s in their respective states for quantifying POC reductions achieved by street sweeping. Bateman (2012) presents values for converting recovered dry mass to nutrient removals. The study conducts a statistical analysis of pollutant load recovery results from 400 samples of swept material, material collected from catch basin sumps, and material collected structural BMPs in Florida MS4s. Results consistently found a log-normal distribution for TP and TN concentrations with the median used for converting recovered dry mass to TP and TN as 361 mg/kg and 563 mg/kg, respectively. Similarly, the Mass Loading Approach presented by the Virginia Department of Environmental Quality (VDEQ 2015) converts collected dry mass to POC reductions as 0.10% for TP, 0.25% for TN and 30% for TSS. VDEQ (2015) concentrations are estimated from Law et al. (2008) and based on values from analysis of a limited number of street particulate matter samples. The method described by Bateman (2012) requires recovered material be converted to dry mass assuming a moisture content of 6%, the median value from Sansalone et al. (2011). In contrast, VDEQ (2015) specifies a much larger conversion to dry mass, assuming 30% moisture content, and also presents a method that converts lane mileage swept to an area assuming a 10-foot lane width and then computes loading rates defined using the Simple Method (Schueler 1987). To assess sweeping reductions, a pick-up factor multiplier is assigned based on the conceptual model results from Law et al. (2008), as previously described.

In response to the increasing obligation of MS4 entities within the Chesapeake Bay watershed to achieve TMDL reductions for compliance with NPDES permits, regulatory agencies have provided guidance for quantifying reductions for BMPs, including the practice of street sweeping. A recent expert panel report for the Chesapeake Bay Program (Schueler et al. 2016) concludes that simulation models are needed for quantifying street sweeping reductions, questioning if future studies will ever collect the number of necessary samples to assess effectiveness downstream. The panel report suggests the use of defined efficiencies based on sweeper type and sweeping frequency applied towards the area swept. Defined efficiencies are the results from a WinSLAMM model simulation with modeled reduction functions mostly derived from previous studies and those predicted at the downstream outfall. Results are grouped by sweeper type and frequency, and find no benefit from sweeping with a mechanical sweeper. Modeled reductions at the outfall are modest, ranging from 2 – 21%, 0 – 4% and 1 – 10% for TSS, TP and TN, respectively for regenerative-air or vacuum sweepers, increasing within the ranges as frequency of sweeping increases. Concerns with this approach are similar to those described for modeling efforts and the low values are likely lost in context to the uncertainty of the modeled water quality improvements developed for large-scale TMDLs. Since provided as a guidance document for MS4s, there is also concern for negative impact on water quality if MS4s are deterred from implementing enhanced sweeping programs due to modest defined removal efficiencies.

2.8 Conclusions

MS4 operators across the country are facing increasing pressure to achieve POC reductions for WLAs and are seeking cost-effective solutions. Street sweeping can potentially provide significant POC reductions within TMDL watersheds due to street area available for treatment, significant POC loadings on the street surface, and since streets are often directly connected to outfalls to surface waters. Street sweeping has been practiced in most urban areas for aesthetic purposes; but is increasingly viewed as a water quality BMP to assist with NPDES compliance. EPA requires MS4s to evaluate the performance of program BMPs with measures of effectiveness for addressing POCs, quantifiable in the case of many TMDLs. NPDES compliance is also dependent on ensuring maintenance of BMPs to ensure long-term performance. In contrast to typical specified maintenance for structural BMPs, street sweeping is dependent on a purposed program with dedicated funding to ensure the appropriate sweeper type is acquired and maintained and qualified sweeper operators are available to perform the necessary sweeping frequency. Non-direct costs such as maintaining an ordinance that prohibits street parking on sweeping days may also need consideration.

A review of past studies finds an abundance of information associated with street sweeping, most notably describing loadings on the street surface, the transport of materials in runoff, and the effectiveness of street sweepers to remove fractions of the material from the street. However, understanding the impacts from street sweeping on water quality remains difficult and further research is needed. Due to the magnitude of potential costs to achieve WLAs, uncertainty with methods and modeling applications based on the previous studies may not be acceptable. Alternatively, MS4s have measured effectiveness with tracking of swept material, sometimes supplemented with analysis of the material, for estimating the quantity of constituents removed from the street surface that would impact water quality. These approaches addresses concerns regarding inappropriateness of assessment of sweepers based on pick-up efficiency, since the amount removed is dependent on the loading on the street (Pitt and Shawley 1981); but do not explicitly represent material removed from surface waters for application towards achieving WLAs. It is anticipated that the need to measure effectiveness of sweeping to assist with NPDES compliance will drive new studies that will add to the body of knowledge and assist local programs to better quantify and maximize POC reductions achievable from sweeping. It is suggested future studies consider the needs of MS4 permittees to: (1) evaluate and compare street sweeping to other options, including structural BMPs, towards achieving

WLAs; and (2) demonstrate a measure of effectiveness that defensibly estimate a quantifiable POC reduction.

Chapter 3: Characterization of Street Sweeping Material for addressing Total Maximum Daily Load Waste Load Allocations

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3.1 Abstract

Municipal separate storm sewer system (MS4) permittees are increasingly required to reduce pollutant of concern (POC) loadings from their service areas to achieve waste load allocations (WLAs) assigned as part of total maximum daily load (TMDL) calculations. Required POC reductions and the associated cost to implement best management practices (BMPs) to achieve reductions necessitates the need to allow for a wide range of BMP options, including source controls. Challenges in detecting measurable impact in surface waters have made it difficult to quantify POC reductions from source controls. However, direct measure and characterization of swept material can provide an obtainable quantification, as demonstrated with the analysis and assessment of 58 samples of swept material collected from six MS4 permitees in Virginia. Results presented indicate particles < 841 µm are readily transported from the swept surface as part of the rainfall-runoff process and discussion finds these particles can also be associated with total suspended sediment (TSS) in the water column of receiving waters. Total phosphorus in collected material is heavily associated with the particle sizes range examined < 250 µm and total nitrogen is associated for each examined particle size ranges < 841 µm. The content of swept material is impacted by the duration since last rainfall, with a decrease in the particles < 841 µm when sweeping occurs within 2-days since rainfall. The type of surface swept impacts the content of swept material to a lesser degree, with larger fractions of smaller particles collected from parking lots and higher concentrations of TN associated with material collected from streets. Assessment of results leads to estimates of mass of POCs removed for total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP), dependent on duration since rainfall and type of surface swept.

3.2 Introduction

Water quality standards for waters of the United States (U.S.) are established by the 1972 amendments to the Federal Water Pollution Control Act, now known as the Clean Water Act (U.S. 1972). The Clean Water Act (CWA) required the U.S. Environmental Protection Agency (EPA) to develop and implement the National Pollutant Discharge Elimination System (NPDES) permit program. The program required point source discharges, initially focused on wastewater treatment and industrial sources, to obtain a NPDES permit for the discharge of pollutants into waters of the U.S. Amendments to the CWA (WQA 1987) sought to also address water quality concerns resulting from stormwater discharges from urbanized areas. NPDES requirements for stormwater discharges were subsequently developed, including for discharges from Municipal Separate Storm Sewer Systems (MS4s). Initially applied to medium and large cities and certain counties, with populations of 100,000 or more (USEPA 1990), the program was subsequently expanded to include smaller jurisdictions operating MS4s in U.S. Census Bureau defined urbanized areas, including nontraditional MS4s such as those operated by universities, military installations, and departments of transportation (USEPA 1999).

NPDES permits require the MS4 operator to develop and implement a stormwater management program to address various permit conditions. These programs incorporate various best management practices (BMPs) to achieve permit objectives. Implementation of the program BMPs is viewed by the EPA to meet the statutory standard of compliance to control pollutants in stormwater runoff to the maximum extent practicable (USEPA 2016). Whereas the maximum extent practicable (MEP) compliance standard has predominantly established qualitative compliance benchmarks, increasingly, a quantitative measure for compliance has been introduced as the result of continued implementation of Section 303(d) of the CWA. Section 303(d) requires states to assess surface water quality to determine if water quality standards are present, and when not, requires the calculation of the maximum amount of the pollutant impairing the waterbody that can be assimilated and still meet water quality standards, known as the total maximum daily load (TMDL). TMDL development requires the identification of the pollutant(s) of concern (POCs) causing the impairment and subsequent development of waste load allocations (WLAs). In part, WLAs designate the portion of the TMDL allocated to NPDES regulated point source discharges within the contributing watershed, including discharges from MS4s. Since EPA guidance requires that TMDLs define WLAs in quantitative terms, WLAs are developed with numeric targets that represent the water quality conditions to which attainment of water quality standards are achieved, often based on conditions in a similar unimpaired stream (Hosseinipour 2015). Establishment of these numerical values is typically guided by input from water quality modeling (Hobson et al. 2015). Upon EPA approval of a TMDL, the NPDES regulations require MS4 permits to include effluent limitations for the identified POC(s) based on the WLAs assigned to an MS4. Many MS4s have been assigned WLAs, with over half of assessed waters in the U.S. designated as impaired. The POCs most often identified as causing impairments are pathogens, sediment, or nutrients (USEPA 2017).

Structural BMPs, such as retention ponds, have historically been employed as a means for complying with NPDES stormwater management regulations for land development. As a result, a multitude of studies and data are available regarding the sediment and nutrient removal efficiencies of these BMPs (Clary et al. 2011). However, considering the scale of TMDL watersheds that apply to large areas serviced by many MS4s, application to address WLAs may be limited due to the relatively small contributing drainage area to structural BMPs (Ouwejan et al. 2007) and limited opportunity in areas already developed (SPU 2012). Structural BMPs may be further limited due to required space for installation in developed urban and DOT MS4 service areas. Structural BMPs also appear less cost effective, specifically in comparison with a source control such as street sweeping. For example, cost for reduction of a pound of total phosphorus (TP) using structural BMPs is presented to have a median value of $10,500 by Raje et al. (2013), and has potential to exceed $50,000 per pound of TP (Nobles et al. 2017). According to CWP (2013), typical structural BMPs such as extended detention can cost $10,571 per pound of TP removal or $70,342 when employing permeable pavement. In contrast, Raje et al. (2013) presents a median cost of $1,656 per pound of TP recovery for street sweeping, a source control, with more conservative estimates from CWP (2013) ranging from $3,500 - $15,700, depending on the quantification method employed.

Since structural BMPs can be limiting towards addressing WLAs and less cost effective, nonstructural BMPs, or source controls, traditionally used to achieve qualitative compliance standards, may be necessary. Source controls are predominantly programmatic in nature, as reflected in reported MS4 practices by Aguilar and Dymond (2016), and have potential for reducing POCs (Taylor and Wong 2002; HEC 2006; Sansalone and Rooney 2007; Gupton and Lennon 2013). However, impacts likely cannot be quantified in any rigorous fashion (Murphy and Lokey 1999) and little development and assessment of source controls to quantify pollutant reductions has been done (Taylor and Wong 2002; Taylor and Cazenas 2010; NCHRP 2013). Lien (2013) suggests long-term monitoring is necessary to validate improvement in water quality with implementation of source controls. However, since programmatic BMPs may already be in place, gathering pre-and post-program implementation monitoring data creates a further challenge in quantifying effectiveness in receiving waters.

As a source control to address WLAs, increasing focus has been given to street sweeping operations and methods for quantifying POC reductions resulting from the practice. Street sweeping can be an attractive option since:

- Transportation related imperviousness can make up a significant fraction of the total imperviousness in urban areas (Schueler 1994),
- Streets contain an abundance of pollutants (Pitt and Shawley 1981),
- Advancements in sweeper technology have the ability to significantly reduce pollutants to surface waters (Breault et al. 2005; USEPA 2006; Rochfort et al. 2009; Sutherland 2009; Selbig 2016), and
- Recent studies indicate the potential for significant impact from street sweeping. Weston Solutions (2010) provides an example, finding mean TSS reductions ranging from 74% to 85% in runoff samples collected directly from the street gutter in swept streets, compared to unswept streets samples. Potential is also demonstrated with downstream sampling by Selbig (2016) with a paired basin design in small residential catchments. In the basin in which aggressive leaf removal and street sweeping was employed, sampling

found 84% and 74% reductions for TP and total nitrogen (TN) in the fall months, respectively.

Despite potential, most efforts to measure the water quality impact of street sweeping to surface waters has proven difficult, and despite the apparent potential, there is little available evidence to quantify the extent to which street sweeping can improve stormwater quality (Allison et al. 1998; Pitt 1985; Zariello et al. 2002; Selbig and Bannerman 2007; Law et al. 2008, Walker and Wong 1999; Rochfort et al. 2009; Kang et al. 2009; Sutherland 2011; Sorenson 2012; Schueler et al. 2016; Hixon and Dymond 2018). Difficulty is attributed to high variability in stormwater-quality loads (Selbig and Bannerman 2007) and sampling methods (Law et al. 2008). To quantify street sweeping specifically, Schueler et al. (2016) questions the practicality of any future studies providing the number of water quality samples necessary to assess effectiveness downstream.

Due to the lack of evidence to quantify POC reductions from street sweeping and the current need to address WLAs, an alternative method to assess this form of source control is emerging throughout the U.S. This method measures pollutants in the material collected by a street sweeper in-lieu of measuring pollutants in the storm drain network or receiving waters. Quantification of total suspended solids (TSS) reductions using this method often assumes that all of the material collected by a street sweeper is equivalent to what would ultimately be delivered to the storm drain network during a rain event and discharged at the outfall (Breault et al 2005; EOA 2007). Other studies suggest reductions be limited to the fraction of material that is < 250 µm, assumed to be the maximum particle size suspended in surface waters (SPU 2012, Bateman 2012). For quantification of other POCs, concentrations have been measured based on recovered material (EOA 2007; Bateman 2012) and constituency measured on the street surface (Law et al. 2008; MDE 2014; VDEQ 2015). Modeling efforts are also used to estimate reductions resulting from street sweeping (Horwatich and Bannerman 2009; Schueler et al. 2016). In order to support these methods, one would require an understanding of swept material that could ultimately impact water quality as well as concentration of pollutants associated with that material. Each of these parameters present uncertainties due to their inherent variability in the natural environment.

The purpose of this study is to characterize the potential for street sweeping to reduce common TMDL POCs based on the analysis of swept material and associated variables. Results are presented with characterization supported by previous research studies and applications for estimating POC reductions that can serve as measurable goals for NPDES reporting and compliance assessments. The study is intended to support ongoing decisions and methods for quantifying POC reductions from street sweeping.

3.3 Methods

Material samples collected from street sweeping by the six MS4s in Virginia listed in Table 3-1 were collected and analyzed to obtain information in support of efforts to quantify TSS, TP, and TN reductions towards achieving TMDL WLAs. Samples were randomly collected directly from street sweepers and analyzed for moisture content, particle size distribution (PSD), and concentrations of TP and TN. For each collected sample, supplemental information was recorded for variables that potentially impact the effectiveness of street sweeping such as sweeper type, adjacent tree canopy and cover conditions, presence of curbing, type of surface swept, time of year, and the duration of time since the previous measurable rainfall. MS4 staff collected samples and were provided training, written procedures, and data collection forms to ensure samples were collected consistently and delivered for laboratory analysis properly using chain of custody protocols. Instruction for sampling included collection of a sample that visually appeared to represent that majority of the overall composition in the hopper, as close as possible. Physical analysis of samples included particle size distribution using standard test methods (ASTM 2007, 2017), and were also processed to determine moisture content (ASTM 2010). Chemical analysis was performed on collected sample to determine TN and TP concentrations. TN concentration was calculated as the sum of total Kjeldahl nitrogen (TKN) and nitrate and nitric nitrogen (NO_{2-3}) using standard methods EPA351.2/R2.0 and 4500-NO_3F (2011), respectively. TP was determined using method 4500PE-2011.

Table 3-1. Summary of sampling performed by participating MS4s.

MS4 Permittee	Sweeper Model	Sweeper Type	No. of samples
City of Salem	Tymco DST-6	Regenerative Air	24[a]
Germanna Community College	Parking Lot Sweeper	Vacuum	8[b]
John Tyler Community College	Eglin Wizard	Mechanical	4
Northern Virginia Community College	Tymco Model 210	Regenerative Air	15
Piedmont Virginia Community College	Eglin Road Wizard	Mechanical	1
Virginia Tech	Tennant Centurion	Mechanical (Older)[c]	6

[a] 7 samples not tested for PSD and moisture content due to appearance and odor of sewage

[b] 2 samples not tested for PSD and moisture content due to appearance and odor of sewage

[c] An age distinction is made due to advancements in sweeper technology improving pick-up efficiency (USEPA 2006; Rochfort et al. 2009; Selbig 2016).

3.4 Results: Assessment of Swept Material

A total of 58 samples were collected, with just over 40% from a traditional phase II MS4 in southwest Virginia and the remainder from non-traditional MS4s, specifically institutions of higher education. Although all samples were collected and analyzed in a consistent and specified manner, they were collected randomly from various geographical areas of Virginia, as depicted in Figure 3-1, and from varying types of street sweepers. Of the 58 samples, PSD analysis was performed on 48 samples, with 10 samples refused for sampling by the geotechnical laboratory due to those samples presenting as sewage. Samples were also tested for moisture content that was found to be relatively consistent, with a mean of 2.7%, a median of 2.2% and within a 0.7% margin of error with a 95% confidence interval. The exceptions were five outliers with moisture content ranging from 10.8 - 25.4%. For comparison, Bateman (2012) recommends application of a 6% moisture content for adjusting wet weight of swept material to a dry weight.

Of the documented variables taken with each sample, the time since the previous rainfall was found to have the largest impact to PSD results, with an apparent recovery time of approximately 2-days to replenish availability of the smaller particles < 841 µm removed from the surface as a result of the rainfall-runoff process. To a lesser degree, PSD results also appear affected by the type of surface from which sweeping occurred, assessed as either streets or parking lot. The impact to results from other collected variables was not observed; but impact may have been difficult to identify due to the relative impact from duration since rainfall and the samples size, which became smaller for each sample subset to account for combinations of variables. Of note is anticipated impact based on time of year that was not observed. With this variable, the inability to identify impact is likely due to insufficient spread of samples across seasons, with half of the randomly collected samples taken in the summer months.

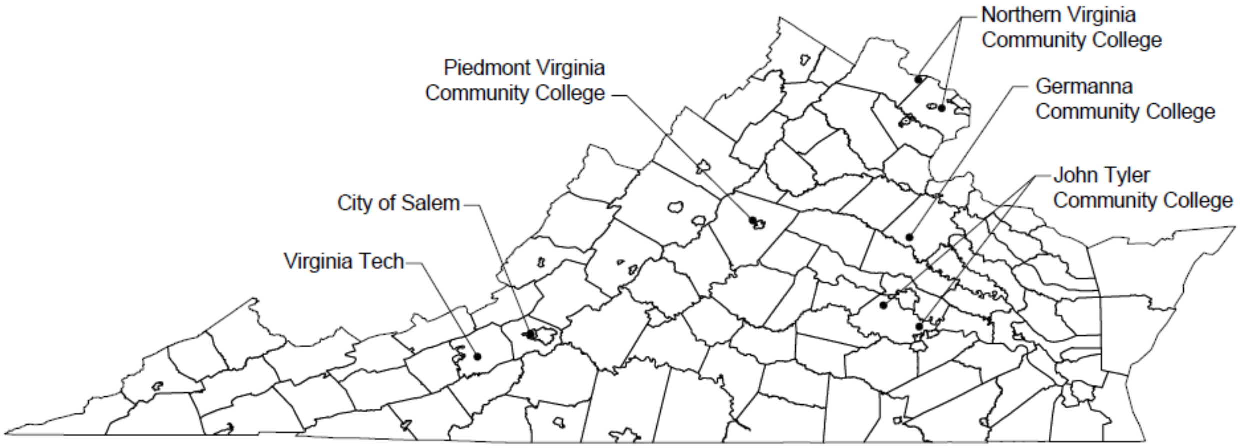

Figure 3-1. Participating MS4s in the Commonwealth of Virginia.

PSD results were similar amongst the sweepers used in the study, with the exception of the results in samples from the older mechanical sweeper, circa 1990s, that included notably lesser amounts of particles < 841 µm. The difference is reflected in Table 3-2, compared only to other samples collected within 2-days since rainfall since all of the collected samples from the mechanical sweeper occurred within 2-days since rainfall and due to the impact from duration since rainfall summarized in Table 3-3. The comparison shows samples from the older mechanical sweeper include fractions of particles in the ranges < 420 µm approximately 50% less than samples from the remaining sweepers used in the study. Conversely, approximately 52% of the swept material from the older mechanical sweeper was > 2,000 µm, compared to approximately 36% and 31% within samples from the newer mechanical and regenerative air/vacuum sweepers, respectively.

Table 3-2. Sweeper type comparison of mean fraction by weight within swept samples per particle size range with sweeping within 2 days since rainfall.

Sweeper Type	**PSD Range (%)**				
	< 250 µm	**250-420 µm**	**420-841 µm**	**841-2,000 µm**	**> 2,000 µm**
Older Mechanical (n=6)	8.6	5.0	10.7	23.7	52.1
Newer Mechanical (n=4)[a]	17.2	11.0	16.3	19.2	36.4
Regenerative-air/Vacuum (n=15)	16.4	10.1	16.1	27.3	31.3

[a] All samples from John Tyler Community College using an Elgin Wizard.

Since mechanical sweepers have traditionally been considered less effective at collecting smaller particles, the relatively consistent results from the newer mechanical sweeper used in the study to the regenerative-air and vacuum sweeper types, especially for particles < 841 µm, is noteworthy. However, this observation is consistent with results from a study by Sutherland (2009) that found newer mechanical sweepers can have comparable performance in the collection of smaller particles. Although noteworthy, the limited number of samples from mechanical sweepers in this study is not sufficient for any conclusion comparing effectiveness amongst sweeper types. For the purposes of this study, results from the older mechanical sweeper were removed from further assessment, so as not to influence observation of impacts from other collected variables. The authors suggest legacy sweepers still in use in the US be studied separately to measure swept content.

As previously mentioned, observed impacts on the content of swept material were 1) time since rainfall and, 2) the type of surface swept, as demonstrated in Table 3-3. Although the collected data did not provide sufficient information to define daily accumulation rates for particles and nutrients, the shift in material content collected after 2-days since rainfall was apparent. The shift demonstrated an increase in the smaller particle size ranges and nutrient concentrations collected after 2-days since rainfall. Continued increase in the fraction of smaller particle sizes as the duration since rainfall increased was not observed nor did the results provide for any significant correlation within 2-days since rainfall.

Table 3-3. Results for all samples analyzed for PSD, TN, and TP concentration within swept samples (excluding the older mechanical sweeper samples, N=6, and 3 samples where sweeping instances included both surface types).

Days Since Rainfall	**Stat.**	**TN (mg/kg)**	**TP (mg/kg)**	**PSD Range (%)**				
				< 250 µm	**250-420 µm**	**420-841 µm**	**841-2,000 µm**	**> 2,000 µm**
				Streets				
≤ 2 days (n=6)	Mean	236	21	19.3	10.3	14.9	26.0	29.4
	Median	***203***	***15***	***13.0***	***6.6***	***9.6***	***24.5***	***43.8***
	SD	159	13	19.0	7.2	10.6	8.2	20.4
> 2 days (n=11)	Mean	567	61	25.0	12.0	19.1	25.7	18.2
	Median	***408***	***51***	***22.4***	***10.8***	***17.8***	***26.1***	***14.5***
	SD	545	36	14.5	6.7	5.7	9.1	15.8
Percent Increase [a]		*+101*	*+240*	*+72*	*+64*	*+85*	*+7*	*-67*
				Parking Lots				
≤ 2 days (n=13)	Mean	144	16	12.7	10.8	17.6	24.2	34.6
	Median	***110***	***10***	***12.3***	***12.3***	***16.0***	***25.9***	***29.7***
	SD	139	16	7.9	5.7	6.9	8.5	18.0
> 2 days (n=10)	Mean	284	77	26.5	15.9	21.4	19.7	16.4
	Median	***277***	***54***	***27.9***	***16.6***	***22.3***	***20.0***	***10.2***
	SD	199	99	13.8	6.2	7.5	8.2	12.8
Percent Increase [a]		*+152*	*+440*	*+127*	*+35*	*+39*	*-23*	*-66*

[a] Percent increase in median values.

Results presented in Table 3-3 demonstrate the effectiveness of rainfall to transport smaller particles from paved surfaces, with a decrease in availability for collection within 2-days since measurable rainfall. As would be expected, this occurs for the smallest particle size range < 250 µm, but is also apparent with increase in particles ranging from 250 – 841 µm when duration since rainfall exceeded 2-days, indicating that particles up to 841 µm are transported from the surface through runoff. As the smaller particles became more available on the street surface after 2-days since rainfall and their fraction of the content in the swept material increased, the fraction > 2,000 µm inversely decreased. The fraction of particles < 250 µm are relatively consistent in material collected from each surface type, dependent on whether they were collected within or after 2-days since rainfall. Particles within the range of 250 – 841µm appear to be slightly more prevalent in material collected from parking lot surfaces compared to streets, both for samples collected within or after 2-days since rainfall. This may be due to less efficient drainage design, as compared to streets, resulting is slower runoff velocities and therefore decreased transport capacity of these larger particles.

The shifts in particle size distribution identifying the 2-day duration since rainfall threshold corresponds with increased nutrient concentrations as the fraction of smaller particles in the collected material increased, as would be expected since nutrients are mostly associated with smaller particles on street surfaces (Sartor and Boyd 1972; Pitt 1979; Pitt and Shawley 1981; Pitt and Bissonette 1984; Vaze and Chiew 2004; Breault et al. 2005; Horwatich and Bannerman 2009). Mean and median values for TP increase approximately three-fold on streets and five-fold on parking lots, compared to samples within 2-days since rainfall. Although small differences are seen in TP concentrations between the parking lot and street samples for their respective duration since rainfall sample set, the authors suggest TP concentrations are fairly consistent, independent of the two surface types. The suggestion is based on timing of the samples, whereas a slightly lower TP concentration on parking lots within the 2-day duration may be due to the majority (70%) of the samples being taken from sweeping occurring within 1-day since rainfall, compared to about 30% taken within 1-day for the street samples. This is consistent with previous findings that accumulation rates of street solids and pollutants increase at a faster rate in the initial day or two after a runoff event (Sartor and Boyd 1972; Pitt 1979; Pitt and Shawley 1981; Sorenson 2012). Similarly, the authors suggest slightly higher TP concentrations in parking lot material collected after 2-days since rainfall may be due to 40% of the samples in the sub-dataset being collected after 7 days since rainfall, in contrast to the street samples which were all collected within 2-7 days since rainfall.

Mean and median TN concentrations in swept material increase between two-fold and 2.5-fold when more than 2-days since rainfall have passed for streets and parking lots, respectively. In contrast to the relative consistency of TP concentrations in material collected from streets and parking lots, TN concentrations were approximately 1.5-fold higher on streets compared to parking lot, both in samples collected within and after 2-days since rainfall. The authors suggest that increased TN concentration on the street surfaces could be due to increased exposure to nitrogen oxides in car exhausts or due to a higher ratio of exposure to adjacent land use sources. Nutrient concentrations are lower in particles > 841 µm, as reflected with increases in concentrations while the fraction of these larger particles significantly decrease or remain relatively constant in samples collected after 2-days since rainfall.

The increase in nutrient concentration in samples collected after 2-days since rainfall demonstrates that nutrients tend to be more associated with smaller particles, consistent with previous findings measuring the content of street material (Sartor and Boyd 1972; Vaze and Chiew 2004; Horwatich and Bannerman 2009). Since the nutrient analysis on samples in this study was performed for the overall sample, assessment of results was employed to identify the particle size ranges most heavily associated with each nutrient. Although nutrients can also be inherent in organic particles such as grass and leaves, it is theorized that increased concentrations associated with smaller particles could be due to larger specific surface area, consistent with assumptions by others (Sartor and Boyd 1972; EOA 2007). Therefore, the assessment considers an exponential association of nutrient concentration to particle size since Sagik et al. (1975) finds an exponential increase in soil adsorption capacity and surface area as particle size decreases, allowing contaminants to increasingly adhere more easily. Considering this relationship, the trends in Figure 3-2A and 3-2B indicate:

- TP concentration is more heavily associated with particles < 250 µm, consistent with findings from Waschbusch et al. (1999), Vaze and Chiew (2004), and Schueler et al. (2016). This is evident in the current study with the decrease in the overall sample TP concentration as the fraction of particles 250 - 841 µm increases, as reflected with the negative exponent in Figure 3-2A.
- Results do not show an apparent reduction in TN concentration as the fraction of the particles ranging from 250 - 841 µm increases, indicating particles in this range have similar concentrations as the fraction of the material < 250 µm. This is reflected in Figure 3-2B with the mass fraction versus the particle size ratio relationship with an R^2 of

zero and exponents near zero, indicating the slope is zero. The association amongst particle size was consistent, independent of surface type swept.

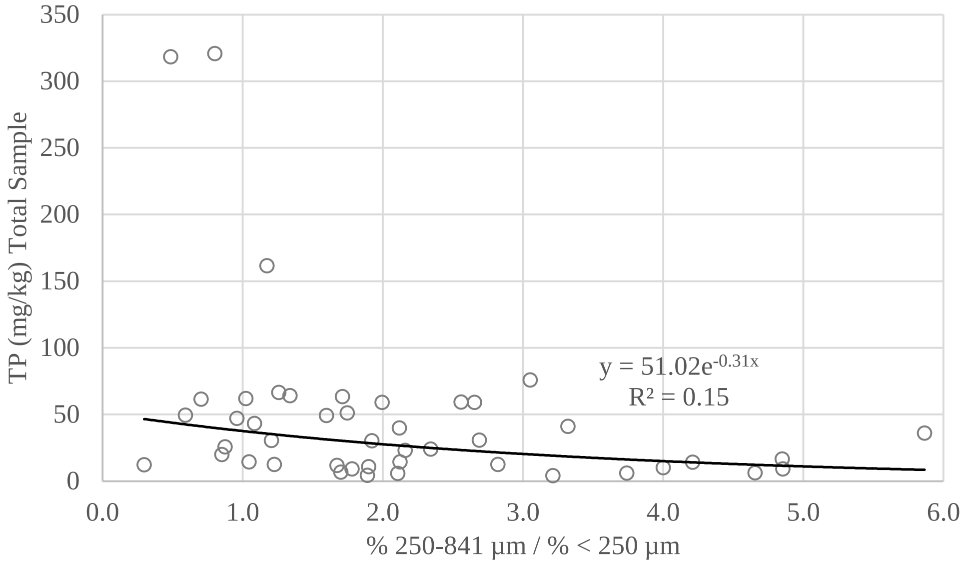

Figure 3-2A. TP mass fraction trends with increasing ratio of particle sizes 250-841 µm/< 250 µm.

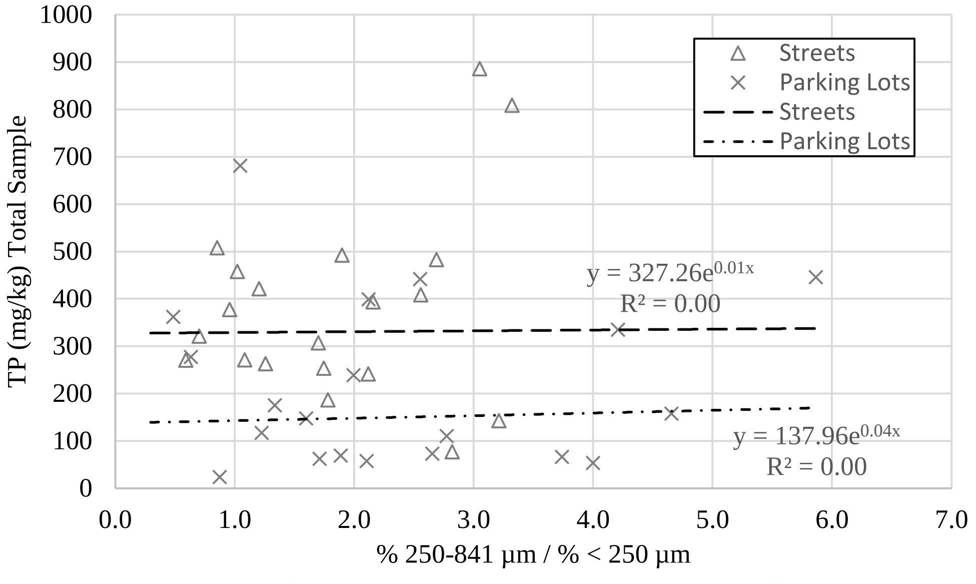

Figure 3-2B. TN mass fraction trends with increasing ratio of particle sizes 250-841 µm/< 250 µm.

Ideally, nutrient concentration analysis would be performed only on the fraction of swept material subject to transport to receiving waters and associated with each nutrient. In the absence of specifically measuring nutrient concentrations for these particle size ranges, estimates were made for the current study with extrapolation as presented in Figure 3-3. Extrapolation, using exponential regression for reasons previously discussed, was separated for each surface type for TN since concentration was found to be higher on streets, as reflected in Table 3-3. Due to the association of TN with the full range of TSS-associated particles < 841 µm, the exponential increase when predicting the concentration in the particle size fraction is smaller when compared to the range for TP association. This is because the smaller particles (< 250 µm) would have increased specific surface area. Although R^2 values reflect the variability of the collected data, the authors suggest that the extrapolation is acceptable for the purpose of this study due to the variability related to random sampling, varied sweeper type employed, limited sample size, and comparable nutrient concentration values in swept material presented by Raje et al. (2013), as summarized in Table 3-4.

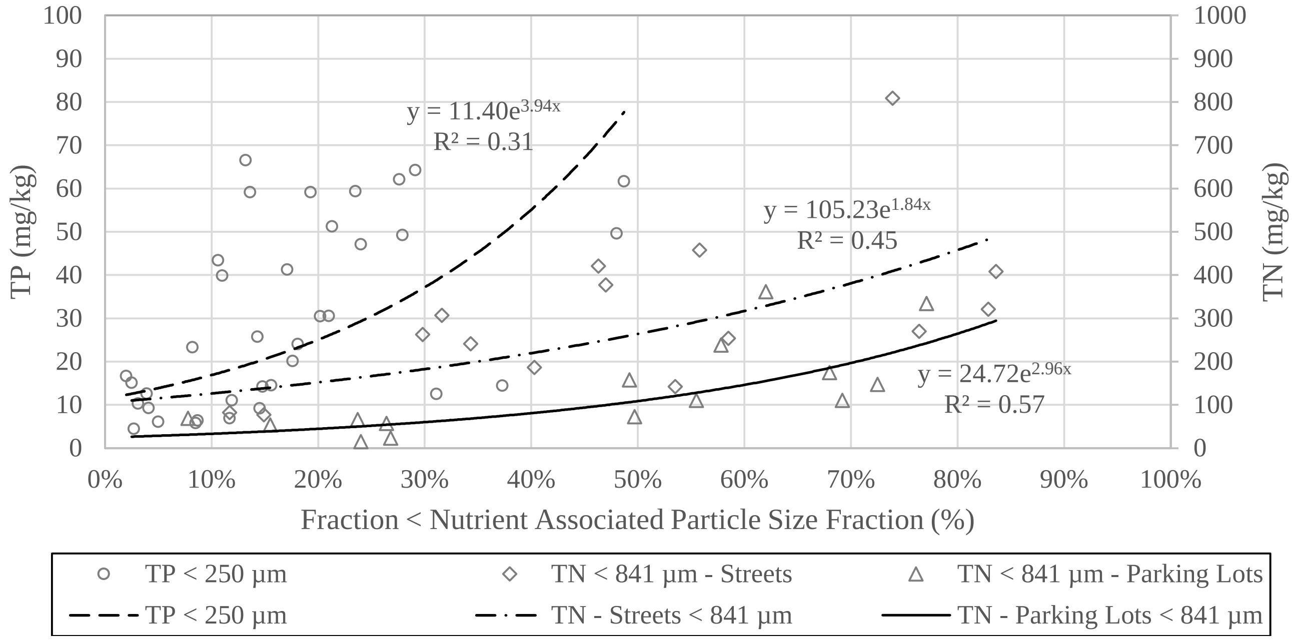

Figure 3-3. Nutrient association with associated particle size fraction subject to runoff.

Table 3-4. Nutrient concentration in swept material (dry weight) subject to transport in runoff.

Study	Surface Type	TN (mg/kg)	TP (mg/kg)
Raje et al. (2013)[a]	Commercial Streets	789.1	482.6
	Residential Streets	1,439.0	425.8
	Highways	826.6	622.0
Presented in Figure 3-3 [b]	Streets	662.6	586.2
	Parking Lots	477.0	

[a] Mean values for measured particulate matter in swept material (defined as < 300 µm).

[b] Concentrations extrapolated from regression equations for particles associated with runoff (i.e. x = 1).

As a measure for quantifying POC reductions towards WLAs, the results of this study suggests that the fraction of material < 841 µm collected by street sweeping, along with the measured moisture content, can be used to quantify TSS reduction from surface waters since:

- Particles < 841 µm are apparently transported from street and parking lot surfaces via the rainfall-runoff process, as demonstrated in Table 3-3; and
- Particles < 841 µm can be associated with suspended particles in the water column of surface waters (Bartram and Balance 1996).

Applying the median moisture content from the samples collected in this study (2.2%) with the median mass of particles < 841 µm, TSS reductions are estimated per ton of swept material, a common measure for swept material, as summarized in Table 3-5. As noted in the table, the fraction of particles < 841 µm is 75% and 65% higher in swept material when more than 2-days have passed since rainfall for streets and parking lots, respectively. The fraction of particles < 841 µm is 40% and 30% higher in swept material from parking lots, compared to material swept from streets when collected within 2-days since rainfall and after 2-days since rainfall, respectively.

Quantification of nutrient reduction from measures of swept material is dependent on the mass of nutrients associated with the particles susceptible to runoff, identified as particles < 841 µm for TN and < 250 µm for TP, as summarized in Table 3-5. Concentration for each category from Table 3-5 is then applied to the respective mass of TSS-associated particles fraction to quantify the mass of nutrients collected that could be expected to have been transported downstream, also summarized in Table 3-5. The values in Table 3-5 could be applied to the measure of mass annually collected from sweeping to compute POC reductions for application towards WLAs, dependent on the duration since rainfall and surface type swept.

Table 3-5. Estimate of POC reduction to surface waters per ton based on analysis of swept materials.

Surface Type	Days Since Rain	TP (< 250 µm)			TN (< 841 µm)			TSS (< 841 µm)
		(mg/kg)[a]	(%)[b]	(lbs/ton)[a]	(mg/kg)[a]	(%)[b]	(lbs/ton)[c]	(lbs/ton)[c]
Streets	≤ 2	586.2	13.0	0.149	662.6	29.2	0.335	571
	> 2		22.4	0.257		51.0	0.585	998
Parking Lots	≤ 2	586.2	12.3	0.141	477.0	40.6	0.466	794
	> 2		27.9	0.320		66.8	0.766	1,307

[a] Nutrient concentration for particle size fraction susceptible to runoff, from Table 3-4.

[b] Fraction of runoff susceptible to downstream transport from Table 3-3 (multiply by dry weight of swept material and associated concentration to compute total mass of POC.)

[c] Mass of POC within ton of swept material. Adjusted using moisture content of 2.2% for dry weight, the median value measured in this study.

3.5 Discussion and Conclusions

The potential need to include source controls as part of a program to address WLAs is evident. However, difficulties measuring the impact of source controls in receiving waters have led to MS4 permittees using alternative methods for quantifying pollutant reductions. As a source control, street sweeping inherently provides an opportunity to measure material removed from swept surfaces, which is positioned to readily be transported to receiving waters. Past studies provide insight in regards to these measures, beginning with an understanding of the particle sizes in urban runoff that provides insight into the fraction of material removed from the street surface that potentially enters receiving surface waters. Further, previous studies demonstrate an association of pollutants with particle size.

TMDLs that identify sediment as a POC often express WLAs as TSS, necessitating the need to characterize TSS by an upper particle size when collected material is used as a measure of POC reduction. However, TSS as a measure of concentration of particles in water has no explicit association with PSD and is not defined by a specific particle size since turbulence in surface waters suspends larger particles than does still water. Understanding the size of particles that can be transported from the street surface to receiving waters is important in an attempt to identify an upper particle size threshold for implicit association with TSS. Selbig and Bannerman (2011) find smaller particles more readily washed from the street surface, estimating 30% of TSS < 250 µm. A review of previous studies by Bent et al. (2001) found that urban runoff contained a wide range of median particles sizes from 13 – 1,000 µm. In simulated tests, Sartor and Boyd (1972) found the majority of particles washed off the street surface were < 841 µm. Horawatich and Bannerman (2009) found nearly 80% of particles in runoff from streets to be < 500 µm, consistent with results presented by urban runoff samples presented by Selbig and Fienen (2011). Winston and Hunt (2017) found the majority < 428 µm with few particles over 1,000 µm in edge of pavement runoff sampling. As a hypothetical exercise using the results from this study, the authors suggest the upper particle size range in collected material for an implicit association with TSS be approximately 841 µm. The suggestion is based on results in Table 3-3 that indicate particles up to this size are readily washed from the surface during the rainfall-runoff and are can be present in the water column of receiving waters (Bartram and Balance 1996).

Although the number of samples in the present study is limited and results include notable variability, collection and analysis of swept material in context to previous studies suggests:

- Street sweeping can remove POCs associated with a broad range of particle size;
- The accumulation of particles < 841 µm increases over time until the onset of rainfall suggesting these particles are more prone to transport in runoff;
- Estimates of nutrient concentrations in swept material suggest an inverse relationship with particle size;
- TN concentration is consistently associated with the full range of particles < 841 µm that are susceptible to transport in runoff;
- TP concentrations appear mostly associated with particles < 250 µm and are similar between surface type; and

- Nutrient concentrations can be directly measured based on specific particle size ranges associated with TSS, specifically the collected fraction < 841 µm for TN and < 250 µm for TP.
- With the exception of an older mechanical sweeper (circa 1990s), variation in PSD and nutrient concentration in swept material was not observed based on sweeper type.

Association of nutrients to particles size range was important in this study since measured concentrations of TP and TN were for the total sample collected, as opposed to the specific nutrient-associated fraction of material that is susceptible to downstream transport, which was uncertain at the onset of this study. Therefore, extrapolation was necessary based on the apparent nutrient association with the specific particles associated with downstream transport. It is suggested that future studies perform nutrient analysis only on the fraction of collected material associated with each nutrient to verify extrapolated values presented in Table 3-5, specifically the collected fraction < 841 µm for TN and < 250 µm for TP. It is further recommended that future sampling studies aim to allow for further evaluation of variables, such as nutrient concentration variation in swept material dependent on time of year.

Challenges in detecting measurable impact in surface waters have made it difficult to quantify POC reductions from source controls. However, direct measure and characterization of swept material can provide an obtainable quantification of potential POC reductions from street sweeping, as demonstrated with the analysis and assessment of the collected material presented in this study. Results presented indicate particles < 841 µm are readily transported from the swept surface as part of the rainfall-runoff process and can also be associated with TSS in the water column of receiving waters. TP in collected material is heavily associated with the particle size range < 250 µm and TN is associated realtively consistently for all particle size ranges < 841 µm. The content of swept material is heavily impacted by the duration since last rainfall, with a decrease of TSS-associated particles in samples from sweeping within 2-days of rainfall. Therefore, sweeping would be most effective when performed at least 2-days after rainfall. The type of surface swept impacts the swept content to a smaller extent, with larger fractions of smaller particles collected from parking lots and higher concentrations of TN associated with material collected from streets.

Annual quantification of POC reductions to surface waters can be utilized to establish measurable goals and as a tool for implementing a street sweeping program towards achieving WLAs. Application of the analysis and assessment of swept material can provide an obtainable measure for quantifying POC reductions for application towards WLAs. The potential of sweeping towards achieving TMDL goals would be dependent on annual tonnage swept and the specific WLA(s) assigned to the MS4 permitee. In addition to tracking tonnage swept, the findings suggests documentation of the duration since rainfall and surface type swept are important for refining esimates of POC reductions from sweeping.

Chapter 4: Quantifying Street Sweeping Pollutant Reductions towards achieving Total Maximum Daily Load Waste Load Allocations

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4.1 Abstract

Street sweeping potentially provides significant impact towards achieving pollutant reductions required by total maximum daily load (TMDL) waste load allocations. However, quantification of reductions for regulatory compliance is difficult due to the inability to measure the impact downstream. As an alternative to direct measures, two approaches have emerged, the application of removal efficiencies resulting from modeling efforts and the direct measure and analysis of swept material. Each method is applied within four sample areas representing varied land uses. Loadings were generated for three scenarios, the first based on land use, similar to typical TMDL model development, the second based on land cover, and a third based on the Chesapeake Bay Model Progress Run 5.3.2, for comparison. The land cover loading scenario results in a majority of annual pollutant loadings generated from non-roof impervious cover and higher fraction of annual loadings from public transportation cover available to sweeping. Quantification of pollutant reductions predicted from modeled removal efficiencies are significantly less than those resulting from the measure of pollutants susceptible to runoff in swept material. Maximum potential with twice weekly sweeping, based on the land cover loadings scenario, achieves a range of 22.3 – 86.6% of required TSS reductions, dependent on land use. The percent of required reductions for TN and TP range from 7.9 – 33.8% and 12.6 – 50.3%, respectively, with twice weekly sweeping. The higher values corresponds with higher fraction of public transportation area available for sweeping. The fraction of required reductions removed are modest with sweeping every other month. In contrast, and dependent on the material collected with each sweeping instance, the method based on measure of swept material

suggests the total required reductions can be achieved with much less frequent sweeping, especially in the residential, industrial, and institutional sample areas.

4.2 Introduction

Municipal separate storm sewer system (MS4) operators face increasing challenges to achieve compliance with the proliferation of Total Maximum Daily Load (TMDL) conditions within National Pollutant Discharge Elimination System (NPDES) permits. These conditions are subsequently introduced to NPDES permits upon approval by the U.S. Environmental Protection Agency (EPA) of TMDLs developed for impaired waterways. TMDLs identify the Pollutant(s) of Concern (POC) that cause the impairment of the receiving waters and determine the loading of the POC that can be assimilated while maintaining water quality standards. In part, the TMDL then assigns waste load allocations (WLAs) to point source discharges, including MS4s, to achieve the water quality standard. WLAs are developed with numeric targets and are typically presented as a percent reduction of a baseline loading for the POC identified as causing a given impairment of the receiving waters. Over half of assessed surface waters in the U.S. have been designated as impaired, with the common POC being pathogens, sediment, or nutrients (USEPA 2017). The cost burden to MS4s resulting from assignment of WLAs is significant, with VSFC (2011) estimating a cost ranging from $9.4 to $11.5 billion for MS4s in Virginia to address the Chesapeake Bay TMDL WLAs. The incorporation of WLAs into NPDES permits also exposes MS4s to potential fines if WLAs cannot be achieved, potentially upwards of $50,000 per day, per violation (Stein 2010).

Inherently, impaired surface waters have watersheds that can encompass significant portions or the entirety of an MS4 service area which creates challenges for MS4 operators when identifying and implementing best management practices (BMPs) to achieve the magnitude of pollutant reductions to achieve WLAs. BMPs to reduce stormwater pollutants can be characterized as either structural or nonstructural (source) controls. The former have traditionally been implemented to address stormwater management at the site scale to comply with NPDES regulations associated with land development. As a result, structural BMPs have been heavily studied, resulting in the assignment of pollutant removal efficiencies to assess performance, with efficiencies based on measures at the inflow and outflow of the BMP. However, relative to the greater watershed-scale, application of structural BMPs may not be practical to address WLAs due to the relatively small drainage areas to structural BMPs (Ouwejan et al. 2007) and limited opportunity in built-out areas common to those served by MS4s (SPU 2012). The practicality is demonstrated by Hixon and Dymond (2018), finding 40% of the impervious cover in the City of Hopewell, Virginia, would need to be treated with structural BMPs of 50% removal efficiency, in order to achieve minimum compliance with the city's WLA for total phosphorus (TP). The same case study indicates that for the small city of approximately 22,000, installation of structural BMPs could range from $5 to $32 million to achieve the total TP reduction of 450 lbs. The estimate is based on a range of values for the cost per pound of removal using various structural BMPs from Raje et al. (2013), Nobles et al. (2017), and CWP (2013).

Section 303(d) of the Clean Water Act requires states, territories, or authorized tribes to determine allowable TMDLs for impaired water bodies; however, there is a lack of guidance from the EPA in regards to model selection and data requirements. The lack of consistency contributes the challenges for MS4s to assess BMP performance in a manner consistent with the TMDL. This is due to development of TMDL WLAs that are based on application of various assumptions and watershed-scale hydrologic models combined with water quality models (Borah et al. 2019). Many watershed models are available; but only a handful are used in TMDL development, selected due to simplicity and/or user friendliness (Stein 2010). Whereas hydrologic models are generally understood; the inclusion of water quality simulations are more complex and are primarily empirical information, resulting in the perception of lacking credibility for assessing BMPs (Borah et al. 2019). For these reasons, TMDL modeling efforts are not as readily available or appropriate for MS4 permittees in the development and assessment of the identification of BMPs towards achieving assigned WLAs.

The limitations of structural BMPs to address pollutant reductions associated with WLAs demonstrate the need to incorporate source controls (Ports 2009). In contrast to structural BMPs that can be described as providing "end of pipe" treatment, source controls aim to remove pollutants prior to transport into stormwater runoff. Although the potential for source controls to improve water quality has been recognized (Murphey and Lokey 1999, Bateman 2005, Lien 2013), studies to quantify impacts to water quality resulting from these controls are limited and sparsely available in the literature (Taylor and Cazenas 2010, NCHRP 2013). The exception is street sweeping, which has been extensively studied for decades, as summarized by Hixon and Dymond (2018). However, despite extensive efforts, quantifying the impact from street sweeping remains elusive (Allison et al. 1998; Walker and Wong 1999; Schilling 2005, HEC 2006, Rochfort et al. 2009; Kang et al. 2009; Sutherland 2011; Sorenson 2012; Schueler et al. 2016). Difficulty measuring the impact in downstream receiving waters is attributed to:

- High variability of flow and composition of urban stormwater, both spatially and temporally (Selbig and Bannerman 2007, Ports 2009), resulting in difficulty measuring differences in sediment and nutrient loadings before and after sweeping (Pitt and Bissonette 1984; Zariello et al. 2002; Selbig and Bannerman 2007; Law et al. 2008);
- Unlikelihood of gathering the large number of water samples necessary to detect any significant change (Selbig and Bannerman 2007; Schueler et al. 2016); and the
- Inaccuracies in sampling methods and lag effect of sediment transport in the storm sewer between storms (Law et al. 2008).

Despite challenges of assessing the impact to water quality in receiving streams, there is potential for street sweeping to reduce significant pollutant loading towards achieving WLAs within regulated MS4 service areas. The premise is based on transportation constituting a significant fraction of the total impervious area in urban areas (Schueler 1994), the presence of an abundance of pollutants on the street surface (Pitt and Shawley 1981), and advancing pickup efficiency of street sweepers, especially the increased ability to collect smaller particles (Breault et al. 2005; USEPA 2006; Rochfort et al. 2009; Sutherland 2009). Results from more recent studies by Weston Solutions (2010) and Selbig (2016) detect significant TSS and nutrient reductions downstream, respectively, in small test areas as a result of street sweeping.

4.3 Background

Due to the difficulty of explicitly measuring the impact to water quality from street sweeping in receiving waters, two general approaches have emerged to estimate pollutant reductions from street sweeping, including:

- The use of continuous simulation watershed modeling that rely on application of information and functions derived from past studies to represent numerous variables such as the material loading on the street surface, washoff, impacts from street parking, and sweeper pickup efficiencies (Sutherland and Jelen 1997; Zarriello et al. 2002; Law et al. 2008; Horwatich and Bannerman 2009; Schueler et al. 2016); and
- The direct measure and analysis of swept material to estimate pollutant reductions (Breault et al 2005; EOA 2007; SPU 2012, Bateman 2012, EOA 2007; MDE 2014; VDEQ 2015; Hixon and Dymond 2019).

In 2011 the Chesapeake Bay Program (CBP) approved methods for quantifying TSS, TP, and TN reductions from street sweeping recommended by an expert panel as presented by MDE (2014) and VDEQ (2015). The recommendations included a method based on a conceptual model (Law et al. 2008) and a method based on the measure of swept material. However, findings from a second expert panel presented by Schueler et al. (2016) recommends the methods be phased out, concluding that a continuous simulation modeling effort is necessary due to the inability to measure impacts downstream. The panel employed a consultant to utilize the Source Loading and Management Model for Windows (WinSLAMM) to simulate sediment reductions for various street cleaning scenarios, dependent on sweeper type and frequency of sweeping. Nutrients are estimated from empirical nutrient enrichment ratios for street solids. The model, reliant on sediment production and washoff functions, resulted in very modest annual reductions unless sweeping occurs at a twice weekly frequency, as summarized in Table 4-1. Schueler et al. (2016) recommends to the CBP that the results from the WinSLAMM model be used for quantifying reductions from sweeping for addressing WLAs associated with the Chesapeake Bay TMDL.

Table 4-1. Removal efficiencies for street sweeping from Schueler et al. (2016).

Sweeping Frequency	Pollutant Removal (%)		
	TSS	TN	TP
Twice weekly	21	4	10
Once weekly	16	3	8
Every other week	11	2	5
Monthly	6	1	3
Every other month	4	0.7	2
Every three months	2	0	1

There are concerns with the use of models to assess the performance of street sweeping. Inconsistencies can include differences in the land use data employed with each model that often aggregate streets as part of other urban or impervious areas (Wu et al. 1998), and such is the case with the Chesapeake Bay TMDL Model Progress Run 5.3.2 (Schueler et al. 2016). This can inhibit the ability to assess streets since streets can contain higher pollutant loadings available for transport to surface waters (Endreny and Thomas 2009) and since streets can contribute a majority of the runoff yield in urban areas, such as demonstrated in a low-density residential area by Pitt and Shawley (1981).

Modeling efforts often utilize data from past studies related to street material loading, accumulation, and washoff, along with sweeper pickup efficiencies. However, most of this data is from early studies by the National Urban Runoff Program (NURP) studies described by USEPA (1983) that have been later questioned due to sampling techniques (Sutherland and Jelen 1997; Kang 2009; Winston and Hunt 2017). Application of build-up functions resulting from the NURP studies and used by many models, including WinSLAMM, are based on Pitt (1979) and may result in unreasonable model predictions if not based on direct measurements (Pitt et al. 2005). Pitt et al. (2005) also expresses concern with the wash-off function typically used and modified by models, including WinSLAMM, citing significant overestimations compared to observed values. WLAs can vary significantly dependent on the model employed (Borah et al. 2006; Wallace et al. 2018). Case studies presented by Mohamoud and Zhang (2019) find low predictive performance for water quality constituents from three models, including poor correlation between simulated and observed total nitrogen (TN), TP, and total suspended sediment (TSS) with the Chesapeake Bay Phase 5.3 Community Watershed Model (VAC 2018). Finally, due to the lack of statistically significant data, application of models to assess street sweeping can be suspect due to the lack of ability to provide calibration.

The direct measure of swept material allows for quantifications unique to an MS4's sweeper program, whether performed intermittently and within targeted locations, or on a regular frequency throughout the regulated area. To determine the fraction of swept material to be quantified towards achieving WLAs, analysis of swept material includes moisture content, particle size distribution, and pollutant concentrations. Hixon and Dymond (2019) present findings from a study that measured street sweeping material collected by MS4s in Virginia, resulting in the concentrations of TSS, TN, and TP within the material that would be subject to downstream transport. The results are presented in Table 4-2 as pounds per ton of material swept, a consistent measure for tracking in street sweeping programs. The study found that pollutant fractions of swept material susceptible to downstream transport are impacted by the time since the previous rainfall. Although direct measure and analysis of swept material provides a method of explicit quantification of reductions, concern regarding its appropriateness are based on the assumptions made to estimate the component of the swept material that would ultimately impact surface waters.

Table 4-2. Estimate of POC reduction to surface waters per ton of swept material collected after 2-days since rainfall (Hixon and Dymond 2019).

Surface Type	**Pollutant Reduction from Swept Material (lbs/ton)**		
	TP	**TN**	**TSS**
Streets	0.257	0.585	998
Parking Lots	0.320	0.766	1,307

Quantification of pollutant reductions using the two methods potentially results in significantly conflicting quantification of reductions. In the case of reductions based on a minimum sweeping frequency, efforts not meeting these guidelines would result in the inability to take credit for pollutants removed, altogether. Since impact on water quality in receiving waters is not verifiable with either method, and the scale of TMDL reductions can be significant and costly, an assessment that compares the impact of application of each method can be beneficial to regulatory authorities developing guidance documents for MS4s.

The purpose of this study is to characterize the scale of potential impact from street sweeping as a water quality BMP based on both direct measure of swept material using measures presented by Hixon and Dymond (2019) and application of the WinSLAMM model presented by Schueler et al. (2016). Characterization is based on evaluation of sample areas of varying land use subject to the Chesapeake Bay TMDL, including estimations of annual loadings from areas available for street sweeping and the portion of those loadings potentially removed from sweeping efforts. Results are compared in order to characterize the potential of sweeping towards achieving WLAs for the sample areas, as would be required by assigned WLAs for the Chesapeake Bay TMDL.

4.4 Methods

This section describes the sample areas, their respective land use and land cover, followed by an explanation of the precipitation data and subsequent computation of runoff in each of the land uses for each sample area type. Following this, discussion is provided describing the generation of the daily and annual TP, TN, and TSS loadings for three different scenarios used for determining the required pollutant reductions to achieve WLAs within the sample areas. With loadings and required reductions known, methods that characterize pollutant reductions from street sweeping are assessed.

Four sample areas from an MS4 jurisdiction in Virginia subject to the Chesapeake Bay TMDL were selected and delineated to incorporate only the representative land use, as depicted in Figures 4-1a – 4-1d (provided at the end of the manuscript for review). For the purposes of assessment of street sweeping potential, land cover is separated as public transportation, rooftop, other impervious, and turf, as summarized in Table 4-3. The public transportation category includes areas owned or operated by the MS4 that would be available for street sweeping, including only public streets for the residential, commercial, and industrial areas; but also including parking lots for the institutional area that is a community college campus. The inclusion of parking lots for the institutional area results in this sample area having the largest fraction of area within the public transportation category among the sample sites. Total imperviousness for the samples areas is 41%, 72%, 53%, and 55% for the residential, commercial, industrial, and institutional areas, respectively.

Table 4-3. Land cover summary for sample areas.

Sample Area	**Total (acres)**	**Land Cover (% of Total Area)**			
		Public Trans.	**Rooftop**	**Other Imp.** [a]	**Pervious (turf)**
Residential	492.58	15.6	17.3	8.0	59.0
Commercial	759.97	13.2	19.7	39.1	28.1
Industrial	502.53	7.2	19.2	25.9	47.7
Institutional	106.60	31.5	8.5	6.3	37.8

[a] All non-roof and non-public transportation impervious cover (i.e. parking lots, sidewalks, etc.)

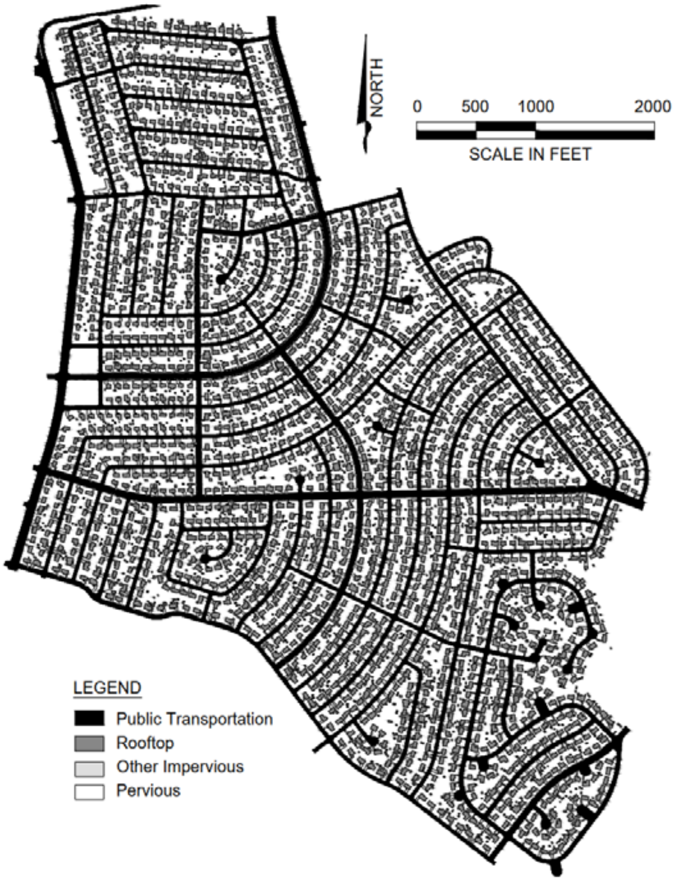

Figure 4-1a. Residential sample area.

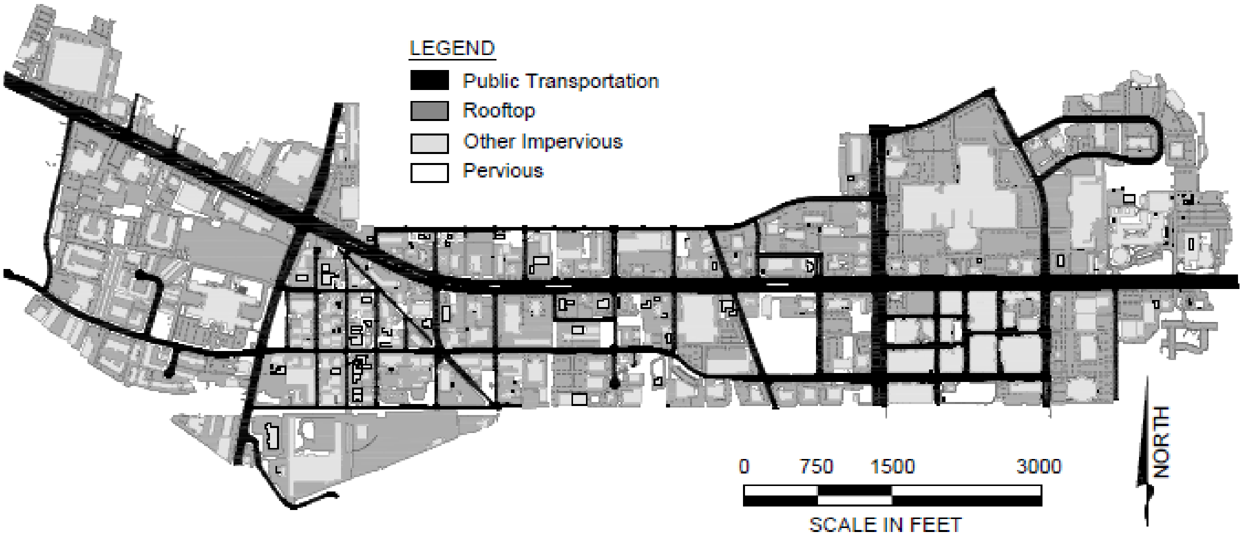

Figure 4-1b. Commercial sample area.

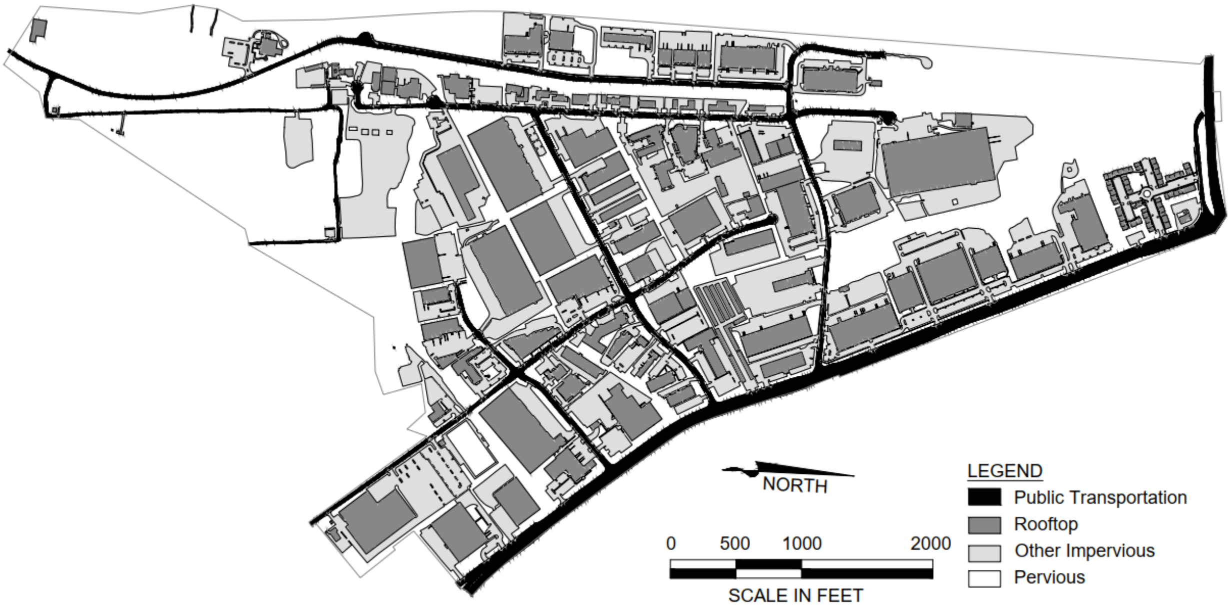

Figure 4-1c. Industrial sample area.

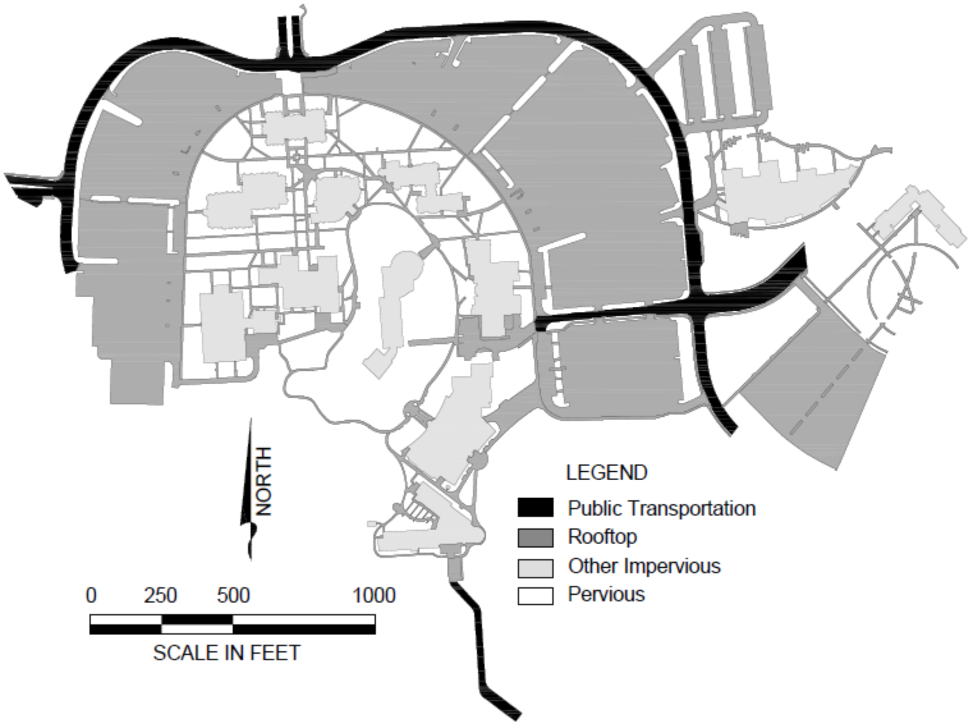

Figure 4-1d. Institutional sample area.

Annual runoff from each sample area was generated using daily local climatology data from the National Oceanic and Atmospheric Administration (NOAA 2019). Daily rainfall records from a year representative of the total average annual rainfall for the sample areas was selected for use with the Soil Conservation Service (SCS 1986) curve number hydrologic methods to generate runoff. A runoff curve number of 98 was used for impervious areas and varied for turf area, dependent on the hydrologic soils group. Daily runoff was calculated using the NRCS runoff equation (NRCS 1986). The total annual rainfall for the sample year was 43.2 inches, including 115 days of measured precipitation resulting in 83 days of runoff producing events. As noted in Table 4-4, most of the storms produced less than 0.5-inches of rainfall, resulting in a fraction of the annual runoff ranging from only 11 - 13%. The majority of runoff was produced from the 28 storms recording greater than 0.5 inches of rainfall, with a significant fraction of the total annual volume resulting from four large storm events.

Table 4-4. Fraction of runoff from storm events.

Sample Area	**Storm Type** (n = number of days of rainfall)		
	Small (< 0.5 in.) (n=87)	**Intermediate (0.5-2 in.)** (n=24)	**Large (> 2 in.)** (n=4)
Residential	0.11	0.46	0.43
Commercial	0.13	0.51	0.36
Industrial	0.12	0.49	0.39
Institutional	0.13	0.50	0.37

Annual loadings were generated for each sample area for the sample year based on three scenarios for each sample area, including a:

(1) land use (LU) scenario that computes loadings based on readily available event mean concentrations (EMCs) for each land use; a

(2) land cover (LC) scenario that separates rooftop as a land cover and adjusts and verifies EMCs for the remaining impervious and pervious cover; and a

(3) Chesapeake Bay (CB) TMDL scenario that applies loading rates for impervious and pervious cover from the Chesapeake Bay Watershed Model Progress Run 5.3.2 (VAC 2018).

Generation of loadings for the LU and LC scenarios are based on EMC values extracted from the National Stormwater Quality Database (NSQD), Version 4.02 (NSQD 2019). These data are predominantly distributed between urban land uses, including the land use types assessed in this study. As described by Pitt et al. (2018), factors impacting water quality values in the database are mostly associated with land use and location, with the latter characterized by EPA rain zones. On that basis, values used from the database were limited to those gathered in EPA rain zone 2, the associated zone for the sample areas. Data were also selected based on sampling methods, with only composite samples included, since first flush datasets can result in significantly larger values not representative of the EMC for the entire storm volume (Pitt et al. 2004a). Since seasonal variation of nutrient loadings have been observed (Selbig 2016; Schueler et al. 2016), EMC data was also categorized by season. It is noted that EMC values for institutional land use were limited within rain zone 2. Therefore, for the purposes of this study, EMC values for the commercial land use were used for institutional land area since the sample areas are similar in regards to including public use parking areas and the fraction of pervious area.

Ideally, estimates of loadings for the LC scenario would be generated using land cover specific EMC values to allow for generation of loadings representative of public transportation land cover available to street sweeping. However, information for specific types of land cover is limited to an inadequate or nonexistent number of samples in the NSQD and the literature (Schueler et al. (2016). Therefore, EMC values were estimated for the cover types listed in Table 4-3 to the extent practicable with the relatively consistent and available information. Specifically, EMC values were estimated for each of the land cover types in Table 4-3 based on the following guidelines:

- Maintain the median EMC values obtained from the NSQD for each storm event to for consistency;
- Although limited, use the mean EMC values of consistent rooftop EMC values available in the literature, as summarized in Table 4-5;
- Assume an equivalent EMC for all non-roof impervious cover since there is limited data to differentiate for various types of impervious such as roads and parking lots;
- Since statistically significant EMC values for urban pervious cover are not available, employ the ratio between urban impervious and pervious loading rates provided by the Chesapeake Bay Model Progress Run 5.3.2 provided by VAC (2018). The loading rate ratios of urban pervious to impervious are 0.15, 0.74, and 0.28 for TSS, TN, and TP, respectively; and
- Compare resulting non-roof impervious and pervious values with available EMC values from comparable land cover types.

Table 4-5. Summary of values from studies with EMC measures from rooftop.

Study	**Pollutant (mg/L)**			**General Description**
	TSS	**TN**	**TP**	
DeBusk and Hunt (2012)	2.6	1.03	0.02	Median values from 4 sites. (n=41)
Taguchi et al. (2019)	0.01	0.61	0.04	Median values from 4 sites. (n=68)
Ahmed et al. (2016)	-	0.55	-	Median of average values from cisterns collecting rooftop runoff from 4 sites
O'Conner et al. (2015)	1.94	0.55	0.04	Median values from rooftop. (n=20, 23, and 27 for TN, TP, and SSC, respectively)

Application of the listed guidelines results in the following equation, applied to daily loading computations for each sample area:

$$EMC_{Per} = \frac{EMC_{NSQD} - \left(EMC_{Roof} \times \frac{Vol_{Roof}}{Vol_{Storm}}\right)}{\frac{Vol_{Per}}{Vol_{Storm}} + \left(\frac{LR_{Imp}}{LR_{Perv}} \times \frac{Vol_{Imp}}{Vol_{Storm}}\right)} \tag{1}$$

Where: EMC_{Per} *= EMC for pervious cover;*

EMC_{NSQD} *= Respective NSQD EMC;*

EMC_{Roof} *= Mean rooftop EMC from Table 4-5;*

Vol_{Roof} *= Volume generated from rooftop for a given storm event;*

Vol_{Per} *= Volume generated from pervious cover for a given storm event;*

Vol_{Imp} *= Volume generated from impervious cover for a given storm event;*

Vol_{Storm} *= Total volume generated for a given storm event;*

LR_{Imp} *= Loading rate for impervious cover from VAC (2018); and*

LR_{Per} *= Loading rate for pervious cover from VAC (2018);*

With the EMC for pervious cover known for each storm event as a result of applying Equation 1, the impervious cover EMC is then computed using the ratio between urban impervious and pervious loading rates as previously described.

Annual loadings for each pollutant from each sample area and for each of the loading scenarios were computed with the summation of daily loadings from the sample year. Daily loadings were generated for each loading scenario as follows:

- LU scenario loadings were generated by multiplying the NSQD land use EMC values, specific to land use type and season, by the respective daily runoff volume. Loadings were generated separately for impervious and pervious runoff volumes.
- LC scenario loadings were generated by multiplying the computed land cover EMC values, specific to land use and season, by the respective daily runoff volume. Loadings were generated separately for runoff volumes from each land cover type in Table 4-3.
- CB scenario loadings were generated using loading rates provided by VAC (2018) based on the Chesapeake Bay Watershed Model Progress Run 5.3.2 for each pollutant as pounds per acre per year.

For the LU and CB scenario, loadings for specific impervious land cover types were computed as the fraction of the cover type area within the total impervious area since both runoff volume, and therefore loading, is proportional to the fraction of impervious area. For example, the fraction of runoff from rooftops would result in the same fraction of the total TN loading from rooftop. This is problematic since the approach would disproportionately reduce loadings from the public transportation land cover fraction of the overall impervious cover that would be used when applying pollutant removal efficiencies, such as those in Table 4-1.

Annual baseline loadings for each scenario were used for determining the required annual reductions for each pollutant to achieve the Chesapeake Bay TMDL WLAs based on the Chesapeake Bay Model Progress Run 5.3.2 provided by VAC (2018) as provided in Table 4-6. Required reductions are 20% and 8.75% for TSS; 9% and 6% for TN; and 16% and 7.25% for TP from the baseline impervious and pervious loadings, respectively. With loadings and required reductions for the sample areas known, potential impact from street sweeping towards achieving the required reductions is assessed based on:

- Application of modeled removal efficiencies to the loadings from the public transportation cover that would be available to street sweeping. Applied removal efficiencies are those presented by Schueler et al. (2016) that are provided in Table 4-1; and
- Application of pollutant concentrations of swept material from Hixon and Dymond (2019) as summarized in Table 4-2. Assessment with this method is characterized in the context of associated pollutant reduction based on the amount of material annually collected by street sweeping.

Table 4-6. Loading rates for the CB loading scenario from the Chesapeake Bay Watershed Model Progress Run 5.3.2.

Sample Area	Pollutant (lbs./ac/yr)	Urban Impervious	Urban Pervious
CB TMDL [a]	TSS	676.94	101.08
	TN	9.39	6.99
	TP	1.76	0.50

[a] As specified for the James River basin within which the sample areas reside (VAC 2018).

4.5 Results

This section first provides results of the extraction of EMC values from the NSQD for use with the LU loading scenario, followed by the computed EMCs for impervious and pervious based on refined rooftop EMCs for the LC scenario. Resulting TSS, TN, and TP loadings from each sample area based on each loading scenario are then provided, followed by the associated loading rates (lbs/acre/year) for comparison of the loading rates specified by the Chesapeake Bay Model Progress Run 5.3.2 for the sample area, as provided by VAC (2018). Subsequently, results based on the two methods to quantify achievable reductions from street sweeping towards achieving the WLA are provided.

4.5.1 EMC values for the LU and LC Scenario

EMC values for the LU scenario are taken from the datasets collected from the NSQD, which demonstrate a lognormal distribution and are represented for the use of generating loadings by the median values in Table 4-7. Median values for TSS were found to be highest in the spring for each land use, with the exception of the industrial winter value. TSS in runoff was comparable between residential and commercial land uses in the summer, each approximately 20% higher than the industrial value for the same season. Conversely, the industrial values in the fall and winter are approximately 18% and 30% higher compared to commercial and residential, respectively. The median values for TN show that commercial land use has the highest values and the industrial land use has the lowest values consistently throughout the year. The median values for TP are higher in residential runoff throughout the year, with the exception of winter which found consistent values across each land use.

Table 4-7. Median EMC values from NSQD, composite samples in EPA Rain Zone 2.

POC	**LU**	**EMC (mg/L)** [b]			
		Spring	**Summer**	**Fall**	**Winter**
TSS	Res.	61	52	33	49
	Co.	62	54	40	57
	Ind.	61	43	49	69
TN [a]	Res.	2.26	2.17	1.75	1.71
	Co.	2.53	2.19	1.88	1.97
	Ind.	1.89	1.80	1.56	1.59
TP	Res.	0.32	0.32	0.29	0.21
	Co.	0.27	0.25	0.22	0.21
	Ind.	0.23	0.22	0.25	0.21

[a] TN from sum of median values for total Kjeldahl nitrogen and nitrate-nitrogen + nitrite nitrogen.

[b] The seasonal range of the number of samples for TSS is 359-515, 139-840, and 65-96 for residential, commercial, and industrial, respectively. The seasonal range for nutrients is 308-526, 106-158, and 58-94 for residential, commercial, and industrial, respectively.

Resulting EMC values for the LC scenario are provided in Table 4-8 and differ from those for the LU scenario due to the separation of roof-top impervious surfaces and pervious to impervious ratio. As with the limited values for rooftop EMCs, information for assessment of the resulting EMC values is also limited, but the values are comparable to available information from previous studies. Calculated EMCs for non-roof impervious are within the range of values for transportation types of land cover compiled by Tetra Tech (2014) for the Chesapeake Bay Program. This study found a median TSS value of 67 mg/L for a transportation land use and median values ranging from 119 – 129 mg/L for runoff from roads. The calculated EMCs for roads are similar to measures found in road runoff by Barrett et al. (1998) and Wu et al. (1998); but lower than measures by Barrett et al. (1998) and Flint and Davis (2007) that present median TSS values of 263 mg/L and 320 mg/L in highway runoff, respectively. The calculated nutrient EMCs for non-roof impervious are mostly within the range of reported values (Barrett et al. 1998; Wu et al. 1998; Flint and Davis 2007; and Tetra Tech 2014), ranging from 2.17 - 3.79 mg/L and 0.11 – 0.44 mg/L for TN and TP, respectively. The exceptions are TP values exceeding reported median values from the residential land use in the spring, summer, and fall. Information to assess the calculated EMC values from pervious cover is also limited. TN values from pervious cover fall within the range of those recommended by Schueler (2011) of 1.5 – 2.5 mg/L from fertilized and non-fertilized lawns, respectively. Calculated values are lower than the 0.2 – 0.4 mg/L recommended by Schueler (2011) for TP from lawns, but exceed the median value of 0.08 mg/L for open space reported by Tetra Tech (2014). TSS values are limited for comparison to the median value from Tetra Tech (2014) of 22 mg/L for pervious land cover.

Table 4-8. Median EMC values computed for pervious and impervious land cover and used for the LC scenario. EMCs applied for roof runoff were held constant per season and sample area and were 1.52, 0.69, and 0.03 mg/L for TSS, TN, and TP, respectively.

POC	**Sample Area**	**Imperious EMC (mg/L)** [a]				**Pervious EMC (mg/L)**			
		Spr.	**Sum.**	**Fall**	**Win.**	**Spr.**	**Sum.**	**Fall**	**Win.**
TSS	Res.	105	89	56	84	16	13	8	13
	Com.	83	73	54	77	12	11	8	11
	Ind.	95	67	76	107	14	10	11	16
	Inst.	76	66	49	70	11	10	7	10
TN	Res.	3.41	3.24	2.53	2.46	2.54	2.43	1.89	1.83
	Com.	3.18	2.72	2.30	2.42	2.37	2.03	1.72	1.81
	Ind.	2.57	2.43	2.05	2.10	1.92	1.81	1.53	1.57
	Inst.	2.94	2.58	2.15	2.26	2.20	1.89	1.60	1.69
TP	Res.	0.53	0.53	0.48	0.34	0.15	0.14	0.15	0.10
	Com.	0.35	0.33	0.29	0.27	0.10	0.09	0.08	0.08
	Ind.	0.34	0.33	0.37	0.31	0.10	0.09	0.11	0.09
	Inst.	0.32	0.30	0.26	0.25	0.09	0.08	0.07	0.07

[a] Non-roof impervious cover.

4.5.2 Pollutant Loadings from Sample Areas

Pollutant loadings for the sample year are provided in Figures 4-2 – 4-4 for TSS, TN, and TP respectively, for each loading scenario. Reflective of the inclusion of EMC adjustments for land cover, contributions from rooftops are lower for each pollutant and sample area with the LC loading scenario. Conversely, the remaining impervious land cover contributions increase compared to the LU scenario loadings. The overall increase in loadings generated from impervious and the decrease from pervious with the LC scenario, as compared to the LU scenario, is a result of the pervious to imperious ratios applied for estimating non-rooftop land cover EMCs. Since required reductions to achieve WLAs are based on a percent reduction of the existing loadings, the scenarios with the largest loadings result in a larger reduction requirement. Therefore, the relative opportunity to have loadings available to street sweeping from the transportation cover type is highest as a result of the LC loadings for all scenarios, representing a higher fraction of total loadings in each case.

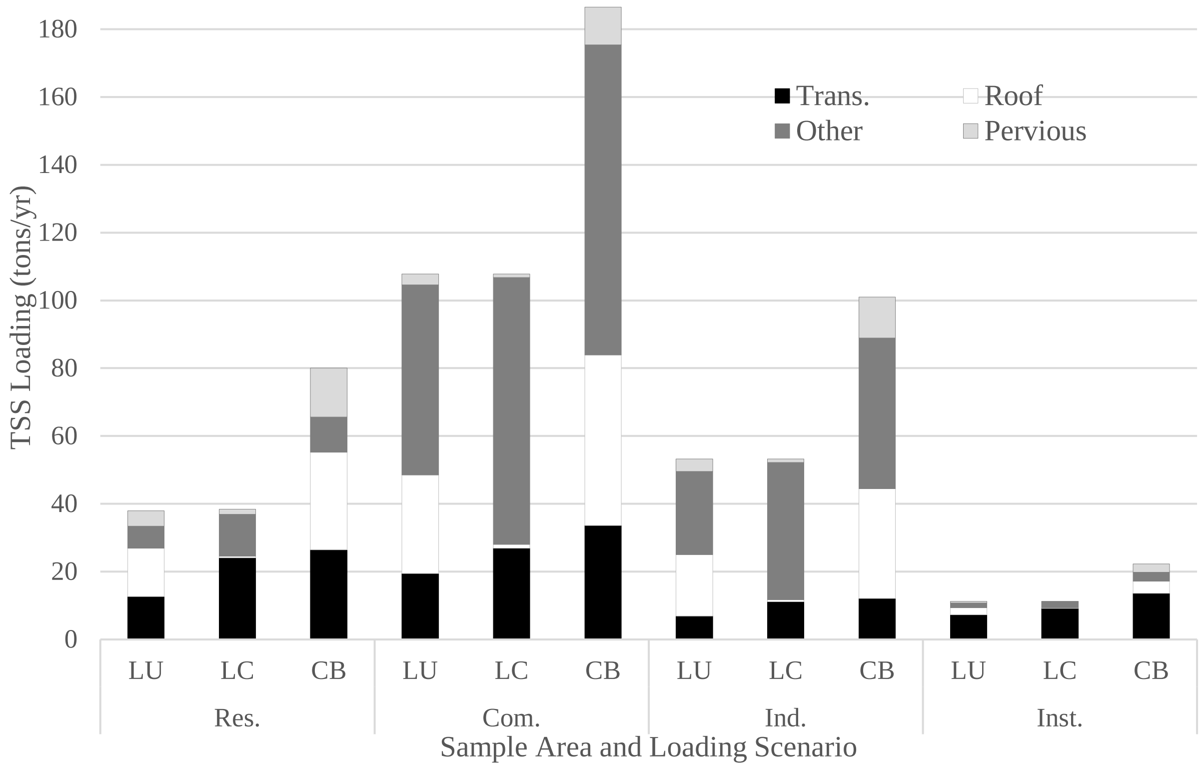

Figure 4-2. TSS annual loadings generated from the sample year based on each loading scenario.

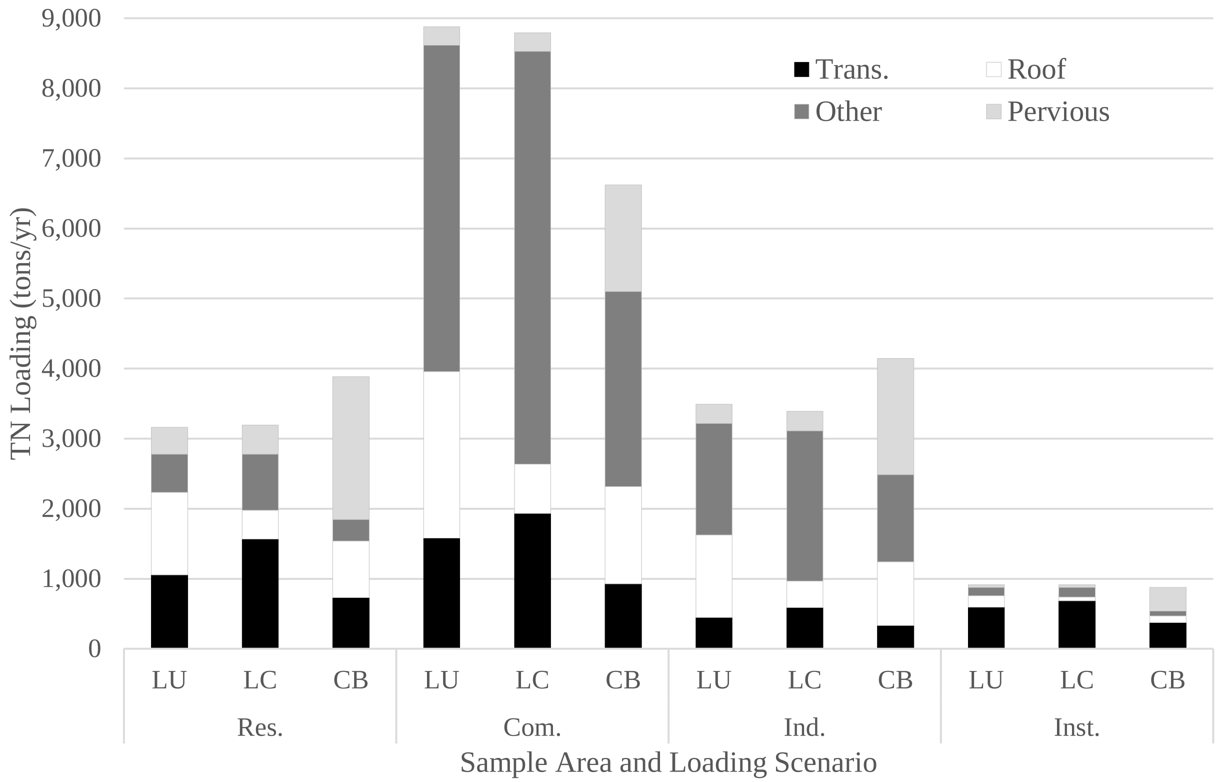

Figure 4-3. TN annual loadings generated from the sample year based on each loading scenario.

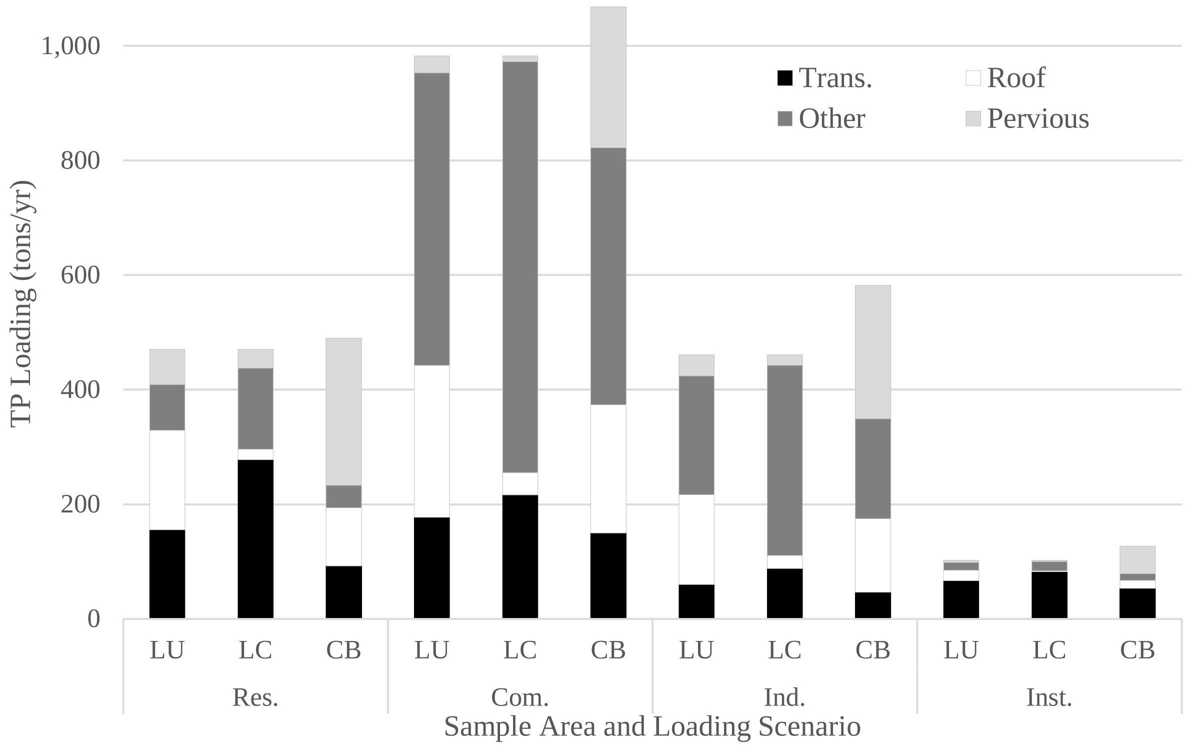

Figure 4-4. TP annual loadings generated from the sample year based on each loading scenario.

Loading rates are provided in Table 4-9 for comparison to the CB scenario loading rates and to assess differences observed from the annual loading results from the sample areas. Adjustments for land cover EMCs result in an increase in loadings from non-rooftop impervious and a decrease in pervious loadings, with the exception of TN from pervious cover due to application of Equation 1 resulting in pervious EMCs near the land use EMCs. This exception occurs due to the rooftop EMC for TN representing a higher fraction of the land use EMC and the smaller difference for TN in the applied pervious to impervious ratio. As noted from Figures 4-2, 4-3, and 4-4, the CB loading scenario reflects the highest contribution of loadings from pervious cover in all cases, a result of the consistency with the higher loading rates for the CB scenario provided in Table 4-6. For context, based on the volumes generated from the sample areas, EMC values to produce the pervious cover CB loading rates would range from 143 – 243 mg/L, 9.93 – 16.81 mg/L, and 0.71 – 1.20 mg/L for TSS, TN, and TP, respectively, in each case, far exceeding pervious EMC values as previously described. It is hypothesized that the fraction of annual runoff volume from pervious cover is not considered with the Chesapeake Bay loading rates that account for 13%, 3%, 8%, and 5% of the annual runoff from the residential, commercial, industrial, and institutional sample areas, respectively.

Table 4-9. Annual loading rates resulting from the LU and LC scenarios.

POC	Sample Area	Loading Rate (lbs/ac/yr)				
		LU Scenario		LC Scenario		
		Imp.	Perv.	Non-Roof Imp.	Roof	Perv.
TSS	Res.	336.30	31.21	628.19	10.58	9.98
	Com.	365.66	30.71	501.19		6.53
	Ind.	369.96	33.67	607.69		9.05
	Inst.	365.66	20.06	461.70		4.09
TN	Res.	13.88	1.38	20.28	4.80	1.48
	Com.	14.89	1.31	18.48		1.21
	Ind.	11.95	1.15	16.01		1.15
	Inst.	14.89	0.86	17.27		0.75
TP	Res.	2.03	0.21	3.59	0.23	0.11
	Com.	1.67	0.15	2.21		0.06
	Ind.	1.59	0.16	2.48		0.07
	Inst.	1.67	0.10	2.05		0.04

4.5.3 Modeled Removal Efficiencies to Quantify Reductions

Required pollutant reductions to achieve the Chesapeake Bay TMDL WLAs were calculated for each sample area using the generated loadings from Figures 2 – 4. Since quantification of pollutant loads based on a removal efficiency are dependent on the loadings to which the efficiency is applied, the annual required reductions are reflected in Figure 4-5 as a fraction of the loadings available from the public transportation land cover. The impact from generating baseline loadings based on land cover, instead of aggregated land use, is demonstrated by smaller required efficiencies required to achieve the required reductions since higher loadings are available. Potential from sweeping is impacted by land use with the fraction of removal decreasing as the fraction of available area for sweeping increases within the total impervious areas; reflected within the residential and institutional sample areas. The fraction of available loadings necessary for removal is higher within the commercial and industrial areas due to area available for sweeping accounting for just 13.2% and 7.2% of the sample areas, respectively. In several cases, the required reductions exceed the loadings available.

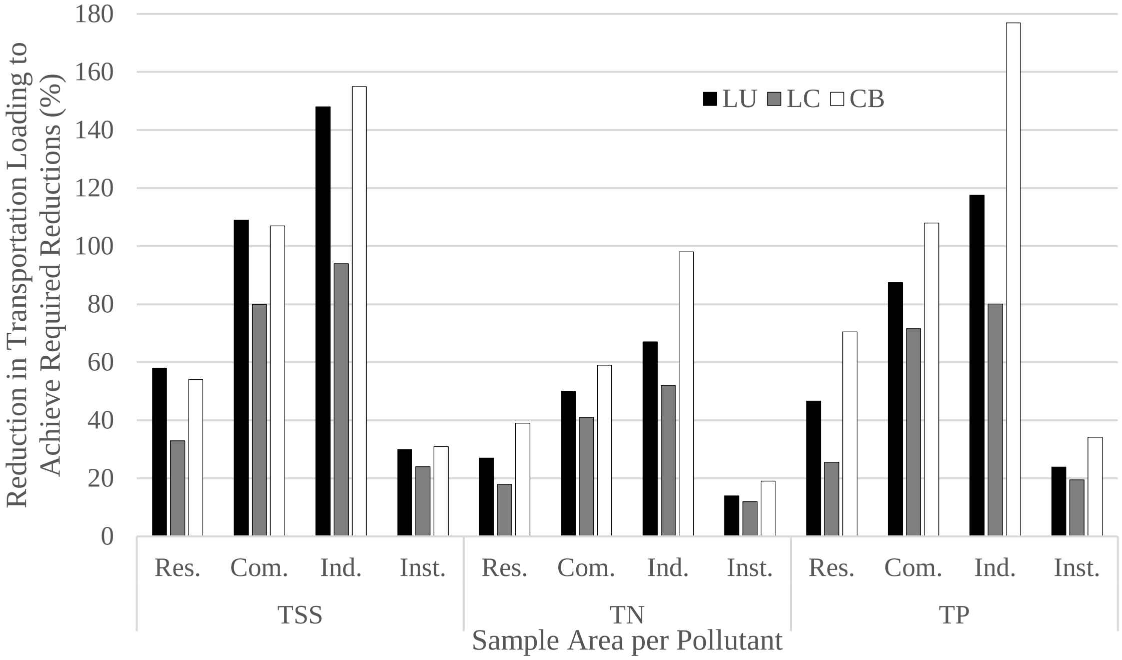

Figure 4-5. Required reductions as a fraction of public transportation loadings.

Potential reductions that could be achieved by street sweeping based on modeled reduction efficiencies, as provided by Schueler et al. (2016), are presented in Figure 4-6. The reductions are calculated using the loadings from public transportation cover, assuming the entire area swept, per the designated frequency. Reflective of the available loadings to sweeping, the impact towards achieving the required reductions is more prevalent in the residential and institutional sample areas. Since MS4 jurisdictions would include each of the four sample area types, overall impact would be dependent on the prevalence of each land use. For example, as the overall fraction of residential land use area increased within the MS4 jurisdiction, the impact of sweeping towards achieving overall reductions would increase, to a maximum of the reduction credit reflected in Figure 4-6 for the sample area. Necessary removal efficiencies are lower with the LC loading scenario as a result of larger available loadings available to sweeping. The highest impact results within the institutional area with a large fraction of the sample area available for sweeping. Impact from commercial and industrial areas is very modest, even with twice weekly sweeping. When frequency drops to once every other month, impact is minimal for all scenarios and land use areas.

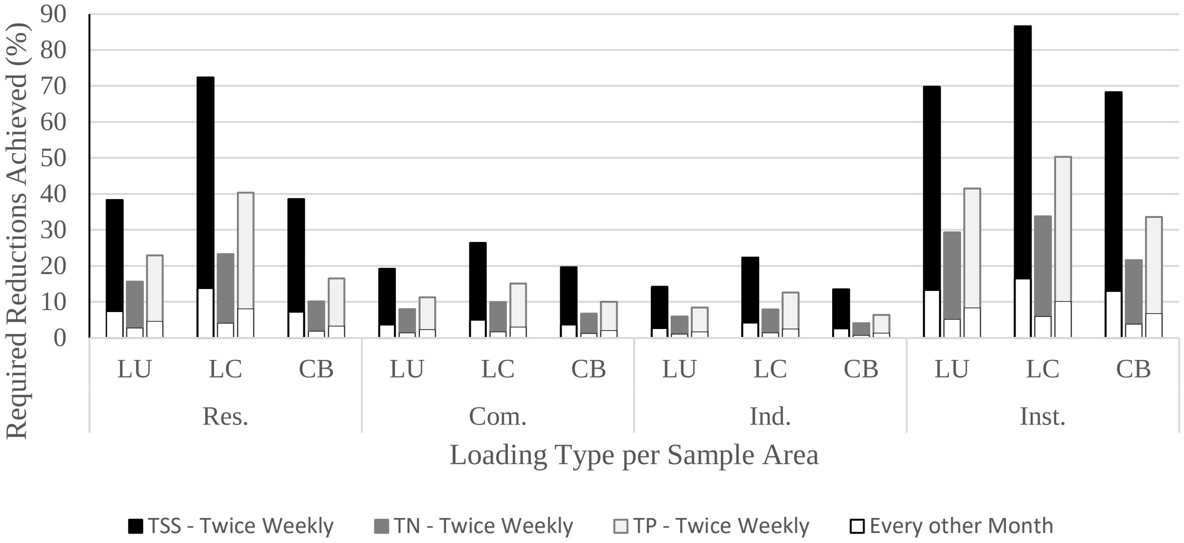

Figure 4-6. Potential towards achieving required pollutant reductions based on removal efficiencies and sweeping frequency from Schueler et al. (2016).

4.5.4 Quantification of Reductions Based on Measure of Material Collected

As an alternative to the application of modeled removal efficiencies to quantify reductions from street sweeping, quantification based on measure and analysis is considered. Quantification with this method is dependent on the tracking of the mass of collected material and analysis of the concentration of pollutants in the portion of the collected mass of the particle size susceptible to downstream transport during runoff events. Removal efficiencies per ton of collected material, computed with the values from Table 4-2 and the public transportation cover loadings, are provided in Table 4-10. Quantification of reductions based on measures of swept material find TN to have the lowest removal efficiencies and TSS the highest, similar to the removal efficiencies from Schueler et al. (2016). Removal efficiencies vary per sample area since the collected material is proportional to the transportation cover loading, with removal efficiency decreasing as the loading increases.

Table 4-10. Pollutant removal efficiencies based on measure of swept material from Hixon and Dymond (2019) for ton of material collected (streets swept ≥ 2 days since runoff).

Sample Area	**Loading Scenario**	**Removal Efficiency Per Ton of Collected Material (%)**		
		TSS	**TN**	**TP**
Res.	LU	3.71	0.05	0.16
	LC	***1.86***	***0.04***	***0.09***
	CB	1.89	0.08	0.28
Com.	LU	2.57	0.04	0.15
	LC	***1.85***	***0.03***	***0.11***
	CB	1.49	0.06	0.17
Ind.	LU	7.20	0.13	0.43
	LC	***4.46***	***0.10***	***0.28***
	CB	4.12	0.18	0.55
Inst.	LU	6.85	0.10	0.39
	LC	***5.43***	***0.09***	***0.31***
	CB	3.67	0.16	0.48

Since a measure of the collected material is necessary to assess the potential for sweeping based on the removal efficiencies in Table 4-10, for context, the tons of swept material that would be necessary to achieve the equivalent reductions achieved by modeled pollutant removal efficiencies is given Table 4-11. It is noted that larger values for the LC loading scenario is reflective of the larger reductions achieved with this scenario. In context, the tonnage of material in the hopper of a street sweeper could range between 2.5 to 8.8 tons for hoppers with material capacity from 2 to 7 cubic yards based on a bulk density conversion for swept material from Sansalone et al. (2011) of 1.5 g/cm^3. This value is conservative compared to an assumed density of swept material of 2.0 g/cm3 estimated by Pitt et al. (2004b) and Breault et al. (2005) and consistent with density in swept sample presented by EEE (2017) ranging from 1.33 and 1.68 g/cm^3. Based on the range of hopper loading capacity, results indicate reductions quantified from swept material to achieve equivalent reductions determined with the Schueler et al. (2016) removal efficiencies could be based on less frequent sweeping.

Table 4-11. Collected material required to achieve equivalent reductions as achieved by removal efficiencies from Schueler et al. (2016) as presented in Figure 4-6.

Sample Area	**Loading Scenario**	**Tonnage of Collected Material**					
		TSS		**TN**		**TP**	
		Twice Weekly	**Every other Month**	**Twice Weekly**	**Every other Month**	**Twice Weekly**	**Every other Month**
Res.	LU	5.7	1.1	76.7	13.4	63.7	12.7
	LC	***11.3***	***2.2***	***113.9***	***19.9***	***117.5***	***23.5***
	CB	11.1	2.1	50.0	8.7	35.9	7.2
Com.	LU	8.2	1.6	108.2	18.9	68.8	13.8
	LC	***11.3***	***2.2***	***132.2***	***23.1***	***91.8***	***18.4***
	CB	14.1	2.7	63.4	11.1	58.2	11.6
Ind.	LU	2.9	0.6	30.7	5.4	23.3	4.7
	LC	***4.7***	***0.9***	***40.2***	***7.0***	***35.4***	***7.1***
	CB	5.1	1.0	22.7	4.0	18.1	3.6
Inst.	LU	3.1	0.6	40.7	7.1	25.8	5.2
	LC	***3.9***	***0.7***	***46.9***	***8.2***	***31.9***	***6.4***
	CB	5.7	1.1	25.4	4.5	20.8	4.2

As demonstrated in Table 4-11, it is necessary to have an understanding of the annual mass of material collected for a specific area to estimate the potential of sweeping based on measure of material. The annual mass collected would inherently depend on variables such as sweeping frequency and the mass collected with each sweeping instance. As an example, the mass swept from a single sweeping instance within the institutional sample area used in this study produced 18.4 tons of material. Comparing this value to the tonnage of collected material necessary to achieve the reductions credited as a result of application of the Schuler et al. (2016) removal efficiencies demonstrates the disparity between the two methods. The measures from the single sweeping instance exceeds the annual tonnage equivalent to sweeping every other month in each sample area and for TSS and within the industrial and institutional areas for TN and TP. The collected material also exceeds the equivalent annual tonnage for TSS credit when sweeping twice weekly. The mass collected with the single instance also accounts for significant fractions of the equivalent tonnage with twice weekly sweeping for TN and TP, respectively. Assuming a sweeping instance could collect at least a similar tonnage of material from the other sample areas, since public transportation areas are similar or larger than the institutional area, comparison can be made to other land uses. For example, if 18.4 tons was collected from the commercial sample area in a single instance, it would suggest 7.1 annual sweeping instances would be necessary to achieve the equivalent reduction credited by Schueler et al. (2016) based on sweeping ~100 times per year.

It is noted that the material collected from a single sweeping event within the institutional area exceeds the modeled annual TSS loading generated from public transportation cover for the LU and LC scenarios and represents 68% of the loading generated with the CB scenario. The authors suggest this discrepancy further questions the validity of modeling to assess street sweeping for TSS since the collected pollutants would have been subject to runoff and ultimate transport to surface waters. However, the same observation is not found with nutrients, with the reductions from the single sweeping instance ranging from 2 - 3% and 6 - 9% of the total annual TN and TP loads generated from the public transportation cover, respectively.

Table 4-12 provides the material that would be required to be collected to achieve the total reductions required for each sample area and loading scenario. In context to the institutional area example, the collected 18.4 tons from a single instance exceeds the required annual reduction for TSS for all loading scenarios. For TN, approximately 13% of the reductions are achieved and approximately 30% of the required TP reductions are achieved. In this case, TN would be the limiting pollutant if sweeping were to be the only means for addressing pollutant reductions, requiring approximately 8 annual sweeping instances within the institutional sample area to achieve the full reductions required for all pollutants. For comparison, the Schueler et al. (2016) method would result in 29%, 34%, and 21% of the TN reductions achieved with sweeping occurring ~100 times annually.

Considering the 18.4 tons per instance example has a hypothetical comparison to the other land use areas, a frequency of approximately 27 instances annually would be necessary to achieve the full reductions for all pollutants in the residential and industrial areas, equal to frequency of every about every two weeks. For the commercial land use, sweeping would be required about every 5 days.

Table 4-12. Required material collection to achieve the full Chesapeake Bay TMDL reductions for each sample site for each loading scenario.

Sample Area	**Loading Scenario**	**Tonnage of Material Required for Collection to Achieve the Total Required Reductions**		
		TSS	**TN**	**TP**
Res.	LU	14.8	491.7	278.7
	LC	***15.8***	***489.9***	***291.4***
	CB	28.8	493.3	217.4
Com.	LU	42.5	1,352.5	607.8
	LC	***43.0***	***1,338.9***	***608.2***
	CB	72.2	940.8	581.3
Ind.	LU	20.5	523.1	277.3
	LC	***21.1***	***507.2***	***280.9***
	CB	37.8	552.5	283.1
Inst.	LU	4.4	138.9	62.1
	LC	***4.5***	***138.9***	***63.4***
	CB	8.4	117.7	61.8

4.3 Conclusions

Street sweeping can potentially provide significant impact towards achieving pollutant reductions resulting from TMDL WLAs. However, measures to quantify reductions to demonstrate regulatory compliance are difficult due to the inability to measure the impact downstream as a result of high variability in stormwater samples, the number of samples required, and the lag effect of transport of pollutants through the MS4. In response, two general methods have emerged, 1) based on application of removal efficiencies resulting from modeling efforts, or 2) with the direct measure and analysis of swept material. When using a modeling approach, pollutant loadings generated based on land cover type, as opposed to aggregated land use, are important to represent the higher loading rates from the street surface since removal efficiencies are applied to those loadings. The land cover loading scenario demonstrates a majority of annual pollutant loadings are generated from non-roof impervious cover and higher fraction of annual loadings from public transportation cover are available to street sweeping compared to the land use based loading scenarios. As the fraction of the impervious area available within varied land uses for sweeping increases, the potential to achieve pollutant reductions with sweeping increases, as would be expected. The application of a method to define EMC values for land cover finds loadings from rooftops to be minimal compared to other impervious cover. The corresponding EMC based on runoff for the sample year finds the Chesapeake Bay TMDL Model Progress Run 5.3.2 loading rates to appear misrepresentative of pervious cover for the sample areas, possibly due to the area application of the loading rates as opposed to the fraction of runoff volume from pervious cover.

Quantification of pollutant reductions predicted from modeled removal efficiencies predict significantly lower impact from sweeping than those resulting from measure of pollutants susceptible to runoff in swept material. Reductions based on modeled efficiencies are modest, even with rigorous twice weekly sweeping, potentially discouraging the use of street sweeping as a management practice. The direct measure of swept material finds inconsistency with an apparent underestimation of modeled annual loadings for TSS from public transportation cover. The inconsistency augments concerns with modeling applications. As a result, the authors suggest the method of direct measure and analysis of swept material as the appropriate method for quantifying reductions achieved by street sweeping. The suggestion is due to the method providing a direct measure of the pollutants of concern that would be susceptible to downstream transport and entry into water ways. Unlike the use of pollutant removal efficiencies resulting from a modeling effort, the direct measure method is dependent on the collected material that will inevitably vary in mass per sweeping instance due to availability of material on the street surface and the expanse of the area swept. Direct measure allows for a measure representative of each unique sweeping program, representative of the unique effort. Alternatively, use of modeled removal efficiencies do not take sweeping program and land use variations into account. Further, the resulting loadings generated for the sample year in this study found 69% of the 83 runoff events each produced loadings that were less than 1% of the annual loading, summing to 13.5% of the annual loading. This suggests that rigorous sweeping frequency may be unnecessarily onerous.

Chapter 5: Dissertation Conclusions

Chapters 2 – 4 of this dissertation provide insight into the potential of street sweeping as a practice for addressing quantifiable WLAs. Due to challenges with quantifying impacts to water quality from street sweeping with long-term water quality monitoring in receiving waters, the research presented in this dissertation sought to answer the following research questions:

- Can relatively easily obtained measures of swept material be defensibly translatable to POC reductions towards WLAs at regulated MS4 outfalls?
- Can street sweeping provide an appreciable amount of POC reductions towards achieving WLAs?

The following sections provide: (1) a summary discussion of the major findings of each chapter; (2) a discussion regarding the broader impact of the findings; and (3) recommendations for future work towards refining quantification of pollutant reductions achieved with street sweeping for regulatory compliance.

5.1 Objectives and Results

Objective 1 was conducted to summarize the abundance of information available from past street sweeping studies in context of potential towards achieving TMDL WLAs. Findings demonstrate the importance to incorporate source controls, such as street sweeping, towards achieving WLAs. Source controls appear necessary since TMDL WLAs apply to loading reductions at a watershed scale, resulting in significant reductions that may not be achievable by structural BMPs, alone. This is due to the relatively small contributing drainage area to structural BMPs and limited opportunity in urban areas. Although the potential of structural controls to achieve pollutant reductions has been recognized, it is difficult to quantify reduction of pollutants to receiving waters. Early studies concluded that the impact to water quality resulting from street sweeping was minimal; however these conclusions have been questioned due to experimental designs, limited samples, sampling techniques, and advancements in sweeper technology. Several more recent well-controlled studies within relatively small drainage areas have demonstrated the potential for significant pollutant reductions to be achieved with street sweeping. However, due to variables associated with stormwater runoff, quantification of reductions achieved by source controls at the larger watershed scale may not be obtainable. The inability to quantify reductions from source controls with direct measure in receiving streams inhibits an MS4s ability to apply reductions from source controls to numerical reductions necessary to achieve WLAs.

Past studies consistently find streets to contain an abundance of pollutants. In MS4 urbanized areas subject to TMDL WLAs, streets are often directly connected to storm sewers, and ultimately outfalls to receiving streams. Transportation related cover directly connected to the storm sewer can also make up a significant fraction of the impervious cover in urbanized areas. A significant fraction of material on the street surface is susceptible to downstream transport during runoff events, as evidenced by the particle size distribution of street material. Pollutants are also mostly associated with the smaller particles susceptible to runoff, likely due to increased surface area. The available pollutant loading on the street surface can vary widely based on surface type, adjacent area, slope, and other variables. Loadings on the street surface are defined to have an initial loading that increases with accumulation for the first couple of days since rainfall (or sweeping), then generally leveling out after a couple of days of accumulation.

Due to the inability to quantify pollutant reductions in the receiving waters, results from modeling applications are being used as guidance for MS4s. Modeling functions widely used for street loadings and washoff of those loadings are foundationally based on the early street sweeping studies. However, later studies have questioned the reliability of these build-up and wash-off functions for assessing street sweeping. Specifically, the loading functions need to be based on direct measurements, which is challenging. Results from wash-off functions have found to far exceed observed quantities. These concerns, in addition to the inability to calibrate models to quantify reductions from sweeping, may result in unacceptable uncertainty considering the costs associated with addressing WLAs. Quantifying reductions from sweeping towards achieving WLAs is further complicated since modeling efforts to develop TMDL WLAs often do not include a transportation land use category, instead aggregating this land cover within urban land use.

MS4s have applied alternative methods to quantify pollutant reductions resulting from street sweeping for NPDES compliance reporting. Most common and notable of these methods involves the measure of the material collected. Quantification of reductions vary, with some assuming the entirety of the collected material is equivalent to the sediment ultimately discharged to surface waters. Others translate swept material to pollutant reductions based on the concentration found in either samples of street materials or the material collected from sweeping, with concentrations varying. Current acceptance of methods on swept material may not remain acceptable to regulatory agencies as evident with a recent expert panel recommendation to the Chesapeake Bay Program to phase out this method in existing guidance documentation in favor of modeled pollutant removal efficiencies. In summary, there is a need for new studies to identify defensible methods for quantifying reductions from street sweeping for NPDES compliance.

Objective 2 was achieved with the implementation of a sampling study that collected and analyzed swept material, including documentation of environmental and operational variables. Results find pollutant concentrations in swept material impacted by the duration since the previous runoff event. Particles < 841 µm were less prevalent in swept material when sweeping occurred within 2 days since rainfall, suggesting these particles are susceptible to downstream transport and, therefore, TMDL loadings. This result is consistent with the range of particle sizes found to be washed from the street surface in previous studies. Particles < 841 µm can also be present in the water column, contributing to measures of TSS. To a lesser degree, the type of surface swept, whether street or parking lot, also had an impact on TN and TSS, while TP generally remained consistent in material from each surface type. Streets had higher concentrations of TN, likely due to increased vehicle emissions; while particles associated with TSS were more prevalent on parking lots perhaps due to less efficient drainage. The advancement in sweeper technology was also demonstrated with an older sweeper used in the study collecting smaller fraction of finer particles.

Nutrient concentrations were found to increase as the fraction of smaller particles in the swept material increased. TN concentration was consistently associated with the full range of particles < 841 µm that are susceptible to transport in runoff; while TP concentrations appear mostly associated with particles < 250 µm. The associations allowed for predictions of the concentrations associated with the fraction of collected material susceptible to runoff. The reduction in pollutants in swept material when collected within 2 days since rainfall suggests a sweeping program should aim to sweep when at least two days has passed to maximize efficiency.

Context for the potential of street sweeping as a practice towards achieving results from implementation of objective 3 was dependent on generating pollutant loadings and the associated TMDL reductions for sample areas of various land use. In generating loadings, it is found EMC values are readily available for land use type; but limited for specific land cover types. However, application of the limited land cover data to separate transportation loadings finds the transportation cover type to generate a higher fraction of the loadings compared to estimates based on aggregated cover within land use type. This demonstrates the importance of explicit representation of transportation cover loadings in the case of a modeling approach that applies pollutant removal efficiencies to the loadings. Generation of loadings using EMC values, both based on land use and land cover, were compared to loadings resulting based on loading rates provided by the Chesapeake Bay TMDL for use by MS4s. Based on the volume of runoff for the sample year used in the study, the comparison finds resulting EMCs to generate the Chesapeake Bay TMDL loadings for pervious cover to far exceed values to be expected. Annual loadings based on land cover type finds non-rooftop impervious to be the source of the majority of the annual loadings, with rooftop and pervious loadings as relatively inconsequential.

Significant difference in potential loading reductions is estimated whether using modeled removal efficiencies or measures of collected material, with the former suggesting much more modest reductions. Potential loading reductions from sweeping is also impacted by land use, increasing as the fraction of available area for sweeping increases within the total impervious areas. Impact is reflected in the sample areas finding higher potential in residential and institutional areas, while lower potential within land use areas where a significant fraction of impervious is on private property (i.e. parking lots in commercial areas). When land cover is considered in loading computations, potential based on the use of the modeled removal efficiencies increases since applied to higher loading rates. Results find application of the modeled removal efficiencies indicate low potential for sweeping to provide loading reductions in commercial and industrial areas, despite sweeping frequency. With an aggressive twice weekly frequency, the fraction of required annual reductions that can be achieved indicates sweeping has potential for inclusion to achieve an appreciable portion of pollutants, higher with TSS. However, as frequency decreases to every other month, potential impact towards achieving reductions is small.

The method based on the measure of collected material finds equivalent reductions estimated based on the modeled removal efficiencies can be achieved with lower sweeping frequency, dependent on land use. The total required reductions could be achieved with a frequency of quarterly, every 18 days, and weekly for the institutional, residential and industrial, and commercial sample areas, respectively. The frequency would be dependent on the measure of the material collected with each sweeping instance. The example used causes further concern with the modeling application as the material collected in a single instance contained a TSS fraction approaching the annual loading based on the Chesapeake Bay TMDL loading rates. However, the same discrepancy was not observed with nutrients.

In summary, implementation of the objectives answered the research questions, with the results of the sampling study presented in context to past studies finding swept material contains the pollutants of concern. The fraction of swept material susceptible to runoff is identified and assumed to be the fraction ultimately removed from annual pollutant loadings. Application of the results of the sampling study demonstrates that street sweeping has the potential to provide an appreciable amount of pollutant reductions towards achieving WLAs. However, the potential is dependent on the quantification method employed. It is suggested that the methods based on measure of swept material are the most appropriate due to concerns and inconsistencies observed from the modeling application. Alternatively, MS4 operators may abandon an impactful practice due to the requirement of modest modeled removal efficiencies.

5.2 Broader Impact

The recent recommendations of an expert panel commissioned by the Chesapeake Bay Program (Schueler et al. 2016), if adopted, would result in the use of modeled removal efficiencies as the standard practice for quantifying pollutant reductions from street sweeping. The panel's conclusion that a modeling approach was necessary is due to the difficulty, and perhaps inability, to measure impact in receiving streams. However, as described in this dissertation, modeling results to assess street sweeping is suspect and the models cannot be calibrated. The modeled removal efficiencies from the expert panel are modest, even in the case of rigorous sweeping, when compared to reductions quantified from swept material. As a result, street sweeping appears an ineffective option towards achieving impactful loading reductions for MS4 operators. However, this research indicates that street sweeping appears to have the potential to provide significant pollutant reductions.

An abundance of information from early street sweeping studies performed in the 1960s and 1970s provides the foundational understandings of pollutant loadings on the street surface, the wash-off of those pollutants, and impact to water quality. The early findings mostly concluded that street sweeping had little impact on improving water quality. However, this dissertation presents findings from subsequent studies indicating that the conclusions of the early studies must be revisited. The results of the sampling study and application of the results to sample areas indicate that street sweeping can have a significant impact on water quality. This primary finding of the research adds to the body of knowledge, providing the foundation for reconsideration of the standard practice that should be used for quantifying pollutant reductions achieved by street sweeping.

Although the primary goal of this research was to assess the potential of street sweeping towards achieving WLAs, secondary findings also add to the body of knowledge regarding the development of TMDLs and an MS4 operator's ability to achieve WLAs. First, the research illustrates inconsistencies with the development of TMDLs that aggregate land cover within land use categories and the ability to assess street sweeping. The aggregation causes concern since loadings from streets are not explicitly represented and therefore reductions cannot be consistently assessed. This illustration supports the need to generate TMDL model loadings based on land cover, as opposed to land use, especially in MS4 jurisdictions and since streets are found to contribute a significant fraction of pollutants. Secondly, the research finds the majority of the annual pollutant loadings to be generated from non-rooftop impervious cover. Depending on land use, the fraction of non-rooftop impervious cover that includes public streets and parking lots available to sweeping varies, impacting the impact of sweeping. As a consequence, the research provides results suggesting that street sweeping can provide significant contributions towards achieving WLAs in residential and institutional areas. Conversely, significant loadings in commercial and industrial areas are generated from non-rooftop impervious areas unavailable for public sweeping. This finding demonstrates the challenges to MS4s within these areas to achieve reductions towards WLAs since reductions to loadings in these areas are unavailable via sweeping. Finally, a comparison of loading scenarios finds EMC values that would generate the loading rates for pervious cover are excessive and not consistent with available information. This secondary finding, in addition to the illustrated importance of modeling loadings by land cover instead of land use, has the potential to provide cause for reconsideration in the loading rates for pervious cover assigned to MS4s throughout the Chesapeake Bay watershed.

5.3 Future Work

The literature review identifies the insufficient information available for quantifying pollutant reductions achieved by street sweeping based on measures in the receiving waters. As a result, it is widely recognized that additional studies are needed; but also recognized that the measures may not be obtainable. However, several small-scale and well-controlled recent studies have provided insight into the potential of street sweeping to provide pollutant reductions. It is suggested that additional small-scale and well-controlled studies can add to the body of knowledge towards better characterizing the impact from street sweeping.

Results of the sampling study in this research identified the fraction of swept material susceptible to runoff, suggesting that fraction is applicable to quantification of pollutant reductions. The results also identified the association of nutrient concentrations within that fraction of material. However, since this information was unknown at the onset of the sampling, measured nutrient concentrations were from the total sample, requiring extrapolation to estimate the concentrations associated with the fraction of material susceptible to runoff. Based on these findings, it is suggested that future studies that analyze nutrient concentration, first separate the fraction of the sample associated with each nutrient and susceptible to runoff, being those particles < 841 µm for TN and < 250 µm for TP. This revised laboratory sampling is now being employed by several of the MS4s that participated in the sampling study. Results from the refined analysis can be used to refine the nutrient concentration values presented in Chapter 3.

Future studies are suggested to assess the impact of developing TMDL pollutant loadings based on land cover, as opposed to land use. This would also necessitate the need for studies that provide EMC values for various land cover types within urbanized areas, at a minimum considering non-rooftop impervious, rooftop, and pervious covers. Based on findings in Chapter 3, it may also be desirable to separate streets and parking lots from non-rooftop impervious cover. Finally, future study is also suggested to investigate the Chesapeake Bay TMDL loading rates for impervious cover, described in Chapter 4. Specifically, EMC values that would generate the loading rates are much higher than those that would be expected from pervious cover based on the annual runoff from pervious cover observed in this research for the sample year. As accomplished by the research described in this dissertation, the suggested future studies can continue to add to the body of knowledge regarding the impact of street sweeping on water quality; perhaps also challenging the conclusions of early studies and further refining obtainable measure to quantify reductions and variables that impact efficiency.

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Appendix A: Example of Street Sweeping Sampling Form

Sweeping Data Collection Form

Instruction: This form shall be completed each time street sweeping operations are performed. The purpose of the data collected on this form is to assist with quantifying pollutant reductions for stormwater permit compliance.

Section 1: General Information	
Sweeper Operator:	**Date:**
Model and Type of Sweeper:	
Estimated % of hopper capacity filled *(start)*:	
Purpose for sweeping activity:	
Work Order # *(if applicable)*:	**Odometer *(start)*:**
***Type of areas swept** *(check **all** that apply)* ☐ Street *with sidewalk* ☐ Street with adjacent tree canopy ☐ Street *with* curb (no street parking) ☐ Street *no* curb (no street parking) ☐ All Parking Lot (no/few cars) ☐ Street *with* curb (street parking) ☐ Street *no* curb (street parking) ☐ Parking Lot, aisles only ☐ Other ______________________________	
Sweeper setting: ☐ Standard vacuum** ***(Take Sample)*** ☐ Leaves (No sample) ☐ Millings (No sample)	
Name/Description of area swept *(attach mapping if necessary)*	
Section 2: Weather Conditions *(check all that apply)*	
☐ Sunny ☐ Cloudy ☐ Partly Cloudy ☐ Cold ☐ Mild ☐ Hot ☐ Raining ☐ Recent rain (within 24 hrs)	
Section 3: Swept Surface Conditions *(check all that apply)*	
☐ Wet ☐ Dry ☐ Snow ☐ Salt/Sand ☐ Few Leaves ☐ Many Leaves ☐ Excessive Trash ☐ Other ______________________________	
Description of any special conditions *(i.e., salt/sand on surface from snow event)*:	
Section 4: Material Collection	
Estimated % of hopper capacity filled *(end)*:	**Odometer *(end)*:**
Description of material in hopper: ☐ Consistent throughout	☐ Non-consistent throughout (i.e., mingled trash)
Section 5: Sample Collection	
**** 2 samples collected:** ☐ Yes ☐ No	***** Sample ID # (AREA_MMDDYY_#):**

* Street parking refers to cars blocking sweeping of curb and gutter

** Material collection per protocol on back of form (two sample collections for each sample = (1) gallon bag & (1) 9 ounce jar).

*** Sample ID is the area, date, and sample # for that day (i.e. A4_031516_1P for a sample from Area 4_ March 15, 2016_ Sample #1)

Sweeping Data Collection Form

Swept Material Sampling Protocol

Please follow the sampling protocol, where applicable. Generally, sampling of typical street sweeping materials is desired (i.e., samples are not necessary for hopper loads predominantly consisting of leaves or millings. Otherwise, collect samples as described below.

1. When indicated in Section 1, collect the following samples from materials from the hopper immediately after completion of the sweeping operation:

   A. **Bag Sample:** Fill (1) gallon zip lock bag with material representative of the overall load (i.e. a mixed sample). Avoid large objects such as limbs and rocks. After filling the bag, ensure the bag is completely sealed (airtight). It is recommended to double bag to protect the sample.

   B. **Jar Sample:** Fill (1) 9-ounce jar with a sample appearing similar to the representative materials as collected in the zip lock bag. Tightly cap the jar once filled.

2. Label each sample as follows:

   A. **Bag Sample:** With a Sharpie, record the **Sample ID # (from Section 5 of the Form)**, **and time** directly onto the label section of the gallon sized zip lock bag.

   B. **Jar Sample:** Record the same **Sample ID # (from Section 5 of the Form)**, **and time** on the provided "Air, Water and Soil" label and place it on the jar. Print your name and sign the Air, Water and Soil Chain of Custody in "Sampler Name and Sampler Signature" boxes.

3. Place ONLY the jar sample in cooler on ice or refrigerate.

4. Please review the completeness of the form, with special attention to the description of the area swept. Provide as thorough of a description as possible.

5. Provide the following to Rebecca Parkhill within 2 business days for shipping:

- Labeled bag sample(s)
- Labeled jar sample(s)
- Completed form(s)

6. Shipping:

- Ship the labeled double bagged 1-gallon zip lock bag with the Schnabel form in a shipping box to:

  Schnabel Engineering
  1901 South Main Street, Suite 11
  Blacksburg, VA 24060
  Ph. 540-953-1239

- Ship the labeled jar in a zip lock bag with ice and a AW&SL Chain of Custody form in a shipping box to:

  Air Water & Soil Laboratories, Inc.
  1941 Reymet Road
  Richmond, VA 23237
  Ph. (804) 358-8295

7. Documentation: Maintain copy the Data Collection Form for evaluation with analysis results.

Appendix B: Summary of Relevant Sampling Data

Appendix B: Summary of Relevant Sampling Data

MS4	**Date**	**TN (mg/kg)**	**TP (mg/kg)**	**Moisture (%)**	**< 250 µm**	**250 - 420 µm**	**420 - 841 µm**	**841 - 2,000 µm**	**> 2,000 µm**	**Duration Since Rain (days)**	**Surface Type [1]**	**Season [2]**
VT	12/18/15-1	70.5	11.5	8.7%	0.04	0.04	0.07	0.11	0.74	0.1	St	Wi
VT	12/18/15-2	65.2	4.2	5.7%	0.03	0.01	0.04	0.19	0.74	0.1	PL	Wi
VT	4/14/16-1	383	22.7	2.6%	0.08	0.05	0.12	0.31	0.44	5.0	St	Sp
VT	4/15/16-1	257	41.2	5.2%	0.11	0.03	0.09	0.29	0.49	6.0	St	Sp
VT	5/12/16-1A	184	9.1	1.3%	0.15	0.09	0.17	0.26	0.34	0.4	St	Sp
VT	5/13/16-2	415	9.3	15.7%	0.12	0.08	0.15	0.27	0.39	0.5	St	Sp
Salem	2/22/17	188	40.9	N/A	N/A	N/A	N/A	N/A	N/A	6.0	St	Wi
Salem	2/24/17	257	65.1	N/A	0.13	0.07	0.10	0.23	0.47	1.5	St	Wi
Salem	3/1/17	80.8	16.3	N/A	0.02	0.02	0.08	0.43	0.45	0.3	St	Wi
Salem	3/3/17	791	40.4	N/A	0.17	0.23	0.33	0.22	0.04	1.0	St	Wi
Salem	3/8/17	241	48.7	5.0%	0.21	0.15	0.22	0.31	0.11	5.0	St	Wi
Salem	3/10/17	230	38	4.8%	0.11	0.06	0.17	0.43	0.23	2.3	St	Wi
Salem	3/15/17	1350	103	12.2%	0.36	0.18	0.25	0.19	0.03	0.8	St	Wi
Salem	3/17/17	397	57.7	2.8%	0.24	0.28	0.32	0.14	0.03	2.8	St	Wi
Salem	3/22/17	242	44.4	10.5%	0.48	0.12	0.17	0.17	0.06	4.0	St	Wi
Salem	3/24/17	306	58.7	4.8%	0.49	0.15	0.19	0.14	0.03	6.0	St	Wi
Salem	3/28/17	394	28.6	6.4%	0.21	0.08	0.17	0.34	0.20	7.0	St	Wi
Salem	4/5/17	235	16.2	N/A	N/A	N/A	N/A	N/A	N/A	0.8	St	Sp
Salem	4/12/17	251	47.9	N/A	N/A	N/A	N/A	N/A	N/A	5.3	St	Sp
Salem	4/14/17	155	82.9	N/A	N/A	N/A	N/A	N/A	N/A	7.3	Mix	Sp
Salem	4/19/17	210	126	N/A	N/A	N/A	N/A	N/A	N/A	12.1	Mix	Sp
Salem	4/26/17	841	36.3	N/A	N/A	N/A	N/A	N/A	N/A	0.8	St	Sp
Salem	4/28/17	86.5	48.1	N/A	N/A	N/A	N/A	N/A	N/A	3.0	St	Sp
Salem	6/8/17	110	11.8	5.4%	0.61	0.13	0.05	0.19	0.03	2.0	St	Su
Salem	6/14/17	375	46.8	0.7%	0.24	0.08	0.15	0.28	0.25	8.0	St	Su
Salem	6/16/17	454	18	10.6%	0.18	0.06	0.09	0.21	0.46	0.3	Mix	Su

Appendix B: Summary of Relevant Sampling Data

MS4	Date	TN (mg/kg)	TP (mg/kg)	Moisture (%)	< 250 µm	250 - 420 µm	420 - 841 µm	841 - 2,000 µm	> 2,000 µm	Duration Since Rain (days)	Surface Type [1]	Season [2]
Salem	6/21/17	300	6.8	2.3%	0.12	0.07	0.13	0.26	0.43	1.6	St	Su
Salem	6/26/17	878	75.4	0.9%	0.08	0.08	0.17	0.32	0.36	2.5	St	Su
Salem	6/28/17	481	30.8	0.3%	0.06	0.05	0.11	0.26	0.53	4.5	St	Su
Salem	6/29/17	448	60.8	2.1%	0.28	0.10	0.18	0.26	0.18	5.5	St	Su
GCC	9/23/16	52.8	10.2	1.2%	0.03	0.04	0.08	0.19	0.65	1.5	PL	Su
GCC	10/14/16	332	14.1	0.8%	0.15	0.26	0.37	0.18	0.05	4.9	PL	Fa
GCC	11/14/16	293	258	19.0%	0.42	0.10	0.10	0.07	0.31	4.8	PL	Wi
GCC	11/18/16	508	10.8	25.4%	0.37	0.20	0.19	0.10	0.14	3.2	PL	Wi
GCC	12/2/16	419	258	5.1%	0.10	0.12	0.15	0.14	0.49	1.3	PL	Wi
GCC	4/14/17	15	9.3	0.2%	0.04	0.05	0.15	0.40	0.36	7.0	PL	Sp
GCC	4/21/17	168	5.8	N/A	N/A	N/A	N/A	N/A	N/A	0.5	PL	Sp
GCC	4/28/17	248	41.6	N/A	N/A	N/A	N/A	N/A	N/A	3.0	PL	Sp
JTCC-M	6/25/16-1	22.5	24.6	4.5%	0.14	0.05	0.08	0.15	0.59	0.5	PL	Su
JTCC-M	6/25/16-2	56.1	5.7	2.4%	0.09	0.05	0.13	0.28	0.46	0.5	PL	Su
JTCC-C	6/26/16-1	105	2.9	4.8%	0.15	0.14	0.27	0.25	0.20	1.0	PL	Su
JTCC-C	6/26/16-2	115	12.3	1.9%	0.31	0.21	0.17	0.10	0.21	1.0	PL	Su
NVCC-An	5/14/16	396	14.4	0.8%	0.16	0.13	0.20	0.28	0.23	0.8	PL	Sp
NVCC-Lo	5/17/16	157	6.4	0.4%	0.09	0.15	0.26	0.32	0.19	0.3	PL	Sp
NVCC-Lo	6/7/16	237	58.8	0.6%	0.19	0.15	0.23	0.25	0.17	1.9	PL	Su
NVCC-An	6/3/16	169	62.1	3.4%	0.29	0.17	0.22	0.22	0.10	4.4	PL	Su
NVCC-Lo	6/22/16	18.8	21.5	10.8%	0.18	0.16	0.27	0.27	0.13	0.5	PL	Su
NVCC-An	6/22/16	142	4.2	0.3%	0.13	0.15	0.26	0.28	0.19	0.5	St	Su
NVCC-Lo	7/12/16	65.9	6.1	0.2%	0.05	0.06	0.13	0.29	0.47	5.0	PL	Su
NVCC-An	7/11/16	444	36	0.3%	0.04	0.06	0.16	0.32	0.43	6.0	PL	Su
NVCC-An	8/8/16	274	0.6	1.2%	0.45	0.12	0.16	0.17	0.10	8.4	PL	Su
NVCC-Lo	9/1/16	72.7	58.9	0.5%	0.14	0.12	0.24	0.31	0.20	10.0	Mix	Su
NVCC-An	8/31/16	147	49.1	0.3%	0.28	0.20	0.25	0.22	0.06	9.3	PL	Su

Appendix B: Summary of Relevant Sampling Data

MS4	**Date**	**TN (mg/kg)**	**TP (mg/kg)**	**Moisture (%)**	**< 250 µm**	**250 - 420 µm**	**420 - 841 µm**	**841 - 2,000 µm**	**> 2,000 µm**	**Duration Since Rain (days)**	**Surface Type [1]**	**Season [2]**
NVCC-An	9/19/16	61.3	62.9	1.1%	0.26	0.21	0.24	0.20	0.09	11.4	PL	Su
NVCC-Lo	9/20/16-1	73.2	15.1	0.3%	0.03	0.05	0.19	0.44	0.30	14.0	St	Su
NVCC-Lo	10/26/16-2	236	30.2	0.9%	0.20	0.16	0.23	0.24	0.17	5.3	Mix	Fa
NVCC-An	10/26/2016	66.4	11.8	0.6%	0.27	0.20	0.25	0.22	0.07	4.4	Mix	Fa
NVCC-Lo	8/4/2016	98	18.4	N/A	N/A	N/A	N/A	N/A	N/A	6.0	Mix	Su
PVCC	4/30/18	535	316	1.5%	0.24	0.07	0.12	0.22	0.35	3.5	Mix	Sp

[1] Surface type swept: St = street; PL = Parking Lot

[2] Season sweeping sample was collected: Wi = winter, Sp = spring; Su = summer; Fa = fall

Appendix C: Data Summary for LU Pollutant Loadings for Sample Areas

Note – Adjusted EMC values for the LC scenario are provided in Chapter 4.

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Jan.	1	201.15	76.9	39.3	85.0	98.0	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	8	201.15	76.9	39.3	85.0	98.0	0.03	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.03	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	12	201.15	76.9	39.3	85.0	98.0	0.3	0.15	49	1.71	0.21	105,880	323.9	11.3	1.4
		291.43				70.3	0.3	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	17	201.15	76.9	39.3	85.0	98.0	0.76	0.56	49	1.71	0.21	409,056	1251.3	43.7	5.4
		291.43				70.3	0.76	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	20	201.15	76.9	39.3	85.0	98.0	0.09	0.01	49	1.71	0.21	6,974	21.3	0.7	0.1
		291.43				70.3	0.09	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	21	201.15	76.9	39.3	85.0	98.0	0.56	0.37	49	1.71	0.21	272,129	832.4	29.1	3.6
		291.43				70.3	0.56	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	22	201.15	76.9	39.3	85.0	98.0	0.1	0.01	49	1.71	0.21	9,715	29.7	1.0	0.1
		291.43				70.3	0.1	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	25	201.15	76.9	39.3	85.0	98.0	0.74	0.54	49	1.71	0.21	395,182	1208.8	42.2	5.2
		291.43				70.3	0.74	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Jan	30	201.15	76.9	39.3	85.0	98.0	0.25	0.11	49	1.71	0.21	77,314	236.5	8.3	1.0
		291.43				70.3	0.25	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Feb	2	201.15	76.9	39.3	85.0	98.0	0.02	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Feb	3	201.15	76.9	39.3	85.0	98.0	0.17	0.05	49	1.71	0.21	36,564	111.8	3.9	0.5
		291.43				70.3	0.17	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Feb	5	201.15	76.9	39.3	85.0	98.0	1.25	1.03	49	1.71	0.21	755,424	2310.8	80.6	9.9
		291.43				70.3	1.25	0.04	49	1.71	0.21	37,594	115.0	4.0	0.5
Feb	6	201.15	76.9	39.3	85.0	98.0	1.77	1.55	49	1.71	0.21	1,129,329	3454.6	120.6	14.8
		291.43				70.3	1.77	0.17	49	1.71	0.21	176,034	538.5	18.8	2.3

Daily LU Scenario Loadings - Residential

Date		**Area (acres)**				**CN_W**	**P (in)**	**Q (in)**	**EMC (mg/L)**			**Runoff (ft^3)**	**Loading (lbs)**		
		Total Area [1]	**Road**	**Other Imp [2]**	**Roof**				**TSS**	**TN**	**TP**		**TSS**	**TN**	**TP**
Feb	9	201.15	76.9	39.3	85.0	98.0	0.46	0.28	49	1.71	0.21	205,857	629.7	22.0	2.7
		291.43				70.3	0.46	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Feb	22	201.15	76.9	39.3	85.0	98.0	0.15	0.04	49	1.71	0.21	27,786	85.0	3.0	0.4
		291.43				70.3	0.15	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Feb	24	201.15	76.9	39.3	85.0	98.0	0.25	0.11	49	1.71	0.21	77,314	236.5	8.3	1.0
		291.43				70.3	0.25	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Feb	25	201.15	76.9	39.3	85.0	98.0	0.07	0.00	49	1.71	0.21	2,666	8.2	0.3	0.0
		291.43				70.3	0.07	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Mar.	2	201.15	76.9	39.3	85.0	98.0	0.64	0.45	61	2.26	0.32	326,355	1242.8	46.0	6.5
		291.43				70.3	0.64	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	3	201.15	76.9	39.3	85.0	98.0	0.95	0.74	61	2.26	0.32	542,168	2064.6	76.5	10.8
		291.43				70.3	0.95	0.00	61	2.26	0.32	2,722	10.4	0.4	0.1
Mar.	11	201.15	76.9	39.3	85.0	98.0	0.08	0.01	61	2.26	0.32	4,609	17.5	0.7	0.1
		291.43				70.3	0.08	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	12	201.15	76.9	39.3	85.0	98.0	0.57	0.38	61	2.26	0.32	278,857	1061.9	39.3	5.6
		291.43				70.3	0.57	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	13	201.15	76.9	39.3	85.0	98.0	0.02	0.00	61	2.26	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	14	201.15	76.9	39.3	85.0	98.0	0.03	0.00	61	2.26	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.03	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	15	201.15	76.9	39.3	85.0	98.0	0.1	0.01	61	2.26	0.32	9,715	37.0	1.4	0.2
		291.43				70.3	0.1	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	22	201.15	76.9	39.3	85.0	98.0	0.06	0.00	61	2.26	0.32	1,204	4.6	0.2	0.0
		291.43				70.3	0.06	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	26	201.15	76.9	39.3	85.0	98.0	0.3	0.15	61	2.26	0.32	105,880	403.2	14.9	2.1
		291.43				70.3	0.3	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Mar.	29	201.15	76.9	39.3	85.0	98.0	2.21	1.98	61	2.26	0.32	1,447,692	5513.0	204.3	28.9
		291.43				70.3	2.21	0.33	61	2.26	0.32	353,019	1344.3	49.8	7.1

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Mar.	30	201.15	76.9	39.3	85.0	98.0	0.09	0.01	61	2.26	0.32	6,974	26.6	1.0	0.1
		291.43				70.3	0.09	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	9	201.15	76.9	39.3	85.0	98.0	0.35	0.19	61	2.26	0.32	135,994	517.9	19.2	2.7
		291.43				70.3	0.35	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	13	201.15	76.9	39.3	85.0	98.0	0.04	0.00	61	2.26	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.04	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	21	201.15	76.9	39.3	85.0	98.0	0.05	0.00	61	2.26	0.32	289	1.1	0.0	0.0
		291.43				70.3	0.05	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	24	201.15	76.9	39.3	85.0	98.0	0.02	0.00	61	2.26	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	25	201.15	76.9	39.3	85.0	98.0	0.18	0.06	61	2.26	0.32	41,208	156.9	5.8	0.8
		291.43				70.3	0.18	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	26	201.15	76.9	39.3	85.0	98.0	0.75	0.55	61	2.26	0.32	402,115	1531.3	56.7	8.0
		291.43				70.3	0.75	0.00	61	2.26	0.32	0	0.0	0.0	0.0
Apr	27	201.15	76.9	39.3	85.0	98.0	0.11	0.02	61	2.26	0.32	12,789	48.7	1.8	0.3
		291.43				70.3	0.11	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	12	201.15	76.9	39.3	85.0	98.0	0.06	0.00	61	2.26	0.32	1,204	4.6	0.2	0.0
		291.43				70.3	0.06	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	13	201.15	76.9	39.3	85.0	98.0	0.13	0.03	61	2.26	0.32	19,803	75.4	2.8	0.4
		291.43				70.3	0.13	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	14	201.15	76.9	39.3	85.0	98.0	0.03	0.00	61	2.26	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.03	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	15	201.15	76.9	39.3	85.0	98.0	0.01	0.00	61	2.26	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	16	201.15	76.9	39.3	85.0	98.0	0.23	0.09	61	2.26	0.32	66,453	253.1	9.4	1.3
		291.43				70.3	0.23	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	17	201.15	76.9	39.3	85.0	98.0	1.09	0.88	61	2.26	0.32	641,342	2442.3	90.5	12.8
		291.43				70.3	1.09	0.01	61	2.26	0.32	14,275	54.4	2.0	0.3

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
May	18	201.15	76.9	39.3	85.0	98.0	0.96	0.75	61	2.26	0.32	549,227	2091.5	77.5	11.0
		291.43				70.3	0.96	0.00	61	2.26	0.32	3,255	12.4	0.5	0.1
May	28	201.15	76.9	39.3	85.0	98.0	0.05	0.00	61	2.26	0.32	289	1.1	0.0	0.0
		291.43				70.3	0.05	0.00	61	2.26	0.32	0	0.0	0.0	0.0
May	30	201.15	76.9	39.3	85.0	98.0	0.31	0.15	61	2.26	0.32	111,795	425.7	15.8	2.2
		291.43				70.3	0.31	0.00	61	2.26	0.32	0	0.0	0.0	0.0
June	1	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	6	201.15	76.9	39.3	85.0	98.0	0.18	0.06	52	2.17	0.32	41,208	133.8	5.6	0.8
		291.43				70.3	0.18	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	9	201.15	76.9	39.3	85.0	98.0	0.23	0.09	52	2.17	0.32	66,453	215.7	9.0	1.3
		291.43				70.3	0.23	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	13	201.15	76.9	39.3	85.0	98.0	0.47	0.29	52	2.17	0.32	212,388	689.5	28.8	4.2
		291.43				70.3	0.47	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	14	201.15	76.9	39.3	85.0	98.0	0.09	0.01	52	2.17	0.32	6,974	22.6	0.9	0.1
		291.43				70.3	0.09	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	16	201.15	76.9	39.3	85.0	98.0	0.84	0.64	52	2.17	0.32	464,844	1509.0	63.0	9.3
		291.43				70.3	0.84	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	20	201.15	76.9	39.3	85.0	98.0	0.42	0.25	52	2.17	0.32	179,996	584.3	24.4	3.6
		291.43				70.3	0.42	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	22	201.15	76.9	39.3	85.0	98.0	0.02	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	23	201.15	76.9	39.3	85.0	98.0	0.05	0.00	52	2.17	0.32	289	0.9	0.0	0.0
		291.43				70.3	0.05	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	24	201.15	76.9	39.3	85.0	98.0	0.25	0.11	52	2.17	0.32	77,314	251.0	10.5	1.5
		291.43				70.3	0.25	0.00	52	2.17	0.32	0	0.0	0.0	0.0
June	25	201.15	76.9	39.3	85.0	98.0	0.1	0.01	52	2.17	0.32	9,715	31.5	1.3	0.2
		291.43				70.3	0.1	0.00	52	2.17	0.32	0	0.0	0.0	0.0

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
June	29	201.15	76.9	39.3	85.0	98.0	1.06	0.85	52	2.17	0.32	620,032	2012.8	84.0	12.4
		291.43				70.3	1.06	0.01	52	2.17	0.32	11,074	35.9	1.5	0.2
June	30	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	10	201.15	76.9	39.3	85.0	98.0	0.67	0.48	52	2.17	0.32	346,898	1126.1	47.0	6.9
		291.43				70.3	0.67	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	13	201.15	76.9	39.3	85.0	98.0	0.05	0.00	52	2.17	0.32	289	0.9	0.0	0.0
		291.43				70.3	0.05	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	14	201.15	76.9	39.3	85.0	98.0	0.13	0.03	52	2.17	0.32	19,803	64.3	2.7	0.4
		291.43				70.3	0.13	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	17	201.15	76.9	39.3	85.0	98.0	0.02	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	19	201.15	76.9	39.3	85.0	98.0	0.89	0.68	52	2.17	0.32	499,914	1622.8	67.7	10.0
		291.43				70.3	0.89	0.00	52	2.17	0.32	514	1.7	0.1	0.0
July	20	201.15	76.9	39.3	85.0	98.0	0.54	0.35	52	2.17	0.32	258,721	839.9	35.0	5.2
		291.43				70.3	0.54	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	25	201.15	76.9	39.3	85.0	98.0	0.06	0.00	52	2.17	0.32	1,204	3.9	0.2	0.0
		291.43				70.3	0.06	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	27	201.15	76.9	39.3	85.0	98.0	0.54	0.35	52	2.17	0.32	258,721	839.9	35.0	5.2
		291.43				70.3	0.54	0.00	52	2.17	0.32	0	0.0	0.0	0.0
July	29	201.15	76.9	39.3	85.0	98.0	3.58	3.35	52	2.17	0.32	2,443,348	7931.7	331.0	48.8
		291.43				70.3	3.58	1.08	52	2.17	0.32	1,137,750	3693.4	154.1	22.7
Aug	1	201.15	76.9	39.3	85.0	98.0	0.44	0.26	52	2.17	0.32	192,871	626.1	26.1	3.9
		291.43				70.3	0.44	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	2	201.15	76.9	39.3	85.0	98.0	0.13	0.03	52	2.17	0.32	19,803	64.3	2.7	0.4
		291.43				70.3	0.13	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	4	201.15	76.9	39.3	85.0	98.0	0.03	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.03	0.00	52	2.17	0.32	0	0.0	0.0	0.0

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Aug	5	201.15	76.9	39.3	85.0	98.0	1.01	0.80	52	2.17	0.32	584,582	1897.7	79.2	11.7
		291.43				70.3	1.01	0.01	52	2.17	0.32	6,606	21.4	0.9	0.1
Aug	8	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	9	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	12	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	13	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	18	201.15	76.9	39.3	85.0	98.0	1.44	1.22	52	2.17	0.32	891,608	2894.4	120.8	17.8
		291.43				70.3	1.44	0.07	52	2.17	0.32	77,875	252.8	10.5	1.6
Aug	19	201.15	76.9	39.3	85.0	98.0	0.24	0.10	52	2.17	0.32	71,837	233.2	9.7	1.4
		291.43				70.3	0.24	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	21	201.15	76.9	39.3	85.0	98.0	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	22	201.15	76.9	39.3	85.0	98.0	0.74	0.54	52	2.17	0.32	395,182	1282.9	53.5	7.9
		291.43				70.3	0.74	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Aug	27	201.15	76.9	39.3	85.0	98.0	0.05	0.00	52	2.17	0.32	289	0.9	0.0	0.0
		291.43				70.3	0.05	0.00	52	2.17	0.32	0	0.0	0.0	0.0
Sept	3	201.15	76.9	39.3	85.0	98.0	0.9	0.69	33	1.75	0.29	506,944	1044.4	55.4	9.2
		291.43				70.3	0.9	0.00	33	1.75	0.29	763	1.6	0.1	0.0
Sept	12	201.15	76.9	39.3	85.0	98.0	0.35	0.19	33	1.75	0.29	135,994	280.2	14.9	2.5
		291.43				70.3	0.35	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Sept	26	201.15	76.9	39.3	85.0	98.0	0.1	0.01	33	1.75	0.29	9,715	20.0	1.1	0.2
		291.43				70.3	0.1	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Sept	27	201.15	76.9	39.3	85.0	98.0	2.11	1.88	33	1.75	0.29	1,375,237	2833.2	150.2	24.9
		291.43				70.3	2.11	0.29	33	1.75	0.29	308,733	636.0	33.7	5.6

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Sept	28	201.15	76.9	39.3	85.0	98.0	0.07	0.00	33	1.75	0.29	2,666	5.5	0.3	0.0
		291.43				70.3	0.07	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Sept	29	201.15	76.9	39.3	85.0	98.0	0.57	0.38	33	1.75	0.29	278,857	574.5	30.5	5.0
		291.43				70.3	0.57	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Sept	30	201.15	76.9	39.3	85.0	98.0	3.57	3.34	33	1.75	0.29	2,436,068	5018.6	266.1	44.1
		291.43				70.3	3.57	1.07	33	1.75	0.29	1,131,072	2330.1	123.6	20.5
Oct	1	201.15	76.9	39.3	85.0	98.0	0.11	0.02	33	1.75	0.29	12,789	26.3	1.4	0.2
		291.43				70.3	0.11	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	3	201.15	76.9	39.3	85.0	98.0	1.16	0.95	33	1.75	0.29	691,171	1423.9	75.5	12.5
		291.43				70.3	1.16	0.02	33	1.75	0.29	23,210	47.8	2.5	0.4
Oct	4	201.15	76.9	39.3	85.0	98.0	0.11	0.02	33	1.75	0.29	12,789	26.3	1.4	0.2
		291.43				70.3	0.11	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	6	201.15	76.9	39.3	85.0	98.0	0.01	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	14	201.15	76.9	39.3	85.0	98.0	0.58	0.39	33	1.75	0.29	285,601	588.4	31.2	5.2
		291.43				70.3	0.58	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	15	201.15	76.9	39.3	85.0	98.0	0.02	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	25	201.15	76.9	39.3	85.0	98.0	0.03	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.03	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	26	201.15	76.9	39.3	85.0	98.0	0.17	0.05	33	1.75	0.29	36,564	75.3	4.0	0.7
		291.43				70.3	0.17	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Oct	28	201.15	76.9	39.3	85.0	98.0	0.14	0.03	33	1.75	0.29	23,686	48.8	2.6	0.4
		291.43				70.3	0.14	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Nov	3	201.15	76.9	39.3	85.0	98.0	0.02	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Nov	4	201.15	76.9	39.3	85.0	98.0	0.33	0.17	33	1.75	0.29	123,793	255.0	13.5	2.2
		291.43				70.3	0.33	0.00	33	1.75	0.29	0	0.0	0.0	0.0

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Nov	5	201.15	76.9	39.3	85.0	98.0	0.1	0.01	33	1.75	0.29	9,715	20.0	1.1	0.2
		291.43				70.3	0.1	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Nov	16	201.15	76.9	39.3	85.0	98.0	0.04	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.04	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Nov	17	201.15	76.9	39.3	85.0	98.0	0.01	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Nov	22	201.15	76.9	39.3	85.0	98.0	0.01	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Nov	26	201.15	76.9	39.3	85.0	98.0	0.03	0.00	33	1.75	0.29	0	0.0	0.0	0.0
		291.43				70.3	0.03	0.00	33	1.75	0.29	0	0.0	0.0	0.0
Dec	1	201.15	76.9	39.3	85.0	98.0	0.33	0.17	49	1.71	0.21	123,793	378.7	13.2	1.6
		291.43				70.3	0.33	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	3	201.15	76.9	39.3	85.0	98.0	0.02	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.02	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	4	201.15	76.9	39.3	85.0	98.0	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	5	201.15	76.9	39.3	85.0	98.0	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	6	201.15	76.9	39.3	85.0	98.0	0.22	0.08	49	1.71	0.21	61,168	187.1	6.5	0.8
		291.43				70.3	0.22	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	11	201.15	76.9	39.3	85.0	98.0	0.4	0.23	49	1.71	0.21	167,244	511.6	17.9	2.2
		291.43				70.3	0.4	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	12	201.15	76.9	39.3	85.0	98.0	0.31	0.15	49	1.71	0.21	111,795	342.0	11.9	1.5
		291.43				70.3	0.31	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	13	201.15	76.9	39.3	85.0	98.0	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	16	201.15	76.9	39.3	85.0	98.0	0.33	0.17	49	1.71	0.21	123,793	378.7	13.2	1.6
		291.43				70.3	0.33	0.00	49	1.71	0.21	0	0.0	0.0	0.0

Daily LU Scenario Loadings - Residential

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Dec	18	201.15	76.9	39.3	85.0	98.0	0.06	0.00	49	1.71	0.21	1,204	3.7	0.1	0.0
		291.43				70.3	0.06	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	19	201.15	76.9	39.3	85.0	98.0	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
		291.43				70.3	0.01	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	25	201.15	76.9	39.3	85.0	98.0	0.12	0.02	49	1.71	0.21	16,162	49.4	1.7	0.2
		291.43				70.3	0.12	0.00	49	1.71	0.21	0	0.0	0.0	0.0
Dec	26	201.15	76.9	39.3	85.0	98.0	0.08	0.01	49	1.71	0.21	4,609	14.1	0.5	0.1
		291.43				70.3	0.08	0.00	49	1.71	0.21	0	0.0	0.0	0.0

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	**Road**	**Other Imp [2]**	**Roof**				**TSS**	**TN**	**TP**		**TSS**	**TN**	**TP**
Jan.	1	574.07	99.94	324.71	149.42	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	8	574.07	99.94	324.71	149.42	98	0.03	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.03	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	12	574.07	99.94	324.71	149.42	98	0.3	0.15	57	1.97	0.21	302,175	1075.26	37.16	3.96
		185.90				69	0.3	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	17	574.07	99.94	324.71	149.42	98	0.76	0.56	57	1.97	0.21	1,167,418	4154.13	143.57	15.30
		185.90				69	0.76	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	20	574.07	99.94	324.71	149.42	98	0.09	0.01	57	1.97	0.21	19,904	70.83	2.45	0.26
		185.90				69	0.09	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	21	574.07	99.94	324.71	149.42	98	0.56	0.37	57	1.97	0.21	776,636	2763.57	95.51	10.18
		185.90				69	0.56	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	22	574.07	99.94	324.71	149.42	98	0.1	0.01	57	1.97	0.21	27,726	98.66	3.41	0.36
		185.90				69	0.1	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	25	574.07	99.94	324.71	149.42	98	0.74	0.54	57	1.97	0.21	1,127,822	4013.23	138.70	14.79
		185.90				69	0.74	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	30	574.07	99.94	324.71	149.42	98	0.25	0.11	57	1.97	0.21	220,648	785.15	27.14	2.89
		185.90				69	0.25	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	2	574.07	99.94	324.71	149.42	98	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	3	574.07	99.94	324.71	149.42	98	0.17	0.05	57	1.97	0.21	104,351	371.32	12.83	1.37
		185.90				69	0.17	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	5	574.07	99.94	324.71	149.42	98	1.25	1.03	57	1.97	0.21	2,155,927	7671.63	265.14	28.26
		185.90				69	1.25	0.02	57	1.97	0.21	16,609	59.10	2.04	0.22
Feb	6	574.07	99.94	324.71	149.42	98	1.77	1.55	57	1.97	0.21	3,223,027	11468.79	396.38	42.25
		185.90				69	1.77	0.14	57	1.97	0.21	93,982	334.42	11.56	1.23
Feb	9	574.07	99.94	324.71	149.42	98	0.46	0.28	57	1.97	0.21	587,501	2090.56	72.25	7.70
		185.90				69	0.46	0.00	57	1.97	0.21	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Feb	22	574.07	99.94	324.71	149.42	98	0.15	0.04	57	1.97	0.21	79,301	282.18	9.75	1.04
		185.90				69	0.15	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	24	574.07	99.94	324.71	149.42	98	0.25	0.11	57	1.97	0.21	220,648	785.15	27.14	2.89
		185.90				69	0.25	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	25	574.07	99.94	324.71	149.42	98	0.07	0.00	57	1.97	0.21	7,609	27.07	0.94	0.10
		185.90				69	0.07	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Mar.	2	574.07	99.94	324.71	149.42	98	0.64	0.45	62	2.53	0.27	931,395	3604.99	147.11	15.70
		185.90				69	0.64	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	3	574.07	99.94	324.71	149.42	98	0.95	0.74	62	2.53	0.27	1,547,311	5988.92	244.39	26.08
		185.90				69	0.95	0.00	62	2.53	0.27	314	1.21	0.05	0.01
Mar.	11	574.07	99.94	324.71	149.42	98	0.08	0.01	62	2.53	0.27	13,152	50.91	2.08	0.22
		185.90				69	0.08	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	12	574.07	99.94	324.71	149.42	98	0.57	0.38	62	2.53	0.27	795,838	3080.32	125.70	13.41
		185.90				69	0.57	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	13	574.07	99.94	324.71	149.42	98	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	14	574.07	99.94	324.71	149.42	98	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		185.90				69	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	15	574.07	99.94	324.71	149.42	98	0.1	0.01	62	2.53	0.27	27,726	107.31	4.38	0.47
		185.90				69	0.1	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	22	574.07	99.94	324.71	149.42	98	0.06	0.00	62	2.53	0.27	3,435	13.29	0.54	0.06
		185.90				69	0.06	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	26	574.07	99.94	324.71	149.42	98	0.3	0.15	62	2.53	0.27	302,175	1169.58	47.73	5.09
		185.90				69	0.3	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	29	574.07	99.94	324.71	149.42	98	2.21	1.98	62	2.53	0.27	4,131,612	15991.53	652.56	69.64
		185.90				69	2.21	0.29	62	2.53	0.27	197,591	764.78	31.21	3.33
Mar.	30	574.07	99.94	324.71	149.42	98	0.09	0.01	62	2.53	0.27	19,904	77.04	3.14	0.34
		185.90				69	0.09	0.00	62	2.53	0.27	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Apr	9	574.07	99.94	324.71	149.42	98	0.35	0.19	62	2.53	0.27	388,119	1502.22	61.30	6.54
		185.90				69	0.35	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	13	574.07	99.94	324.71	149.42	98	0.04	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		185.90				69	0.04	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	21	574.07	99.94	324.71	149.42	98	0.05	0.00	62	2.53	0.27	824	3.19	0.13	0.01
		185.90				69	0.05	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	24	574.07	99.94	324.71	149.42	98	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	25	574.07	99.94	324.71	149.42	98	0.18	0.06	62	2.53	0.27	117,603	455.19	18.57	1.98
		185.90				69	0.18	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	26	574.07	99.94	324.71	149.42	98	0.75	0.55	62	2.53	0.27	1,147,608	4441.85	181.26	19.34
		185.90				69	0.75	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	27	574.07	99.94	324.71	149.42	98	0.11	0.02	62	2.53	0.27	36,500	141.28	5.76	0.62
		185.90				69	0.11	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	12	574.07	99.94	324.71	149.42	98	0.06	0.00	62	2.53	0.27	3,435	13.29	0.54	0.06
		185.90				69	0.06	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	13	574.07	99.94	324.71	149.42	98	0.13	0.03	62	2.53	0.27	56,518	218.75	8.93	0.95
		185.90				69	0.13	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	14	574.07	99.94	324.71	149.42	98	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		185.90				69	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	15	574.07	99.94	324.71	149.42	98	0.01	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	16	574.07	99.94	324.71	149.42	98	0.23	0.09	62	2.53	0.27	189,651	734.05	29.95	3.20
		185.90				69	0.23	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	17	574.07	99.94	324.71	149.42	98	1.09	0.88	62	2.53	0.27	1,830,346	7084.41	289.09	30.85
		185.90				69	1.09	0.01	62	2.53	0.27	4,965	19.22	0.78	0.08
May	18	574.07	99.94	324.71	149.42	98	0.96	0.75	62	2.53	0.27	1,567,456	6066.89	247.57	26.42
		185.90				69	0.96	0.00	62	2.53	0.27	464	1.79	0.07	0.01

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
May	28	574.07	99.94	324.71	149.42	98	0.05	0.00	62	2.53	0.27	824	3.19	0.13	0.01
		185.90				69	0.05	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	30	574.07	99.94	324.71	149.42	98	0.31	0.15	62	2.53	0.27	319,055	1234.91	50.39	5.38
		185.90				69	0.31	0.00	62	2.53	0.27	0	0.00	0.00	0.00
June	1	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	6	574.07	99.94	324.71	149.42	98	0.18	0.06	54	2.19	0.25	117,603	396.45	16.08	1.84
		185.90				69	0.18	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	9	574.07	99.94	324.71	149.42	98	0.23	0.09	54	2.19	0.25	189,651	639.33	25.93	2.96
		185.90				69	0.23	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	13	574.07	99.94	324.71	149.42	98	0.47	0.29	54	2.19	0.25	606,141	2043.37	82.87	9.46
		185.90				69	0.47	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	14	574.07	99.94	324.71	149.42	98	0.09	0.01	54	2.19	0.25	19,904	67.10	2.72	0.31
		185.90				69	0.09	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	16	574.07	99.94	324.71	149.42	98	0.84	0.64	54	2.19	0.25	1,326,632	4472.22	181.37	20.70
		185.90				69	0.84	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	20	574.07	99.94	324.71	149.42	98	0.42	0.25	54	2.19	0.25	513,696	1731.72	70.23	8.02
		185.90				69	0.42	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	22	574.07	99.94	324.71	149.42	98	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	23	574.07	99.94	324.71	149.42	98	0.05	0.00	54	2.19	0.25	824	2.78	0.11	0.01
		185.90				69	0.05	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	24	574.07	99.94	324.71	149.42	98	0.25	0.11	54	2.19	0.25	220,648	743.83	30.17	3.44
		185.90				69	0.25	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	25	574.07	99.94	324.71	149.42	98	0.1	0.01	54	2.19	0.25	27,726	93.47	3.79	0.43
		185.90				69	0.1	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	29	574.07	99.94	324.71	149.42	98	1.06	0.85	54	2.19	0.25	1,769,528	5965.27	241.92	27.62
		185.90				69	1.06	0.01	54	2.19	0.25	3,515	11.85	0.48	0.05

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
June	30	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	10	574.07	99.94	324.71	149.42	98	0.67	0.48	54	2.19	0.25	990,022	3337.47	135.35	15.45
		185.90				69	0.67	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	13	574.07	99.94	324.71	149.42	98	0.05	0.00	54	2.19	0.25	824	2.78	0.11	0.01
		185.90				69	0.05	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	14	574.07	99.94	324.71	149.42	98	0.13	0.03	54	2.19	0.25	56,518	190.53	7.73	0.88
		185.90				69	0.13	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	17	574.07	99.94	324.71	149.42	98	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	19	574.07	99.94	324.71	149.42	98	0.89	0.68	54	2.19	0.25	1,426,720	4809.62	195.06	22.27
		185.90				69	0.89	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	20	574.07	99.94	324.71	149.42	98	0.54	0.35	54	2.19	0.25	738,371	2489.13	100.95	11.52
		185.90				69	0.54	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	25	574.07	99.94	324.71	149.42	98	0.06	0.00	54	2.19	0.25	3,435	11.58	0.47	0.05
		185.90				69	0.06	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	27	574.07	99.94	324.71	149.42	98	0.54	0.35	54	2.19	0.25	738,371	2489.13	100.95	11.52
		185.90				69	0.54	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	29	574.07	99.94	324.71	149.42	98	3.58	3.35	54	2.19	0.25	6,973,146	23507.22	953.35	108.83
		185.90				69	3.58	1.00	54	2.19	0.25	671,595	2264.02	91.82	10.48
Aug	1	574.07	99.94	324.71	149.42	98	0.44	0.26	54	2.19	0.25	550,440	1855.59	75.25	8.59
		185.90				69	0.44	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	2	574.07	99.94	324.71	149.42	98	0.13	0.03	54	2.19	0.25	56,518	190.53	7.73	0.88
		185.90				69	0.13	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	4	574.07	99.94	324.71	149.42	98	0.03	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.03	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	5	574.07	99.94	324.71	149.42	98	1.01	0.80	54	2.19	0.25	1,668,357	5624.21	228.09	26.04
		185.90				69	1.01	0.00	54	2.19	0.25	1,641	5.53	0.22	0.03

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	**Road**	**Other Imp [2]**	**Roof**				**TSS**	**TN**	**TP**		**TSS**	**TN**	**TP**
Aug	8	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	9	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	12	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	13	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	18	574.07	99.94	324.71	149.42	98	1.44	1.22	54	2.19	0.25	2,544,587	8578.07	347.89	39.71
		185.90				69	1.44	0.06	54	2.19	0.25	38,356	129.30	5.24	0.60
Aug	19	574.07	99.94	324.71	149.42	98	0.24	0.10	54	2.19	0.25	205,017	691.13	28.03	3.20
		185.90				69	0.24	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	21	574.07	99.94	324.71	149.42	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	22	574.07	99.94	324.71	149.42	98	0.74	0.54	54	2.19	0.25	1,127,822	3802.01	154.19	17.60
		185.90				69	0.74	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	27	574.07	99.94	324.71	149.42	98	0.05	0.00	54	2.19	0.25	824	2.78	0.11	0.01
		185.90				69	0.05	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Sept	3	574.07	99.94	324.71	149.42	98	0.9	0.69	40	1.88	0.22	1,446,783	3612.79	169.80	19.87
		185.90				69	0.9	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	12	574.07	99.94	324.71	149.42	98	0.35	0.19	40	1.88	0.22	388,119	969.18	45.55	5.33
		185.90				69	0.35	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	26	574.07	99.94	324.71	149.42	98	0.1	0.01	40	1.88	0.22	27,726	69.23	3.25	0.38
		185.90				69	0.1	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	27	574.07	99.94	324.71	149.42	98	2.11	1.88	40	1.88	0.22	3,924,832	9800.76	460.64	53.90
		185.90				69	2.11	0.25	40	1.88	0.22	171,434	428.09	20.12	2.35
Sept	28	574.07	99.94	324.71	149.42	98	0.07	0.00	40	1.88	0.22	7,609	19.00	0.89	0.10
		185.90				69	0.07	0.00	40	1.88	0.22	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Sept	29	574.07	99.94	324.71	149.42	98	0.57	0.38	40	1.88	0.22	795,838	1987.30	93.40	10.93
		185.90				69	0.57	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	30	574.07	99.94	324.71	149.42	98	3.57	3.34	40	1.88	0.22	6,952,369	17360.87	815.96	95.48
		185.90				69	3.57	0.99	40	1.88	0.22	667,513	1666.86	78.34	9.17
Oct	1	574.07	99.94	324.71	149.42	98	0.11	0.02	40	1.88	0.22	36,500	91.15	4.28	0.50
		185.90				69	0.11	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	3	574.07	99.94	324.71	149.42	98	1.16	0.95	40	1.88	0.22	1,972,554	4925.70	231.51	27.09
		185.90				69	1.16	0.01	40	1.88	0.22	9,265	23.14	1.09	0.13
Oct	4	574.07	99.94	324.71	149.42	98	0.11	0.02	40	1.88	0.22	36,500	91.15	4.28	0.50
		185.90				69	0.11	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	6	574.07	99.94	324.71	149.42	98	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	14	574.07	99.94	324.71	149.42	98	0.58	0.39	40	1.88	0.22	815,085	2035.36	95.66	11.19
		185.90				69	0.58	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	15	574.07	99.94	324.71	149.42	98	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	25	574.07	99.94	324.71	149.42	98	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	26	574.07	99.94	324.71	149.42	98	0.17	0.05	40	1.88	0.22	104,351	260.58	12.25	1.43
		185.90				69	0.17	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	28	574.07	99.94	324.71	149.42	98	0.14	0.03	40	1.88	0.22	67,598	168.80	7.93	0.93
		185.90				69	0.14	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	3	574.07	99.94	324.71	149.42	98	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	4	574.07	99.94	324.71	149.42	98	0.33	0.17	40	1.88	0.22	353,297	882.22	41.46	4.85
		185.90				69	0.33	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	5	574.07	99.94	324.71	149.42	98	0.1	0.01	40	1.88	0.22	27,726	69.23	3.25	0.38
		185.90				69	0.1	0.00	40	1.88	0.22	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Nov	16	574.07	99.94	324.71	149.42	98	0.04	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.04	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	17	574.07	99.94	324.71	149.42	98	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	22	574.07	99.94	324.71	149.42	98	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	26	574.07	99.94	324.71	149.42	98	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		185.90				69	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Dec	1	574.07	99.94	324.71	149.42	98	0.33	0.17	57	1.97	0.21	353,297	1257.17	43.45	4.63
		185.90				69	0.33	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	3	574.07	99.94	324.71	149.42	98	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	4	574.07	99.94	324.71	149.42	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	5	574.07	99.94	324.71	149.42	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	6	574.07	99.94	324.71	149.42	98	0.22	0.08	57	1.97	0.21	174,570	621.19	21.47	2.29
		185.90				69	0.22	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	11	574.07	99.94	324.71	149.42	98	0.4	0.23	57	1.97	0.21	477,302	1698.43	58.70	6.26
		185.90				69	0.4	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	12	574.07	99.94	324.71	149.42	98	0.31	0.15	57	1.97	0.21	319,055	1135.32	39.24	4.18
		185.90				69	0.31	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	13	574.07	99.94	324.71	149.42	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	16	574.07	99.94	324.71	149.42	98	0.33	0.17	57	1.97	0.21	353,297	1257.17	43.45	4.63
		185.90				69	0.33	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	18	574.07	99.94	324.71	149.42	98	0.06	0.00	57	1.97	0.21	3,435	12.22	0.42	0.05
		185.90				69	0.06	0.00	57	1.97	0.21	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Commercial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft³)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Dec	19	574.07	99.94	324.71	149.42	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		185.90				69	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	25	574.07	99.94	324.71	149.42	98	0.12	0.02	57	1.97	0.21	46,127	164.14	5.67	0.60
		185.90				69	0.12	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	26	574.07	99.94	324.71	149.42	98	0.08	0.01	57	1.97	0.21	13,152	46.80	1.62	0.17
		185.90				69	0.08	0.00	57	1.97	0.21	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Jan.	1	502.23	36.00	134.15	96.37	98	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	8	502.23	36.00	134.15	96.37	98	0.03	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.03	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	12	502.23	36.00	134.15	96.37	98	0.3	0.15	69	1.59	0.21	140,289	604.30	13.93	1.84
		236.01				70	0.3	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	17	502.23	36.00	134.15	96.37	98	0.76	0.56	69	1.59	0.21	541,989	2334.63	53.80	7.11
		236.01				70	0.76	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	20	502.23	36.00	134.15	96.37	98	0.09	0.01	69	1.59	0.21	9,241	39.80	0.92	0.12
		236.01				70	0.09	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	21	502.23	36.00	134.15	96.37	98	0.56	0.37	69	1.59	0.21	360,563	1553.14	35.79	4.73
		236.01				70	0.56	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	22	502.23	36.00	134.15	96.37	98	0.1	0.01	69	1.59	0.21	12,872	55.45	1.28	0.17
		236.01				70	0.1	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	25	502.23	36.00	134.15	96.37	98	0.74	0.54	69	1.59	0.21	523,606	2255.44	51.97	6.86
		236.01				70	0.74	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Jan	30	502.23	36.00	134.15	96.37	98	0.25	0.11	69	1.59	0.21	102,439	441.26	10.17	1.34
		236.01				70	0.25	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Feb	2	502.23	36.00	134.15	96.37	98	0.02	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Feb	3	502.23	36.00	134.15	96.37	98	0.17	0.05	69	1.59	0.21	48,446	208.68	4.81	0.64
		236.01				70	0.17	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Feb	5	502.23	36.00	134.15	96.37	98	1.25	1.03	69	1.59	0.21	1,000,917	4311.47	99.35	13.12
		236.01				70	1.25	0.03	69	1.59	0.21	27,634	119.03	2.74	0.36
Feb	6	502.23	36.00	134.15	96.37	98	1.77	1.55	69	1.59	0.21	1,496,332	6445.49	148.53	19.62
		236.01				70	1.77	0.16	69	1.59	0.21	135,806	584.99	13.48	1.78
Feb	9	502.23	36.00	134.15	96.37	98	0.46	0.28	69	1.59	0.21	272,755	1174.90	27.07	3.58
		236.01				70	0.46	0.00	69	1.59	0.21	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Feb	22	502.23	36.00	134.15	96.37	98	0.15	0.04	69	1.59	0.21	36,816	158.59	3.65	0.48
		236.01				70	0.15	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Feb	24	502.23	36.00	134.15	96.37	98	0.25	0.11	69	1.59	0.21	102,439	441.26	10.17	1.34
		236.01				70	0.25	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Feb	25	502.23	36.00	134.15	96.37	98	0.07	0.00	69	1.59	0.21	3,532	15.22	0.35	0.05
		236.01				70	0.07	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Mar.	2	502.23	36.00	134.15	96.37	98	0.64	0.45	61	1.89	0.23	432,412	1646.67	51.02	6.21
		236.01				70	0.64	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	3	502.23	36.00	134.15	96.37	98	0.95	0.74	61	1.89	0.23	718,359	2735.59	84.76	10.31
		236.01				70	0.95	0.00	61	1.89	0.23	1,548	5.89	0.18	0.02
Mar.	11	502.23	36.00	134.15	96.37	98	0.08	0.01	61	1.89	0.23	6,106	23.25	0.72	0.09
		236.01				70	0.08	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	12	502.23	36.00	134.15	96.37	98	0.57	0.38	61	1.89	0.23	369,478	1407.01	43.59	5.31
		236.01				70	0.57	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	13	502.23	36.00	134.15	96.37	98	0.02	0.00	61	1.89	0.23	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	14	502.23	36.00	134.15	96.37	98	0.03	0.00	61	1.89	0.23	0	0.00	0.00	0.00
		236.01				70	0.03	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	15	502.23	36.00	134.15	96.37	98	0.1	0.01	61	1.89	0.23	12,872	49.02	1.52	0.18
		236.01				70	0.1	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	22	502.23	36.00	134.15	96.37	98	0.06	0.00	61	1.89	0.23	1,595	6.07	0.19	0.02
		236.01				70	0.06	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	26	502.23	36.00	134.15	96.37	98	0.3	0.15	61	1.89	0.23	140,289	534.23	16.55	2.01
		236.01				70	0.3	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Mar.	29	502.23	36.00	134.15	96.37	98	2.21	1.98	61	1.89	0.23	1,918,154	7304.53	226.32	27.54
		236.01				70	2.21	0.32	61	1.89	0.23	275,802	1050.28	32.54	3.96
Mar.	30	502.23	36.00	134.15	96.37	98	0.09	0.01	61	1.89	0.23	9,241	35.19	1.09	0.13
		236.01				70	0.09	0.00	61	1.89	0.23	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Apr	9	502.23	36.00	134.15	96.37	98	0.35	0.19	61	1.89	0.23	180,189	686.18	21.26	2.59
		236.01				70	0.35	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Apr	13	502.23	36.00	134.15	96.37	98	0.04	0.00	61	1.89	0.23	0	0.00	0.00	0.00
		236.01				70	0.04	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Apr	21	502.23	36.00	134.15	96.37	98	0.05	0.00	61	1.89	0.23	383	1.46	0.05	0.01
		236.01				70	0.05	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Apr	24	502.23	36.00	134.15	96.37	98	0.02	0.00	61	1.89	0.23	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Apr	25	502.23	36.00	134.15	96.37	98	0.18	0.06	61	1.89	0.23	54,599	207.92	6.44	0.78
		236.01				70	0.18	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Apr	26	502.23	36.00	134.15	96.37	98	0.75	0.55	61	1.89	0.23	532,792	2028.93	62.86	7.65
		236.01				70	0.75	0.00	61	1.89	0.23	0	0.00	0.00	0.00
Apr	27	502.23	36.00	134.15	96.37	98	0.11	0.02	61	1.89	0.23	16,946	64.53	2.00	0.24
		236.01				70	0.11	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	12	502.23	36.00	134.15	96.37	98	0.06	0.00	61	1.89	0.23	1,595	6.07	0.19	0.02
		236.01				70	0.06	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	13	502.23	36.00	134.15	96.37	98	0.13	0.03	61	1.89	0.23	26,239	99.92	3.10	0.38
		236.01				70	0.13	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	14	502.23	36.00	134.15	96.37	98	0.03	0.00	61	1.89	0.23	0	0.00	0.00	0.00
		236.01				70	0.03	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	15	502.23	36.00	134.15	96.37	98	0.01	0.00	61	1.89	0.23	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	16	502.23	36.00	134.15	96.37	98	0.23	0.09	61	1.89	0.23	88,048	335.30	10.39	1.26
		236.01				70	0.23	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	17	502.23	36.00	134.15	96.37	98	1.09	0.88	61	1.89	0.23	849,762	3235.98	100.26	12.20
		236.01				70	1.09	0.01	61	1.89	0.23	9,918	37.77	1.17	0.14
May	18	502.23	36.00	134.15	96.37	98	0.96	0.75	61	1.89	0.23	727,712	2771.20	85.86	10.45
		236.01				70	0.96	0.00	61	1.89	0.23	1,911	7.28	0.23	0.03

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
May	28	502.23	36.00	134.15	96.37	98	0.05	0.00	61	1.89	0.23	383	1.46	0.05	0.01
		236.01				70	0.05	0.00	61	1.89	0.23	0	0.00	0.00	0.00
May	30	502.23	36.00	134.15	96.37	98	0.31	0.15	61	1.89	0.23	148,126	564.08	17.48	2.13
		236.01				70	0.31	0.00	61	1.89	0.23	0	0.00	0.00	0.00
June	1	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	6	502.23	36.00	134.15	96.37	98	0.18	0.06	43	1.8	0.22	54,599	146.57	6.14	0.75
		236.01				70	0.18	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	9	502.23	36.00	134.15	96.37	98	0.23	0.09	43	1.8	0.22	88,048	236.36	9.89	1.21
		236.01				70	0.23	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	13	502.23	36.00	134.15	96.37	98	0.47	0.29	43	1.8	0.22	281,409	755.41	31.62	3.86
		236.01				70	0.47	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	14	502.23	36.00	134.15	96.37	98	0.09	0.01	43	1.8	0.22	9,241	24.81	1.04	0.13
		236.01				70	0.09	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	16	502.23	36.00	134.15	96.37	98	0.84	0.64	43	1.8	0.22	615,906	1653.34	69.21	8.46
		236.01				70	0.84	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	20	502.23	36.00	134.15	96.37	98	0.42	0.25	43	1.8	0.22	238,490	640.20	26.80	3.28
		236.01				70	0.42	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	22	502.23	36.00	134.15	96.37	98	0.02	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	23	502.23	36.00	134.15	96.37	98	0.05	0.00	43	1.8	0.22	383	1.03	0.04	0.01
		236.01				70	0.05	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	24	502.23	36.00	134.15	96.37	98	0.25	0.11	43	1.8	0.22	102,439	274.99	11.51	1.41
		236.01				70	0.25	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	25	502.23	36.00	134.15	96.37	98	0.1	0.01	43	1.8	0.22	12,872	34.55	1.45	0.18
		236.01				70	0.1	0.00	43	1.8	0.22	0	0.00	0.00	0.00
June	29	502.23	36.00	134.15	96.37	98	1.06	0.85	43	1.8	0.22	821,526	2205.30	92.32	11.28
		236.01				70	1.06	0.01	43	1.8	0.22	7,541	20.24	0.85	0.10

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
June	30	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	10	502.23	36.00	134.15	96.37	98	0.67	0.48	43	1.8	0.22	459,630	1233.83	51.65	6.31
		236.01				70	0.67	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	13	502.23	36.00	134.15	96.37	98	0.05	0.00	43	1.8	0.22	383	1.03	0.04	0.01
		236.01				70	0.05	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	14	502.23	36.00	134.15	96.37	98	0.13	0.03	43	1.8	0.22	26,239	70.44	2.95	0.36
		236.01				70	0.13	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	17	502.23	36.00	134.15	96.37	98	0.02	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	19	502.23	36.00	134.15	96.37	98	0.89	0.68	43	1.8	0.22	662,373	1778.07	74.43	9.10
		236.01				70	0.89	0.00	43	1.8	0.22	167	0.45	0.02	0.00
July	20	502.23	36.00	134.15	96.37	98	0.54	0.35	43	1.8	0.22	342,798	920.21	38.52	4.71
		236.01				70	0.54	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	25	502.23	36.00	134.15	96.37	98	0.06	0.00	43	1.8	0.22	1,595	4.28	0.18	0.02
		236.01				70	0.06	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	27	502.23	36.00	134.15	96.37	98	0.54	0.35	43	1.8	0.22	342,798	920.21	38.52	4.71
		236.01				70	0.54	0.00	43	1.8	0.22	0	0.00	0.00	0.00
July	29	502.23	36.00	134.15	96.37	98	3.58	3.35	43	1.8	0.22	3,237,372	8690.40	363.78	44.46
		236.01				70	3.58	1.05	43	1.8	0.22	901,832	2420.88	101.34	12.39
Aug	1	502.23	36.00	134.15	96.37	98	0.44	0.26	43	1.8	0.22	255,549	686.00	28.72	3.51
		236.01				70	0.44	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	2	502.23	36.00	134.15	96.37	98	0.13	0.03	43	1.8	0.22	26,239	70.44	2.95	0.36
		236.01				70	0.13	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	4	502.23	36.00	134.15	96.37	98	0.03	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.03	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	5	502.23	36.00	134.15	96.37	98	1.01	0.80	43	1.8	0.22	774,556	2079.22	87.04	10.64
		236.01				70	1.01	0.00	43	1.8	0.22	4,276	11.48	0.48	0.06

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Aug	8	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	9	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	12	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	13	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	18	502.23	36.00	134.15	96.37	98	1.44	1.22	43	1.8	0.22	1,181,357	3171.23	132.75	16.22
		236.01				70	1.44	0.07	43	1.8	0.22	58,830	157.92	6.61	0.81
Aug	19	502.23	36.00	134.15	96.37	98	0.24	0.10	43	1.8	0.22	95,182	255.51	10.70	1.31
		236.01				70	0.24	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	21	502.23	36.00	134.15	96.37	98	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	22	502.23	36.00	134.15	96.37	98	0.74	0.54	43	1.8	0.22	523,606	1405.57	58.84	7.19
		236.01				70	0.74	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Aug	27	502.23	36.00	134.15	96.37	98	0.05	0.00	43	1.8	0.22	383	1.03	0.04	0.01
		236.01				70	0.05	0.00	43	1.8	0.22	0	0.00	0.00	0.00
Sept	3	502.23	36.00	134.15	96.37	98	0.9	0.69	49	1.56	0.25	671,688	2054.67	65.41	10.48
		236.01				70	0.9	0.00	49	1.56	0.25	301	0.92	0.03	0.00
Sept	12	502.23	36.00	134.15	96.37	98	0.35	0.19	49	1.56	0.25	180,189	551.19	17.55	2.81
		236.01				70	0.35	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Sept	26	502.23	36.00	134.15	96.37	98	0.1	0.01	49	1.56	0.25	12,872	39.38	1.25	0.20
		236.01				70	0.1	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Sept	27	502.23	36.00	134.15	96.37	98	2.11	1.88	49	1.56	0.25	1,822,154	5573.91	177.46	28.44
		236.01				70	2.11	0.28	49	1.56	0.25	240,688	736.26	23.44	3.76
Sept	28	502.23	36.00	134.15	96.37	98	0.07	0.00	49	1.56	0.25	3,532	10.81	0.34	0.06
		236.01				70	0.07	0.00	49	1.56	0.25	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	**Road**	**Other Imp [2]**	**Roof**				**TSS**	**TN**	**TP**		**TSS**	**TN**	**TP**
Sept	29	502.23	36.00	134.15	96.37	98	0.57	0.38	49	1.56	0.25	369,478	1130.22	35.98	5.77
		236.01				70	0.57	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Sept	30	502.23	36.00	134.15	96.37	98	3.57	3.34	49	1.56	0.25	3,227,726	9873.51	314.34	50.38
		236.01				70	3.57	1.05	49	1.56	0.25	896,488	2742.33	87.31	13.99
Oct	1	502.23	36.00	134.15	96.37	98	0.11	0.02	49	1.56	0.25	16,946	51.84	1.65	0.26
		236.01				70	0.11	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	3	502.23	36.00	134.15	96.37	98	1.16	0.95	49	1.56	0.25	915,784	2801.35	89.19	14.29
		236.01				70	1.16	0.02	49	1.56	0.25	16,648	50.93	1.62	0.26
Oct	4	502.23	36.00	134.15	96.37	98	0.11	0.02	49	1.56	0.25	16,946	51.84	1.65	0.26
		236.01				70	0.11	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	6	502.23	36.00	134.15	96.37	98	0.01	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	14	502.23	36.00	134.15	96.37	98	0.58	0.39	49	1.56	0.25	378,414	1157.55	36.85	5.91
		236.01				70	0.58	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	15	502.23	36.00	134.15	96.37	98	0.02	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	25	502.23	36.00	134.15	96.37	98	0.03	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.03	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	26	502.23	36.00	134.15	96.37	98	0.17	0.05	49	1.56	0.25	48,446	148.20	4.72	0.76
		236.01				70	0.17	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Oct	28	502.23	36.00	134.15	96.37	98	0.14	0.03	49	1.56	0.25	31,383	96.00	3.06	0.49
		236.01				70	0.14	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Nov	3	502.23	36.00	134.15	96.37	98	0.02	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Nov	4	502.23	36.00	134.15	96.37	98	0.33	0.17	49	1.56	0.25	164,023	501.74	15.97	2.56
		236.01				70	0.33	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Nov	5	502.23	36.00	134.15	96.37	98	0.1	0.01	49	1.56	0.25	12,872	39.38	1.25	0.20
		236.01				70	0.1	0.00	49	1.56	0.25	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Nov	16	502.23	36.00	134.15	96.37	98	0.04	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.04	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Nov	17	502.23	36.00	134.15	96.37	98	0.01	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Nov	22	502.23	36.00	134.15	96.37	98	0.01	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Nov	26	502.23	36.00	134.15	96.37	98	0.03	0.00	49	1.56	0.25	0	0.00	0.00	0.00
		236.01				70	0.03	0.00	49	1.56	0.25	0	0.00	0.00	0.00
Dec	1	502.23	36.00	134.15	96.37	98	0.33	0.17	69	1.59	0.21	164,023	706.53	16.28	2.15
		236.01				70	0.33	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	3	502.23	36.00	134.15	96.37	98	0.02	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.02	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	4	502.23	36.00	134.15	96.37	98	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	5	502.23	36.00	134.15	96.37	98	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	6	502.23	36.00	134.15	96.37	98	0.22	0.08	69	1.59	0.21	81,047	349.11	8.04	1.06
		236.01				70	0.22	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	11	502.23	36.00	134.15	96.37	98	0.4	0.23	69	1.59	0.21	221,594	954.52	22.00	2.91
		236.01				70	0.4	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	12	502.23	36.00	134.15	96.37	98	0.31	0.15	69	1.59	0.21	148,126	638.05	14.70	1.94
		236.01				70	0.31	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	13	502.23	36.00	134.15	96.37	98	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	16	502.23	36.00	134.15	96.37	98	0.33	0.17	69	1.59	0.21	164,023	706.53	16.28	2.15
		236.01				70	0.33	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	18	502.23	36.00	134.15	96.37	98	0.06	0.00	69	1.59	0.21	1,595	6.87	0.16	0.02
		236.01				70	0.06	0.00	69	1.59	0.21	0	0.00	0.00	0.00

Daily LU Scenario Loadings - Industrial

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Dec	19	502.23	36.00	134.15	96.37	98	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
		236.01				70	0.01	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	25	502.23	36.00	134.15	96.37	98	0.12	0.02	69	1.59	0.21	21,415	92.25	2.13	0.28
		236.01				70	0.12	0.00	69	1.59	0.21	0	0.00	0.00	0.00
Dec	26	502.23	36.00	134.15	96.37	98	0.08	0.01	69	1.59	0.21	6,106	26.30	0.61	0.08
		236.01				70	0.08	0.00	69	1.59	0.21	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area[1]	Road	Other Imp[2]	Roof				TSS	TN	TP		TSS	TN	TP
Jan.	1	58.70	39.90	8.00	10.80	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	8	58.70	39.90	8.00	10.80	98	0.03	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.03	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	12	58.70	39.90	8.00	10.80	98	0.3	0.15	57	1.97	0.21	30,898	109.95	3.80	0.41
		47.90				64	0.3	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	17	58.70	39.90	8.00	10.80	98	0.76	0.56	57	1.97	0.21	119,371	424.77	14.68	1.56
		47.90				64	0.76	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	20	58.70	39.90	8.00	10.80	98	0.09	0.01	57	1.97	0.21	2,035	7.24	0.25	0.03
		47.90				64	0.09	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	21	58.70	39.90	8.00	10.80	98	0.56	0.37	57	1.97	0.21	79,413	282.58	9.77	1.04
		47.90				64	0.56	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	22	58.70	39.90	8.00	10.80	98	0.1	0.01	57	1.97	0.21	2,835	10.09	0.35	0.04
		47.90				64	0.1	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	25	58.70	39.90	8.00	10.80	98	0.74	0.54	57	1.97	0.21	115,322	410.36	14.18	1.51
		47.90				64	0.74	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Jan	30	58.70	39.90	8.00	10.80	98	0.25	0.11	57	1.97	0.21	22,562	80.28	2.77	0.30
		47.90				64	0.25	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	2	58.70	39.90	8.00	10.80	98	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	3	58.70	39.90	8.00	10.80	98	0.17	0.05	57	1.97	0.21	10,670	37.97	1.31	0.14
		47.90				64	0.17	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	5	58.70	39.90	8.00	10.80	98	1.25	1.03	57	1.97	0.21	220,448	784.44	27.11	2.89
		47.90				64	1.25	0.00	57	1.97	0.21	334	1.19	0.04	0.00
Feb	6	58.70	39.90	8.00	10.80	98	1.77	1.55	57	1.97	0.21	329,561	1172.71	40.53	4.32
		47.90				64	1.77	0.06	57	1.97	0.21	10,731	38.18	1.32	0.14
Feb	9	58.70	39.90	8.00	10.80	98	0.46	0.28	57	1.97	0.21	60,073	213.76	7.39	0.79
		47.90				64	0.46	0.00	57	1.97	0.21	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Feb	22	58.70	39.90	8.00	10.80	98	0.15	0.04	57	1.97	0.21	8,109	28.85	1.00	0.11
		47.90				64	0.15	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	24	58.70	39.90	8.00	10.80	98	0.25	0.11	57	1.97	0.21	22,562	80.28	2.77	0.30
		47.90				64	0.25	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Feb	25	58.70	39.90	8.00	10.80	98	0.07	0.00	57	1.97	0.21	778	2.77	0.10	0.01
		47.90				64	0.07	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Mar.	2	58.70	39.90	8.00	10.80	98	0.64	0.45	62	2.53	0.27	95,237	368.62	15.04	1.61
		47.90				64	0.64	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	3	58.70	39.90	8.00	10.80	98	0.95	0.74	62	2.53	0.27	158,216	612.38	24.99	2.67
		47.90				64	0.95	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	11	58.70	39.90	8.00	10.80	98	0.08	0.01	62	2.53	0.27	1,345	5.21	0.21	0.02
		47.90				64	0.08	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	12	58.70	39.90	8.00	10.80	98	0.57	0.38	62	2.53	0.27	81,376	314.97	12.85	1.37
		47.90				64	0.57	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	13	58.70	39.90	8.00	10.80	98	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	14	58.70	39.90	8.00	10.80	98	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		47.90				64	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	15	58.70	39.90	8.00	10.80	98	0.1	0.01	62	2.53	0.27	2,835	10.97	0.45	0.05
		47.90				64	0.1	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	22	58.70	39.90	8.00	10.80	98	0.06	0.00	62	2.53	0.27	351	1.36	0.06	0.01
		47.90				64	0.06	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	26	58.70	39.90	8.00	10.80	98	0.3	0.15	62	2.53	0.27	30,898	119.59	4.88	0.52
		47.90				64	0.3	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Mar.	29	58.70	39.90	8.00	10.80	98	2.21	1.98	62	2.53	0.27	422,465	1635.16	66.73	7.12
		47.90				64	2.21	0.17	62	2.53	0.27	29,105	112.65	4.60	0.49
Mar.	30	58.70	39.90	8.00	10.80	98	0.09	0.01	62	2.53	0.27	2,035	7.88	0.32	0.03
		47.90				64	0.09	0.00	62	2.53	0.27	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Apr	9	58.70	39.90	8.00	10.80	98	0.35	0.19	62	2.53	0.27	39,686	153.61	6.27	0.67
		47.90				64	0.35	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	13	58.70	39.90	8.00	10.80	98	0.04	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		47.90				64	0.04	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	21	58.70	39.90	8.00	10.80	98	0.05	0.00	62	2.53	0.27	84	0.33	0.01	0.00
		47.90				64	0.05	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	24	58.70	39.90	8.00	10.80	98	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	25	58.70	39.90	8.00	10.80	98	0.18	0.06	62	2.53	0.27	12,025	46.54	1.90	0.20
		47.90				64	0.18	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	26	58.70	39.90	8.00	10.80	98	0.75	0.55	62	2.53	0.27	117,345	454.19	18.53	1.98
		47.90				64	0.75	0.00	62	2.53	0.27	0	0.00	0.00	0.00
Apr	27	58.70	39.90	8.00	10.80	98	0.11	0.02	62	2.53	0.27	3,732	14.45	0.59	0.06
		47.90				64	0.11	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	12	58.70	39.90	8.00	10.80	98	0.06	0.00	62	2.53	0.27	351	1.36	0.06	0.01
		47.90				64	0.06	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	13	58.70	39.90	8.00	10.80	98	0.13	0.03	62	2.53	0.27	5,779	22.37	0.91	0.10
		47.90				64	0.13	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	14	58.70	39.90	8.00	10.80	98	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		47.90				64	0.03	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	15	58.70	39.90	8.00	10.80	98	0.01	0.00	62	2.53	0.27	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	16	58.70	39.90	8.00	10.80	98	0.23	0.09	62	2.53	0.27	19,392	75.06	3.06	0.33
		47.90				64	0.23	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	17	58.70	39.90	8.00	10.80	98	1.09	0.88	62	2.53	0.27	187,156	724.39	29.56	3.15
		47.90				64	1.09	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	18	58.70	39.90	8.00	10.80	98	0.96	0.75	62	2.53	0.27	160,275	620.35	25.31	2.70
		47.90				64	0.96	0.00	62	2.53	0.27	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
May	28	58.70	39.90	8.00	10.80	98	0.05	0.00	62	2.53	0.27	84	0.33	0.01	0.00
		47.90				64	0.05	0.00	62	2.53	0.27	0	0.00	0.00	0.00
May	30	58.70	39.90	8.00	10.80	98	0.31	0.15	62	2.53	0.27	32,624	126.27	5.15	0.55
		47.90				64	0.31	0.00	62	2.53	0.27	0	0.00	0.00	0.00
June	1	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	6	58.70	39.90	8.00	10.80	98	0.18	0.06	54	2.19	0.25	12,025	40.54	1.64	0.19
		47.90				64	0.18	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	9	58.70	39.90	8.00	10.80	98	0.23	0.09	54	2.19	0.25	19,392	65.37	2.65	0.30
		47.90				64	0.23	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	13	58.70	39.90	8.00	10.80	98	0.47	0.29	54	2.19	0.25	61,979	208.94	8.47	0.97
		47.90				64	0.47	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	14	58.70	39.90	8.00	10.80	98	0.09	0.01	54	2.19	0.25	2,035	6.86	0.28	0.03
		47.90				64	0.09	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	16	58.70	39.90	8.00	10.80	98	0.84	0.64	54	2.19	0.25	135,651	457.29	18.55	2.12
		47.90				64	0.84	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	20	58.70	39.90	8.00	10.80	98	0.42	0.25	54	2.19	0.25	52,526	177.07	7.18	0.82
		47.90				64	0.42	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	22	58.70	39.90	8.00	10.80	98	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	23	58.70	39.90	8.00	10.80	98	0.05	0.00	54	2.19	0.25	84	0.28	0.01	0.00
		47.90				64	0.05	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	24	58.70	39.90	8.00	10.80	98	0.25	0.11	54	2.19	0.25	22,562	76.06	3.08	0.35
		47.90				64	0.25	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	25	58.70	39.90	8.00	10.80	98	0.1	0.01	54	2.19	0.25	2,835	9.56	0.39	0.04
		47.90				64	0.1	0.00	54	2.19	0.25	0	0.00	0.00	0.00
June	29	58.70	39.90	8.00	10.80	98	1.06	0.85	54	2.19	0.25	180,938	609.96	24.74	2.82
		47.90				64	1.06	0.00	54	2.19	0.25	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		**Area (acres)**				**CN$_W$**	**P (in)**	**Q (in)**	**EMC (mg/L)**			**Runoff (ft^3)**	**Loading (lbs)**		
		Total Area [1]	**Road**	**Other Imp** [2]	**Roof**				**TSS**	**TN**	**TP**		**TSS**	**TN**	**TP**
June	30	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	10	58.70	39.90	8.00	10.80	98	0.67	0.48	54	2.19	0.25	101,232	341.26	13.84	1.58
		47.90				64	0.67	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	13	58.70	39.90	8.00	10.80	98	0.05	0.00	54	2.19	0.25	84	0.28	0.01	0.00
		47.90				64	0.05	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	14	58.70	39.90	8.00	10.80	98	0.13	0.03	54	2.19	0.25	5,779	19.48	0.79	0.09
		47.90				64	0.13	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	17	58.70	39.90	8.00	10.80	98	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	19	58.70	39.90	8.00	10.80	98	0.89	0.68	54	2.19	0.25	145,885	491.79	19.94	2.28
		47.90				64	0.89	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	20	58.70	39.90	8.00	10.80	98	0.54	0.35	54	2.19	0.25	75,500	254.52	10.32	1.18
		47.90				64	0.54	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	25	58.70	39.90	8.00	10.80	98	0.06	0.00	54	2.19	0.25	351	1.18	0.05	0.01
		47.90				64	0.06	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	27	58.70	39.90	8.00	10.80	98	0.54	0.35	54	2.19	0.25	75,500	254.52	10.32	1.18
		47.90				64	0.54	0.00	54	2.19	0.25	0	0.00	0.00	0.00
July	29	58.70	39.90	8.00	10.80	98	3.58	3.35	54	2.19	0.25	713,018	2403.66	97.48	11.13
		47.90				64	3.58	0.73	54	2.19	0.25	126,482	426.38	17.29	1.97
Aug	1	58.70	39.90	8.00	10.80	98	0.44	0.26	54	2.19	0.25	56,284	189.74	7.69	0.88
		47.90				64	0.44	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	2	58.70	39.90	8.00	10.80	98	0.13	0.03	54	2.19	0.25	5,779	19.48	0.79	0.09
		47.90				64	0.13	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	4	58.70	39.90	8.00	10.80	98	0.03	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.03	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	5	58.70	39.90	8.00	10.80	98	1.01	0.80	54	2.19	0.25	170,593	575.09	23.32	2.66
		47.90				64	1.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN$_W$	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Aug	8	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	9	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	12	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	13	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	18	58.70	39.90	8.00	10.80	98	1.44	1.22	54	2.19	0.25	260,189	877.12	35.57	4.06
		47.90				64	1.44	0.01	54	2.19	0.25	2,529	8.53	0.35	0.04
Aug	19	58.70	39.90	8.00	10.80	98	0.24	0.10	54	2.19	0.25	20,963	70.67	2.87	0.33
		47.90				64	0.24	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	21	58.70	39.90	8.00	10.80	98	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	22	58.70	39.90	8.00	10.80	98	0.74	0.54	54	2.19	0.25	115,322	388.76	15.77	1.80
		47.90				64	0.74	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Aug	27	58.70	39.90	8.00	10.80	98	0.05	0.00	54	2.19	0.25	84	0.28	0.01	0.00
		47.90				64	0.05	0.00	54	2.19	0.25	0	0.00	0.00	0.00
Sept	3	58.70	39.90	8.00	10.80	98	0.9	0.69	40	1.88	0.22	147,936	369.41	17.36	2.03
		47.90				64	0.9	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	12	58.70	39.90	8.00	10.80	98	0.35	0.19	40	1.88	0.22	39,686	99.10	4.66	0.55
		47.90				64	0.35	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	26	58.70	39.90	8.00	10.80	98	0.1	0.01	40	1.88	0.22	2,835	7.08	0.33	0.04
		47.90				64	0.1	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	27	58.70	39.90	8.00	10.80	98	2.11	1.88	40	1.88	0.22	401,322	1002.15	47.10	5.51
		47.90				64	2.11	0.14	40	1.88	0.22	24,257	60.57	2.85	0.33
Sept	28	58.70	39.90	8.00	10.80	98	0.07	0.00	40	1.88	0.22	778	1.94	0.09	0.01
		47.90				64	0.07	0.00	40	1.88	0.22	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Sept	29	58.70	39.90	8.00	10.80	98	0.57	0.38	40	1.88	0.22	81,376	203.21	9.55	1.12
		47.90				64	0.57	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Sept	30	58.70	39.90	8.00	10.80	98	3.57	3.34	40	1.88	0.22	710,893	1775.18	83.43	9.76
		47.90				64	3.57	0.72	40	1.88	0.22	125,600	313.64	14.74	1.73
Oct	1	58.70	39.90	8.00	10.80	98	0.11	0.02	40	1.88	0.22	3,732	9.32	0.44	0.05
		47.90				64	0.11	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	3	58.70	39.90	8.00	10.80	98	1.16	0.95	40	1.88	0.22	201,698	503.66	23.67	2.77
		47.90				64	1.16	0.00	40	1.88	0.22	8	0.02	0.00	0.00
Oct	4	58.70	39.90	8.00	10.80	98	0.11	0.02	40	1.88	0.22	3,732	9.32	0.44	0.05
		47.90				64	0.11	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	6	58.70	39.90	8.00	10.80	98	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	14	58.70	39.90	8.00	10.80	98	0.58	0.39	40	1.88	0.22	83,344	208.12	9.78	1.14
		47.90				64	0.58	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	15	58.70	39.90	8.00	10.80	98	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	25	58.70	39.90	8.00	10.80	98	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	26	58.70	39.90	8.00	10.80	98	0.17	0.05	40	1.88	0.22	10,670	26.64	1.25	0.15
		47.90				64	0.17	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Oct	28	58.70	39.90	8.00	10.80	98	0.14	0.03	40	1.88	0.22	6,912	17.26	0.81	0.09
		47.90				64	0.14	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	3	58.70	39.90	8.00	10.80	98	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	4	58.70	39.90	8.00	10.80	98	0.33	0.17	40	1.88	0.22	36,125	90.21	4.24	0.50
		47.90				64	0.33	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	5	58.70	39.90	8.00	10.80	98	0.1	0.01	40	1.88	0.22	2,835	7.08	0.33	0.04
		47.90				64	0.1	0.00	40	1.88	0.22	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Nov	16	58.70	39.90	8.00	10.80	98	0.04	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.04	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	17	58.70	39.90	8.00	10.80	98	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	22	58.70	39.90	8.00	10.80	98	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Nov	26	58.70	39.90	8.00	10.80	98	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
		47.90				64	0.03	0.00	40	1.88	0.22	0	0.00	0.00	0.00
Dec	1	58.70	39.90	8.00	10.80	98	0.33	0.17	57	1.97	0.21	36,125	128.55	4.44	0.47
		47.90				64	0.33	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	3	58.70	39.90	8.00	10.80	98	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.02	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	4	58.70	39.90	8.00	10.80	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	5	58.70	39.90	8.00	10.80	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	6	58.70	39.90	8.00	10.80	98	0.22	0.08	57	1.97	0.21	17,850	63.52	2.20	0.23
		47.90				64	0.22	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	11	58.70	39.90	8.00	10.80	98	0.4	0.23	57	1.97	0.21	48,805	173.67	6.00	0.64
		47.90				64	0.4	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	12	58.70	39.90	8.00	10.80	98	0.31	0.15	57	1.97	0.21	32,624	116.09	4.01	0.43
		47.90				64	0.31	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	13	58.70	39.90	8.00	10.80	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	16	58.70	39.90	8.00	10.80	98	0.33	0.17	57	1.97	0.21	36,125	128.55	4.44	0.47
		47.90				64	0.33	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	18	58.70	39.90	8.00	10.80	98	0.06	0.00	57	1.97	0.21	351	1.25	0.04	0.00
		47.90				64	0.06	0.00	57	1.97	0.21	0	0.00	0.00	0.00

Daily LC Scenario Loadings - Institutional

Date		Area (acres)				CN_W	P (in)	Q (in)	EMC (mg/L)			Runoff (ft^3)	Loading (lbs)		
		Total Area [1]	Road	Other Imp [2]	Roof				TSS	TN	TP		TSS	TN	TP
Dec	19	58.70	39.90	8.00	10.80	98	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
		47.90				64	0.01	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	25	58.70	39.90	8.00	10.80	98	0.12	0.02	57	1.97	0.21	4,717	16.78	0.58	0.06
		47.90				64	0.12	0.00	57	1.97	0.21	0	0.00	0.00	0.00
Dec	26	58.70	39.90	8.00	10.80	98	0.08	0.01	57	1.97	0.21	1,345	4.79	0.17	0.02
		47.90				64	0.08	0.00	57	1.97	0.21	0	0.00	0.00	0.00