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NUTRIENT AND CARBON LOADING IN GROSS SOLIDS IN URBAN CATCH BASINS

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ABSTRACT

Title: Nutrient and Carbon Loading in Gross Solids in Urban Catch Basins

Gross solids are particles comprising organic debris, litter, and coarse sediments. Examples include leaf matter, plastic, and fragments of soil. Gross solids are conveyed by storm drainage networks. Currently, there are no data quantifying the pollutant loads in debris collected from urban catch basins in North Carolina. Sixteen basins were monitored (four each in Burlington, Greensboro, Raleigh, and Wilmington, North Carolina) to establish baseline pollutant loads in gross solids, determine which of the monitored land uses contributed the largest pollutant loads, and develop maintenance recommendations for collecting gross solids. The basins drained four land uses including high-density residential, low-density residential built before 1990 and after 2000, and urban/ downtown. Two forms of the low-density land use were monitored for comparisons between established and newly planted trees. Collected debris samples were composited and analyzed for the following: total nitrogen (TN), total phosphorus (TP), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), nickel (Ni), lead (Pb), and total carbon (TC). Maximum cumulative annual TN, TP, and TC loads were 6.14, $54.60*10^{-2}$, and 206.12 lb ac^{-1} yr^{-1}, respectively. Using previous research identifying the nutrient content and leaching rates of leaf matter for certain tree species, labile TN and TP loads from debris were estimated. Labile loads were then compared with typical aqueous TN and TP loads in stormwater runoff from previous studies. Labile loads from debris contributed a maximum of 12.7% of a watershed's total aqueous (stormwater + labile) pollutant load. As a result, collecting gross solids appears to only modestly improve downstream water quality.

Maximum cumulative annual Fe, Zn, Mn, Cu, Ni, and Pb loads in collected debris were: $31.59*10^{-1}$, $14.68*10^{-2}$, $24.56*10^{-2}$, $16.68*10^{-3}$, $28.59*10^{-4}$, and $184.05*10^{-4}$ lb ac^{-1} yr^{-1}, respectively. Overall, baseline pollutant loads were identified in gross solids, and statistical analyses showed pollutant loads were affected by location, land use, and season. Differences among loads were attributed to variations in rainfall, street sweeping frequencies, and tree abundance. Additionally, it was determined the downtown land use contributed the largest pollutant loads. Possible explanations for these results include downtown sites had the largest recorded average annual daily traffic (AADT) volumes and most tree abundance. Based upon this research, it is suggested municipalities continue to street sweep the downtown land use. More importantly, municipalities should consider allocating their resources to downtown streets with extensive overhanging tree canopy and abundance. On average, samples from the downtown land use were collected every 15 days and received a daily volume of solids ranging from 0.06 to 0.09 ft^3 day^{-1}. Based on the analyses, it is recommended, at a minimum, downtown streets are swept weekly. However, other factors including sweeper and operator efficiencies, overhanging tree canopy, financial resources, and typical durations between storm events should also be evaluated. Piedmont municipalities may also consider sweeping more frequently during autumn. In contrast, Coastal Plain municipalities may be better served if sweeping was more frequent during winter. Additionally, municipalities may consider retrofitting catch basins draining the low-density residential land use built before 1990 with proprietary units designed specifically to trap gross solids. To decrease maintenance frequency, it is recommended devices that collect solids using the entire basin volume should be installed.

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INTRODUCTION

1.1 Introduction

Urbanization degrades water quality by introducing pollutants that are transported via stormwater conveyance systems to surface water bodies (US EPA, 2000; Goonetilleke et al., 2005; Leopold, 1968). Urbanization alters the volume, quality, and peak flow characteristics of stormwater runoff which increases sediment yield and the accumulation of litter in water bodies (Leopold, 1968; Armitage and Rooseboom, 2000). Pollutants and litter disrupt the existing biota, degrade aesthetics, and increase the risk of entanglement, ingestion, or suffocation of aquatic fauna. To counteract the impacts of urbanization and manage pollutants discharged to downstream water bodies, the Clean Water Act (CWA) was established in 1972 to require National Pollution Discharge Elimination Systems (NPDES) permits for all municipal stormwater discharges (US EPA, 2000).

Per federal and state regulations, many municipalities must implement stormwater management programs that prevent pollution, maintain stormwater infrastructure, and manage stormwater for new development and redevelopment (US EPA, 2000; NCDENR, 2009). For example, total nitrogen (TN) and total phosphorus (TP) discharge limits have been imposed on post-development sites within several nutrient sensitive watersheds in North Carolina (NCDENR, 2009, (Table 1.1).

Table 1.1: Nutrient Limits for North Carolina Watersheds (NCDENR, 2009)

Watershed	TN (lb/ac/yr)	TP (lb/ac/yr)
Falls Lake	2.19	0.33
Haw	3.84	1.43
Neuse River Basin	3.60	-

Often stormwater control measures (SCMs) such as bioretention cells, wetlands, detention or retention ponds, and grassed swales are used to comply with regulations. The effectiveness of SCMs are typically evaluated with automated water quality samplers that cannot effectively sample particles greater than 250 µm in diameter (Clark et al., 2009). Moreover, a significant amount of stormwater is still managed by gray infrastructure that includes catch basins (Roy et al., 2008; Backstrom et al., 2002). Research by Smith (2010) and Hobbie et al. (2014) suggests current sampling techniques do not account for loads contributed by particulate-bound pollutants. A comprehensive peer-reviewed study quantifying the loads from particulate-bound pollutants, or gross solids, which are not able to be sampled ~~un-sample-able~~ using typical measures has not been completed in North Carolina.

1.2 Defining Gross Solids

Particles with a minimum diameter of 1/4 inch have been defined as gross solids (Urban Water Resources Research Council Gross Solids, 2009; Roesner et al., 2007; Allison et al., 1998; Smith, 2010). Limited published research exists on these particulate-bound pollutants, which are characterized as either organic debris, litter, or coarse sediments (Urban Water Resources Research Council Gross Solids, 2009, (Table 1.2)).

Table 1.2: Gross Solids Categories (Urban Water Resources Research Council, 2009)

Category	Examples
Organic Debris	Leaves, branches, twigs, seeds, grass clippings
Litter	Styrofoam, paper, plastic, metal, glass
Coarse Sediments	Fragments of soil, pavement and building materials

1.3 Nutrient Content of Organic Debris

Previous research has focused on quantifying the nutrient content in leaf matter. Mitchell (1936) collected leaves from trees in the Black Rock Forest of Cornwall, New York, during the 1935 growing season. He analyzed TN and TP, the leaves' dry weight, and moisture content. He determined the average percentage of TN and TP in dry leaf weight ranged from 1.9 to 3.0% and from 0.2 to 0.3%, respectively. Similar to Mitchell (1936), Chandler (1941) collected freshly fallen leaves between October and November from hardwood forests in central New York. He found TN and TP contents varied from 0.41 to 1.04% and from 0.08 to 0.29%, respectively. Results from Mitchell (1936) and Chandler (1941) illustrate more TN than TP exists in leaf matter.

1.4 Leachable TN and TP from Organic Debris

Studies by Dorney (1986) and Cowen and Lee (1973) simulated the effects of urban runoff, for leachable TP analyzed by soaking leaves in distilled water. Dorney (1986) found an average leachable P concentration of 148.1 $\mu g\ g^{-1}$ of dry leaf weight, for tree species in Milwaukee and Shorewood, Wisconsin. Similarly, Cowen and Lee (1973) compared oak and poplar leaves from Madison, Wisconsin, and determined 140 $\mu g\ g^{-1}$ of dry leaf weight of total soluble P leached from poplar leaves. They also found that intact oak leaves leached less reactive soluble P (230 $\mu g\ g^{-1}$ of dry leaf weight) than cut oak leaves (650 $\mu g\ g^{-1}$ of dry leaf weight).

In addition to studying leachable nutrients, Hobbie et al. (2014) determined decomposition rates for five deciduous tree species in St. Paul, Minnesota. They found at least 78% of N and P was decomposed at a "slow" rate. However, decomposition occurred more quickly in the monitored parking lot storm drain than in nearby forests, which was attributed to a combination of urban

temperatures, higher initial concentrations, and leaf fragmentation caused by vehicles. Hobbie et al. (2014) determined an average total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) concentration of 0.000854 g g^{-1} of dry leaf weight and 0.000657 g g^{-1} of dry leaf weight, respectively were leached after soaking leaves for 24 hr. Results from Dorney (1986), Cowen and Lee (1973), and Hobbie et al. (2014) show leaf matter leaches nutrients; more details regarding these studies are included in Appendix C.

1.5 Organic Debris in Stormwater

Organic debris and labile nutrients in stormwater runoff were examined by Allison et al. (1998), who monitored for gross solids collected in a hydrodynamic separator in Coburg, Victoria, Australia. Approximately 80% of the collected solids were leaf matter (Table C.7). Average concentrations of TN and TP in debris were estimated as 0.11 mg L^{-1} and 0.01 mg L^{-1}, respectively. Water quality was also monitored within the catchment; TN and TP concentrations ranged from 1.5 to 4.0 mg L^{-1} and from 0.3 to 0.6 mg L^{-1}, respectively. Allison et al. (1998) concluded that with an estimated leaching rate ranging from 5 to 20% the nutrient load from the collected leaf matter was approximately two orders of magnitude smaller than the loads associated with stormwater (Appendix C).

Smith (2010) monitored effluent from a baffle box in Rockledge, Florida. Hydrology and water quality samples for the water column were obtained with ISCO 6712 automated stormwater samplers coupled with an ISCO 750 area-velocity flow meter and compared to sediment and gross solids trapped by the device. Smith (2010) determined excluding the chamber and screen results would underestimate the reduction of pollutants discharged from the baffle box (Table 1.3). Despite somewhat conflicting conclusions, results from Allison et al. (1998) and Smith (2010) suggest leaf matter contributes nutrients loads to the water column.

Table 1.3: Baffle Box Pollutant Mass Removals (Smith, 2010)

Constituent	Chambers + Screen[a] (g)	Water[b] Column (g)	Ratio Water Column to Chambers+Screen
Non-dissolved Solids	$1.18*10^6$	$4.41*10^4$	0.037
TN	$1.70*10^3$	$-3.45*10^2$	-0.20
TP	$6.44*10^2$	-34.0	-0.053
Chromium	$1.20*10^2$	-0.46	-0.004
Copper	27.8	-2.85	-0.10
Nickel	3.92	-	-
Zinc	$1.51*10^2$	57.5	0.38
Mercury	0.06	-	-

[a] Solids trapping devices

[b] Negative values correspond to exported pollutant mass from baffle box

1.6 Street Sweeping for Gross Solids

US EPA (2014b) and Marais et al. (2004) recommended street sweeping as an effective tool to remove gross solids from impervious surfaces. Previous research has indicated street sweeper removal efficiencies increase as sediment particle size increases; these efficiencies ranged from 31 to 94% (Breault et al., 2005; Sartor et al., 1974; Selbig and Bannerman, 2007).
While past street sweeper studies have focused on sediment, Kalinosky et al. (2014) began quantifying the removal of nutrient loads from swept leaves in Prior Lake, Minnesota. Their preliminary results found recovered cumulative TP loads increased from 4.1 lb curb-mile^{-1} to 9.8 lb curb-mile^{-1} as tree canopy increased along routes. Coarse particles accounted for 91% and 67% of removed TN and TP, respectively. Additionally, Kalinosky et al. (2014) has drafted a model utilizing tree canopy coverage and curb miles swept to estimate the annual loads of N and P associated with swept solids.

RESEARCH OBJECTIVES

The review of literature determined nutrients exist in leaf matter, leaf litter is a part of gross solids, and gross solids are conveyed by storm drainage networks. Thus a need exists to comprehensively study gross solids in North Carolina. The primary goal of this research was to quantify the pollutant loads in organic debris collected from urban catch basins in four cities in North Carolina. The first objective was to establish a baseline for pollutant loads in gross solids. The second objective was to identify which monitored land uses contributed the largest pollutant loads, which in turn led to the third objective: the identification of maintenance regimens for gross solids collection.

MATERIALS AND METHODS

3.1 Study Areas

The project sites were located in Burlington, Greensboro, Raleigh, and Wilmington, North Carolina (Figure 3.1, Table 3.1). Four catch basins draining land uses of interest were monitored in each city from January 2014 to March 2015. The monitored land uses included:

- High-density residential
- Low-density residential built before 1990
- Low-density residential built after 2000
- Urban/Downtown

Two forms of the low-density residential land use were monitored for the comparison between established and newly planted trees.

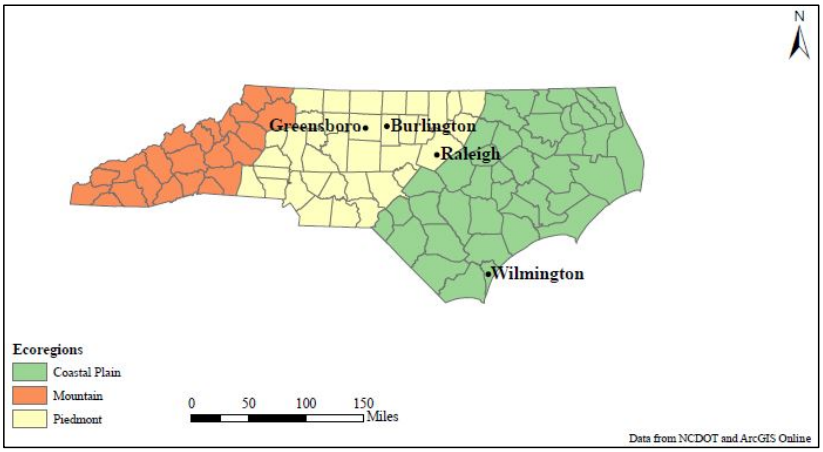

Figure 3.1: Study Areas within North Carolina

Table 3.1: Summary of Study Location's Normal Climate Data and Populations

Municipality	Normal Annual Precipitation[a] (in)	Normal Annual Temperature[a] (°F)	2013 Population[b]
Burlington	45.0	59.2	51,510
Greensboro	43.1	58.1	279,639
Raleigh	46.4	59.5	431,746
Wilmington	57.0	63.9	112,067

[a] State Climate Office of North Carolina (2015), 1971-2000
[b] U.S. Census Bureau (2015)

3.2 Site Selection and Characterization

Municipal officials assisted with catch basin selection to verify the inlets drained the characteristic land use, were maintained by the municipality, provided safe access, and possessed a curb throat inlet (Figure 3.2). Also for each land cover, efforts were made to choose sites with comparable traits such as watershed area. Basins with combination inlets (Figure 3.2) were not selected to ensure all gross solids were captured by the collection device fabricated by NC State.

Figure 3.2: Combination Inlet (not used), Curb Throat Inlet (used)

Total station surveys (Sokkia Set 530R) and ArcGIS data were used to delineate the basins' drainage areas (Appendix D). When applicable, ranges of average annual daily traffic (AADT) volumes were estimated from interactive maps that included automatic traffic counter data (North Carolina Department of Transportation, 2015). Methods from Berland and Hopton (2014) were used to approximate tree canopy located in rights-of-way and municipal land (Equation 3.1); residents did not allow access onto their property. Data from Hansen et al. (2013) were also

used to estimate basal area, and tree species were identified by a certified local arborist for each site. Details regarding tree species (USDA-NRCS, 2015; NC Cooperative Extension, 2015) are summarized in Appendix D. Rainfall occurring between sampling events was obtained from local weather stations (State Climate Office of North Carolina, 2015).

$$TC = \left(\frac{DBH}{200}\right)^2 * \pi * 10.76 \quad (3.1)$$

Where:
TC= Tree canopy (ft^2)
DBH= Tree diameter at breast height (m)

3.3 High-Density Residential Land Use

The high-density residential land use (hereafter referred to as high-density) had dwellings located on an average parcel size of 0.14 ac with an average watershed area of 1.01 ac (Figure 3.3). Sites monitored in this land use had percent impervious coverage that ranged from 32.2 to 78.6%, and percent directly connected impervious areas (DCIAs) that varied from 16.5 to 72.7% (Table 3.2). Hereinafter, the basins draining this land use in Burlington, Greensboro, Raleigh, and Wilmington will be referred to as sites B-HD, G-HD, R-HD, and W-HD, respectively. Appendix D provides more details regarding each monitored location.

Figure 3.3: Clockwise from top left Site: B-HD, G-HD, R-HD, and W-HD

Table 3.2: High-Density Site Characteristics

Characteristic	**Site**			
	B-HD	G-HD	R-HD	W-HD
Average Parcel Area (ac)	0.05	0.15	0.25	0.12
CRONOS Weather Station[a]	KBUY-ASOS	NCAT-ECONET	LAKE-ECONET	KILM-ASOS
Total Rainfall During Monitoring Period[a] (in)	31.94	34.74	61.03	63.01
Monitoring Period (yr)	1.13	1.12	1.14	1.10
Total Watershed Area (ac)	0.54	0.35	0.17	2.99
Street Area (ac)	0.20	0.02	0.07	0.40
Length of Curb (mi)	0.12	0.03	0.04	0.24
Percent Pervious Area (%)	22.7	21.4	28.6	67.8
Percent Impervious Area (%)	77.3	78.6	71.4	32.2
Percent DCIA (%)	72.7	71.4	57.1	16.5
Measured Tree Canopy (ft^2)	-	-	4.31	83.10
Tree Abundance	3.0	1.0	4.0	15.0

[a] State Climate Office of North Carolina (2015)

3.4 Low-Density Residential Built Prior to 1990 Land Use

Homes situated in the low-density residential land use built before 1990 (hereinafter referenced as low-density old) were located on an average parcel size of 0.36 ac with an average watershed area of 1.38 ac (Figure 3.4). Sites monitored in this land use had percent impervious coverage ranging from 18.2 to 100% and percent DCIAs varying from 7.3 to 100% (Table 3.3). The large percent impervious was the result of pervious areas draining away from the basin in the Greensboro watershed.

Due to reoccurring flooding, sampling of the initial Raleigh basin ceased after 70 days, and data collected from this site were not included in statistical analyses. Monitoring of a new catch basin began March 2014. For identification purposes, the storm inlets draining this land cover in Burlington, Greensboro, Raleigh, and Wilmington will be referred to as sites B-LDO, G-LDO, R-LDO, and W-LDO, respectively. Further descriptions of these sites are summarized in Appendix D.

Figure 3.4: Clockwise from top left Site: B-LDO, G-LDO, R-LDO, and W-LDO

Table 3.3: Low-Density Old Site Characteristics

Characteristic	Site			
	B-LDO	G-LDO	R-LDO	W-LDO
Average Parcel Area (ac)	0.32	0.32	0.44	0.35
CRONOS Weather Station[a]	KBUY-ASOS	NCAT-ECONET	REED-ECONET	KILM-ASOS
Total Rainfall During Monitoring Period[a] (in)	30.14	31.41	49.26	63.01
Monitoring Period (yr)	1.13	1.12	0.96	1.10
Total Watershed Area (ac)	1.98	0.30	1.56	1.71
Street Area (ac)	0.20	0.30	0.37	0.15
Length of Curb (mi)	0.09	0.17	0.17	0.13
Percent Pervious (%)	62.5	0	52.4	43.6
Percent Impervious (%)	37.5	100.0	47.6	18.2
Percent DCIA (%)	23.8	100.0	31.7	7.3
Measured Tree Canopy (ft^2)	8.29	-	-	74.59
Tree Abundance	4.0	8.0	11.0	37.0

[a] State Climate Office of North Carolina (2015)

3.5 Low-Density Residential Built After 2000 Land Use

The low-density residential land use built after 2000 (hereafter referenced as low-density new) had homes located on an average parcel area of 0.36 ac with an average watershed area of 0.63 ac (Figure 3.5). Sites draining this land use had impervious coverage varying from 50 to 60.5%, and percent DCIAs ranging from 40 to 52.6% (Table 3.4); sites' tree canopy was not accessible for measurements. Hereinafter, the basins for this land use in Burlington, Greensboro, Raleigh, and Wilmington will be referred to as sites B-LDN, G-LDN, R-LDN, and W-LDN, respectively (Figure 3.5). Appendix D provides more details about each basin.

Figure 3.5: Clockwise from top left Site: B-LDN, G-LDN, R-LDN, and W-LDN

Table 3.4: Low-Density New Site Characteristics

Characteristic	**Site**			
	B-LDN	G-LDN	R-LDN	W-LDN
Average Parcel Area (ac)	0.35	0.27	0.44	0.37
CRONOS Weather Station[a]	KBUY-ASOS	NCAT-ECONET	REED-ECONET	KILM-ASOS
Total Rainfall During Monitoring Period[a] (in)	31.94	34.74	56.48	56.81
Monitoring Period (yr)	1.13	1.12	1.14	1.10
Total Watershed Area (ac)	0.40	0.94	0.25	0.94
Street Area (ac)	0.10	0.12	0.05	0.25
Length of Curb (mi)	0.04	0.06	0.04	0.10
Percent Pervious (%)	50.0	47.4	50.0	39.5
Percent Impervious (%)	50.0	52.6	50.0	60.5
Percent DCIA (%)	50.0	52.6	40.0	42.1
Tree Abundance	3.0	3.0	5.0	10.0

[a] State Climate Office of North Carolina (2015)

3.6 Urban/Downtown Land Use

In contrast to the previous land covers, the urban or downtown land use (hereafter referred to as downtown) was composed of businesses rather than residences. The average parcel size and watershed area were 1.92 and 1.49 ac, respectively (Figure 3.6). Catch basins draining this land use were surrounded by percent impervious coverage varying from 75 to 88.9%, and percent DCIA ranging from 46 to 77.6% (Table 3.5). Due to reoccurring flooding, monitoring of the initial Raleigh basin ceased after 89 days, and data collected from this site were not included in statistical analyses. Sampling of a new catch basin in this municipality began April 2014. For identification purposes, basins in this land use for Burlington, Greensboro, Raleigh, and Wilmington will be referenced as sites B-DT, G-DT, R-DT, and W-DT, respectively. Appendix D includes more specifics about each site.

Figure 3.6: Clockwise from top left Site: B-DT, G-DT, R-DT, and W-DT

Table 3.5: Downtown Site Characteristics

Characteristic	Site			
	B-DT	G-DT	R-DT	W-DT
Average Parcel Area (ac)	3.95	2.99	0.52	0.22
CRONOS Weather Station[a]	KBUY-ASOS	NCAT-ECONET	LAKE-ECONET	KILM-ASOS
Total Rainfall During Monitoring Period[a] (in)	23.83	31.52	51.80	33.02
Monitoring Period (yr)	1.13	1.12	0.92	1.10
Total Watershed Area (ac)	1.66	0.67	1.56	2.08
Street Area (ac)	0.44	0.12	0.44	0.42
Length of Curb (mi)	0.16	0.06	0.12	0.14
Percent Pervious (%)	22.4	11.1	19.0	25.0
Percent Impervious (%)	77.6	88.9	81.0	75.0
Percent DCIA (%)	77.6	70.4	46.0	72.6
Estimated Tree Canopy (ft^2)	236.38	21.96	160.60	32.18
Tree Abundance	9.0	7.0	21.0	12.0
AADT Volume Range[b]	5000-9999	2000-4999	5000-9999	2000-4999

[a] State Climate Office of North Carolina (2015)
[b] North Carolina Department of Transportation (2015)

3.7 Sampling Design

Gross solids were collected using custom-made traps comprised of 1/4 inch wire mesh, lumber, and a corrugated plastic pipe with perforations (Figure 3.7). The lumber provided structural support, and the perforated pipe was included as an emergency overflow to prevent flooding. The traps were configured perpendicular to the incoming runoff and solids (Figure 3.8).

Figure 3.7: Clockwise from top: Lumber, Mesh, and Assembled Trap

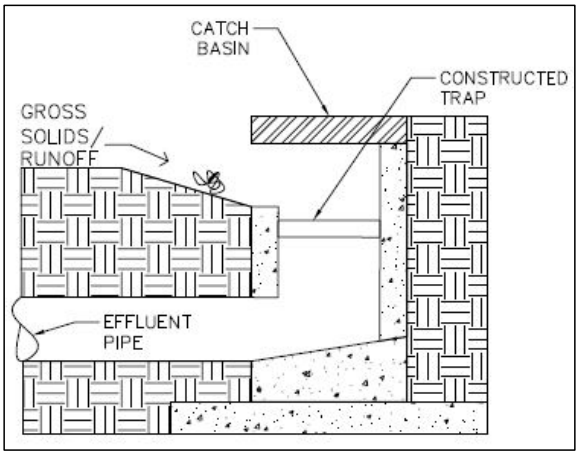

Figure 3.8: Side View of Assembled Trap (not to scale)

3.8 Sample Collection

On average, samples were collected every 15 days by hand and or with a portable vacuum (60.5-L Shop-Vac 975-63-11) powered by a gasoline generator (2000W Honda EU2000i). Each

sample was then placed in a clean 40 gal bag marked with the collection date and site identity. After collecting each sample, the vacuum was cleaned to ensure that sample cross-contamination did not occur, and the functionality of the traps was verified. Samples were then transported to NC State campus for sorting and preliminary analysis.

3.9 Sample Analysis

All litter and coarse sediments were removed prior to sample analysis. A sorting technique was developed to obtain a composite sample of the collected leaf matter that was representative of the entire debris sample and could be replicated regardless of the sample size (Appendix E). The composite debris samples were then transferred to the NCDA&CS Agronomic Services Division Laboratory in Raleigh, North Carolina, for chemical analysis.

All transferred samples were composited by the laboratory such that only a subsample of approximately 15.3 in^3 was analyzed (NCDA&CS, 2013). The subsample was weighed (Mettler PM4800), dried overnight at 176°F for 12 to 24 hr, and reweighed. The leaves, including the stems, were then ground with a stainless steel grinder (Intermediate Wiley Mill) to pass through a 0.04 in screen. The ground solids were analyzed for the following: TN, TP, iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni), lead (Pb), and total carbon (TC).

Oxygen combustion gas chromatography with an elemental analyzer (NA1500) was used to identify the TN and TC concentrations from 5 to 10 mg of the ground subsample (NCDA&CS, 2013). For most metals and TP, 0.5 g of the ground subsample (1.0 g for Ni and Pb) were digested in 10 mL of 15.6N HNO_3 for 5 to 30 min in a microwave digestion system (MARS & MDS2100; CEM Corporation), brought to a volume of 50 mL with deionized water, and then analyzed using an inductively coupled plasma (ICP) spectrophotometer (Optim 3300 DV; Perkin Elmer Corporation). All results were reported on a dry-weight basis (in ppm) with an equivalence to mg kg^{-1}. Moisture contents derived from reported sub-composite dry and wet weights were used to determine the dry weights of the collected debris samples using Equations 3.2 and 3.3 (ASTM Standard D4442, 2007). Due to financial restrictions, composite samples were evaluated for Ni and Pb every second analysis.

$$MC = \left(\frac{A - B}{B}\right) * 100\% \quad (3.2)$$

Where:
MC= Moisture content (%)
A= Original weight (g)
B= Oven-dried weight (g)

$$D = \left(\frac{W}{1 + MC}\right) * 100\% \quad (3.3)$$

Where:
D= Dry-weight debris sample (lb)
W= Wet-weight debris sample (lb)
MC= Moisture content

3.10 Monitoring Challenges

Challenges did occur throughout the monitoring period. As previously noted, flooding was a reoccurring issue. Probable causes for the flooding were watersheds with excess sediment and traps with clogged mesh (Figure 3.9).

Figure 3.9: Flooding at Initial Raleigh Sites

A more prominent issue was broken traps due to poor structural support (Figure 3.10). Traps broke 24 times throughout the study and impacted 6% of the sampling events. The issue was corrected by adjusting the angle of the mesh and lumber (Figure 3.11) and by adding additional cross braces. Broken traps resulted in the total weight and volume of the sample to be underestimated; these samples were omitted from statistical analyses. Additionally, corresponding rainfall data was not recorded.

Figure 3.10: Broken Trap at Site W-DT (left) and Site B-DT (right)

Figure 3.11: Plan View of Altered Trap Design

3.11 Data Analysis

Pollutant loads for each sample were calculated with Equation 3.4; annual pollutant loads were determined from Equation 3.5 for general comparisons between sites. Average annual loads for each land use and pollutant were found using Equation 3.6.

$$PL = \frac{\left(\frac{X * D}{1000^2}\right) * 2.20}{A} \quad (3.4)$$

Where:
PL= Pollutant load (lb/ac)
X= Reported pollutant concentration (mg/kg)
D= Dry weight of debris sample (kg)
A= Watershed area (ac)

$$AL = \left(\frac{\sum_{i=1}^{n} PL_i}{M}\right) * 365 \quad (3.5)$$

Where:
AL= Annual pollutant load (lb/ac/yr)
L= Pollutant load (lb/ac)
M= Monitoring period (days)

$$AL = \frac{(LB + LG + LR + LW)}{4} \quad (3.6)$$

Where:
AL= Average pollutant load (lb/ac/yr)
LB= Annual pollutant load collected from Burlington site (lb/ac/yr)
LG= Annual pollutant load collected from Greensboro site (lb/ac/yr)
LR= Annual pollutant load collected from Raleigh site (lb/ac/yr)
LW= Annual pollutant load collected from Wilmington site (lb/ac/yr)

Pollutant loads were normalized by both the total watershed area and only the street area within the watershed. The data never followed a normal distribution despite transformations, and studentized residual plots indicated extreme values that were characteristic of a gamma distribution. Therefore, a PROC GLIMMIX model fitting a gamma distribution was built using SAS 9.4© to make statistical inferences about each normalized load (Equation 3.7); significance was established at α=0.05 for all inferences. Convergence of the model was determined with the restricted maximum likelihood method (SAS Institute Inc., 2014). Sampling dates were included as a factor but not as a main effect because dates were a source of a variability and could be grouped into seasons. Interaction effects were modeled as the interactions between location, land use, and season, respectively. Residuals were the random effects in the model, and it was assumed equally correlated residuals were modeled. Table 3.6 summarizes the levels of the main effects used in the PROC GLIMMIX model (Equation 3.7), and sample code is provided in Appendix N.

Table 3.6: Main Effects and Levels for PROC GLIMMIX Model

Main Effect	Number of Levels	Level Description
Land Use	4	High-Density, Low-Density Old, Low-Density New, Downtown
Location	4	Burlington, Greensboro, Raleigh, Wilmington
Season	4	Fall, Spring, Summer, Winter

Type III tests were used to determine the significance of the fixed effects, and Tukey's Honest Significant Difference (HSD) with a Tukey-Kramer adjustment was used for multiple pair-wise comparisons between the computed Least squares means (LSMEANS) or estimated population marginal means. Population represents all of the possible collected samples, and marginal refers to the averaging of other factors' effects to find the LSMEAN of interest. LSMEANS were calculated using the PROC GLIMMIX model (Equation 3.7), where each parameter's estimate was adjusted for the model's other effects. Predicted loads rather than actual loads are needed for statistical analyses and are used to compare differences among multiple groups within the data. Land uses contributing the largest pollutant loads were determined using the Gupta-Hsu method (Gupta and Hsu, 1984). Refer to Appendix H for more details regarding the Gupta-Hsu method. The PROC GLIMMIX model used is as follows:

$$Pollutant = Location + Land_Use + (Location * Land_Use) + Season + (Season * Location) \quad (3.7)$$

Where:
Location= Municipality sample was collected from
Land_Use= Land use sample was collected from
Season= Season sample was collected during
Location*Land_Use= Interaction between location and land use
Season* Location= Interaction between season and location
Pollutant= Pollutant load (lb/ac)

RESULTS AND DISCUSSION

4.1 Number of Samples per Land Use

There were 394 samples collected from unbroken traps that were processed by the NCDA&CS laboratory during the monitoring period, and all were included in the statistical analyses of the pollutant loads with the previously noted exceptions of Ni and Pb (Table 4.1). Due to financial restrictions, only 185 samples were used in the Ni and Pb load analyses.

Table 4.1: Number of Samples per Land Use and Location

Location	**Land Use**				
	High-Density	Low-Density Old	Low-Density New	Downtown	**Total**
Burlington	21	24	22	20	87
Greensboro	20	22	25	23	90
Raleigh	28	34	31	32	125
Wilmington	26	25	24	17	92
Total	95	105	102	92	**394**

4.2 Nutrient Loads

4.2.1 TN

Annual TN loads ranged from 0.13 to 3.86 lb ac^{-1} yr^{-1} (Table 4.2). For the Piedmont municipalities, loads from the low-density old land use were the largest among residential land covers. Differences among Wilmington's residential loads were attributed to the total debris load collected from each site; the smallest and largest loads were sampled from the low-density old and high-density land use, respectively. Also, downtown sites yielded the largest loads for Burlington and Raleigh. Overall, the smallest and largest cumulative TN loads were collected in Burlington and Greensboro, respectively.

Table 4.2: Annual and Cumulative TN Loads from Collected Debris

Location	Land Use	TN Load (lb/ac/yr)	Cumulative TN Load (lb/ac/yr)
Burlington	High-Density	0.13	1.26
	Low-Density Old	0.38	
	Low-Density New	0.19	
	Downtown	0.56	
Greensboro	High-Density	0.17	6.14
	Low-Density Old	3.86	
	Low-Density New	0.62	
	Downtown	1.49	
Raleigh	High-Density	0.80	4.77
	Low-Density Old	1.27	
	Low-Density New	0.85	
	Downtown	1.86	
Wilmington	High-Density	1.30	3.51
	Low-Density Old	0.56	
	Low-Density New	0.66	
	Downtown	0.98	

Average annual TN loads varied between 0.58 and 1.52 lb ac^{-1} yr^{-1} (Table 4.3). Average loads collected from the high-density and low-density new land uses were comparable. Also, the low-density old average load was larger than the downtown average load; this difference was attributed to the load collected from Greensboro's low-density site. This site had the second smallest monitored watershed and was not reflective of the watershed contributing the collected organic debris.

Table 4.3: Average Annual TN Load per Land Use

Land Use	Average TN Load (lb/ac/yr)
High-Density	0.60
Low-Density Old	1.52
Low-Density New	0.58
Downtown	1.22

LSMEANS for the land uses within each city or for the interaction between land use and location are shown in Figure 4.1 and Table 4.4. These LSMEANS are also known as estimated population

marginal means, where population represents all of the possible samples collected, and marginal refers to the averaging of other factors' effects. LSMEANS were calculated using the PROC GLIMMIX model (Equation 3.7), where each parameter estimate was adjusted for the model's other effects. Predicted loads rather than actual loads are needed for statistical analyses and are used to compare statistical differences among multiple groups within data. It is important to note these estimated values represent the pollutant load within a collected debris sample.

Except for Greensboro, the largest TN load from a sample was collected from the downtown sites. For the Piedmont residential land uses, the most TN was collected from watersheds draining the low-density old land cover. In contrast, the largest TN load sampled from Wilmington's residential land uses was collected from the high-density site.

Commented [LW1]: Am I missing something? Looks like largest in Wilmington is from downtown – clarify? Diff between predicted and actual?

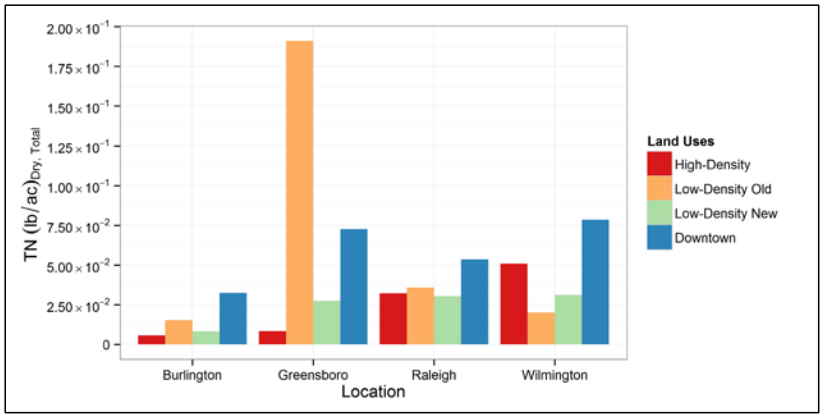

Figure 4.1: Predicted TN Loads for Location*Land Use Effect

Table 4.4: Predicted TN Loads per Location and Land Use

Location	Land Use	Predicted TN Load*10^{-2} (lb/ac)
Burlington	High-Density	0.57
	Low-Density Old	1.52
	Low-Density New	0.82
	Downtown	3.25
Greensboro	High-Density	0.84
	Low-Density Old	19.10
	Low-Density New	2.74
	Downtown	7.26
Raleigh	High-Density	3.21
	Low-Density Old	3.57
	Low-Density New	3.03
	Downtown	5.36
Wilmington	High-Density	5.08
	Low-Density Old	2.01
	Low-Density New	3.12
	Downtown	7.85

The interaction between location and land use was significant (p-value < 0.05), indicating TN loads were affected by location and land use. Significant comparisons between LSMEANS are summarized in Table 4.5 and determine if TN loads were statistically different within locations and or among sites draining comparable land uses. Boldfaced comparisons denote loads that were significantly different among land uses in the same location.

Loads collected from Burlington's low-density new land use were statistically different from loads collected in Greensboro, Raleigh, and Wilmington. Additionally, TN loads sampled from Raleigh's and Wilmington's high-density sites were significantly different from loads collected in Burlington and Greensboro. Within Burlington, loads sampled from the downtown site were statistically different from loads collected in the high-density and low-density new land uses. In Greensboro, the TN loads retrieved from the downtown site were significantly different from loads collected from the remaining sites. Overall, these results show TN loads were statistically different, for a given location and or land use.

Table 4.5: Significant Differences between TN Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**0.0153**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Raleigh	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	Low-Density Old	Raleigh	Low-Density Old	0.0211
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	0.0004
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**0.0008**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Raleigh	High-Density	<0.0001
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	**Low-Density Old**	**Greensboro**	**Downtown**	**0.0218**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Greensboro	**Low-Density New**	**Greensboro**	**Downtown**	**0.0168**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0157**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0002**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

LSMEANS for the interaction between location and season are shown in Figure 4.2 and Table 4.6. Similar to the LSMEANS for the interaction between location and land use, these LSMEANS are the predicted TN loads for the population (all of the possible samples collected from a given location and season). For Raleigh and Wilmington, the largest loads were collected during summer. Trends between loads were similar for Burlington and Greensboro, and the largest loads were sampled during fall. It is postulated TN loads collected during winter were the largest in Wilmington because leaf fall straddles autumn and winter in the Coastal Plain, and fewer trees shed their leaves in autumn in southeastern North Carolina. Also, field observations found larger amounts of debris were collected during winter from Wilmington compared to samples collected in the Piedmont.

The interaction between location and season was significant (p-value < 0.05). This indicates seasonal effects on TN loads were also influenced by location. Further comparisons between LSMEANS found loads collected in Burlington during summer and winter were statistically different from loads collected in other locations (Table 4.7). TN loads sampled during fall in Greensboro were significantly different from loads collected in Burlington and Wilmington. Additionally, loads collected in Wilmington during summer were statistically different from loads sampled during fall and spring.

Overall, the results show TN loads collected from a particular location are affected by land use and season. More importantly, it is indicated there is potential to collect more TN in debris from certain land uses and during certain seasons. Appendix I includes details regarding TN loads normalized by street area while Appendix L summarizes predicted TN loads for each location's land use and season.

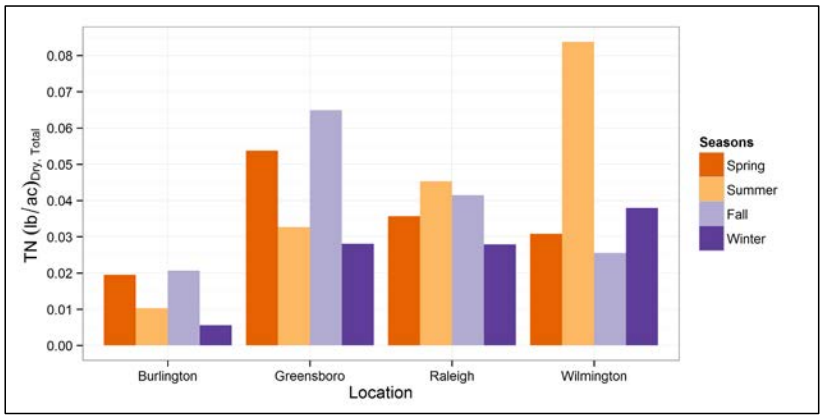

Figure 4.2: Predicted TN Loads for Location*Season Effect

Table 4.6: Predicted TN Loads per Location and Season

Location	Season	Predicted TN Load*10^{-2} (lb/ac)
Burlington	Spring	1.95
	Summer	1.03
	Fall	2.07
	Winter	0.55
Greensboro	Spring	5.38
	Summer	3.27
	Fall	6.49
	Winter	2.81
Raleigh	Spring	3.56
	Summer	4.5
	Fall	4.14
	Winter	2.79
Wilmington	Spring	3.08
	Summer	8.38
	Fall	2.55
	Winter	3.80

Table 4.7: Significant Differences between TN Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	0.0012
Burlington	**Spring**	**Burlington**	**Winter**	**0.0004**
Burlington	Spring	Greensboro	Spring	0.0176
Burlington	Summer	Greensboro	Summer	0.0032
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	Fall	Wilmington	Fall	0.0223
Wilmington	**Fall**	**Wilmington**	**Summer**	**0.0019**
Wilmington	**Spring**	**Wilmington**	**Summer**	**0.0294**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

To estimate loads in collected debris, TN concentrations were normalized by watershed area, and predicted concentration limits were found using the PROC GLIMMIX model described in Section 3.11 (Tables 4.8 and 4.9). Those who apply these concentrations must understand they are only 95% confident the collected debris' true or correct pollutant concentration is within the given interval. Note either predicted concentrations for each land use or season should be used to estimate pollutant loads in collected debris. Refer to Appendix J for an example illustrating how these concentration limits can be applied to estimate TN loads in collected debris. Also, details regarding the Excel tool incorporating these concentrations are discussed in Appendix M.

Table 4.8: TN Concentration Limits per Land Use

Land Use	Lower Limit TN (lb/lb/ac)	Upper Limit TN (lb/lb/ac)
High-Density	0.0183	0.02087
Low-Density Old	0.009887	0.01122
Low-Density New	0.0216	0.02453
Downtown	0.007168	0.008228

Table 4.9: TN Concentration Limits per Season

Season	Lower Limit TN (lb/lb/ac)	Upper Limit TN (lb/lb/ac)
Spring	0.01554	0.01768
Summer	0.01563	0.01794
Fall	0.01121	0.01274
Winter	0.01029	0.01168

State regulations require select municipalities to restrict nutrient discharge (NCDENR, 2009). TN loads exist in organic matter suggesting collecting debris may help municipalities comply with these regulations. Loads were influenced by location, land use, and season. For the Piedmont municipalities, the largest loads were collected in the downtown and low-density old land uses during fall. In Wilmington, the largest loads were sampled from the downtown and high-density land uses during summer.

The statistical analyses found both location and land use affected TN loads, and significant differences existed among loads. Greensboro's low-density old site contributed larger pollutant loads because of its watershed area that was 100% DCIA; the normalizing watershed area was also not reflective of the watershed contributing the collected leaf matter. Overall, difference in

loads can be attributed to variations in watershed characteristics that include tree abundance and variety (or lack thereof). For example, among the low-density new sites, tree abundance and variety at site B-LDN was the smallest. In turn, it had the lowest "yield" of TN from comparable sites. Published research has shown TN concentrations vary among species (Mitchell, 1936; Chandler, 1941; Hobbie et al., 2006; Gosz et al., 1973; Hobbie et al., 2014). In general, trees were more abundant and varied in the low-density old and downtown land uses and predicted TN loads were larger for sites draining these land uses.

As expected, debris loads were also larger for sites with more tree abundance and basal area. Data from Hansen et al. (2013) were used to estimate each site's tree canopy loss from 2000 to 2013. They analyzed Landsat images over time to define changes or disturbances in trees that were at least 16 ft tall. An interactive map they created showed tree canopy loss from 2000 to 2013 was greater for the low-density new land use compared to the low-density old land use (Table 4.10). In support of this, loads from the low-density new land use were typically smaller than loads yielded by low-density old sites. It can be concluded tree abundance and variety are important factors influencing loads because of the opportunity to collect more organic matter with potentially higher initial TN concentrations.

Table 4.10: Site's Tree and Debris Characteristics

Location	Land Use[a]	Measured Tree Canopy (ft^2)	Tree Quantity	Estimated Tree Loss[b]	Cumulative Debris Load (lb/ac)
Burlington	HD	-	3	Loss	12.58
	LDO	8.29	4	No Loss	33.28
	LDN	-	3	Loss	11.69
	DT	236.38	9	No Loss	58.08
Greensboro	HD	-	1	Loss	23.64
	LDO	-	8	No Loss	358.12
	LDN	-	3	Loss	75.66
	DT	21.96	7	No Loss	163.63
Raleigh	HD	4.31	4	Loss	64.24
	LDO	-	11	No Loss	105.37
	LDN	-	5	Loss	90.02
	DT	160.60	21	No Loss	217.78
Wilmington	HD	83.10	15	No Loss	136.50
	LDO	74.59	37	No Loss	49.69
	LDN	-	10	Loss	56.21
	DT	32.18	12	No Loss	132.22

[a] High-density (HD), low-density old (LDO), low-density new (LDN), downtown (DT)
[b] Estimated tree loss from 2000 to 2013 (Hansen et al., 2013)

Wilmington and Burlington sites had the largest tree canopy for residential and downtown land covers, respectively (Table 4.10). It is postulated loads from Burlington were the smallest among downtown sites (despite its basal area) because street sweeping occurred three times a week (D. Scales, personal communication, May 29, 2015); in comparison, downtown streets in Wilmington were swept bi-weekly (J. Thorpe, personal communication, July 15, 2015), and Greensboro's downtown streets were swept monthly (W. Brown, personal communication, September 10, 2015). In Raleigh, downtown streets located within the boundaries of East Street, Boylan Avenue, Jones Street, and South Street were swept weekly (D. Mailliard, personal communication, August 28, 2015). Also, residential streets maintained by the city were swept quarterly in Raleigh and Greensboro while Wilmington's residential streets were swept bi-weekly. The range in sweeping frequencies and resultant pollutant loads suggest street sweeping is important factor affecting how much debris and thus TN that can be collected. Consequently, TN concentrations were also normalized by the watershed's curb length and duration between sampling events for each land use (Table 4.11) and season (Table 4.12). Similar to loads normalized by watershed area, these predicted concentration limits were also found using the PROC GLIMMIX model described in Section 3.11. Refer to Appendix K for an example illustrating how these concentration limits can be applied to estimate TN loads in street sweepings. Also, details regarding the Excel tool incorporating these concentrations are discussed in Appendix M.

Table 4.11: Daily TN Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit TN (lb/lb/mile-day)	Upper Limit TN (lb/lb/mile-day)
High-Density	0.008553	0.010317
Low-Density Old	0.006272	0.007505
Low-Density New	0.013848	0.016596
Downtown	0.00681	0.008288

Table 4.12: Daily TN Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit TN (lb/lb/mile-day)	Upper Limit TN (lb/lb/mile-day)
Spring	0.011964	0.014386
Summer	0.01047	0.012743
Fall	0.007211	0.008648
Winter	0.005602	0.006716

Predicted TN concentrations in debris samples were found using the PROC GLIMMIX model and are included in Appendix J; these concentrations were also compared to unpublished data from Lockerman and Rubin (2015) and Stack et al. (2013).

Seasonal effects on TN loads were dependent on location, and statistical differences existed among loads. Variation in rainfall likely contributed to these differences; field observations herein showed debris collections were larger when total rainfall occurring between sampling events was larger, supporting research by Gosz et al. (1972). Table 4.13 shows the cumulative observed rainfall that occurred between sampling events for each season and location (State Climate Office of North Carolina, 2015). For Burlington and Greensboro, the largest rainfall amount occurred during spring; predicted TN loads were also the second largest during spring. In contrast, the largest total rainfall for Wilmington and Raleigh occurred during summer, when the largest TN loads were yielded. Observed total rainfall occurring between each sampling event also followed these trends (Appendix D).

Table 4.13: Cumulative Observed Rainfall between Sampling Events

Location	Season	Cumulative Rainfall[a] (in)	CRONOS Weather Station[a]
Burlington	Spring	10.79	KBUY-ASOS
	Summer	5.75	
	Fall	6.06	
	Winter	9.92	
Greensboro	Spring	12.80	NCAT-ECONET
	Summer	6.18	
	Fall	6.38	
	Winter	10.28	
Raleigh	Spring	13.70	LAKE-ECONET
	Summer	19.25	
	Fall	9.92	
	Winter	20.43	
Wilmington	Spring	12.68	KILM-ASOS
	Summer	24.69	
	Fall	8.03	
	Winter	17.60	

[a] State Climate Office of North Carolina (2015)

Lawn maintenance, particularly fertilization, may also have contributed to differences among loads. Homeowners in the North Carolina Piedmont and Coastal Plain are encouraged to fertilize

Bermuda grass from April to September and Tall fescue from February to November (NC Cooperative Extension, 2009). Additionally, Bermuda grass (*Cynodon dactylon* (L.) Pers.) should be mowed bi-weekly, and the height of Tall fescue (*Festuca arundinacea*) should be maintained at 3 in (NC Cooperative Extension, 2009). Research by Ostertag (2010) and Sword Sayer et al. (2004) determined foliar N and P increased after fertilization. Residents' maintenance strategies were not monitored but evidence of fertilization were observed during sampling events. Also, grass clippings were collected from traps draining high-density and low-density new sites during spring and summer. Significant differences among pollutant loads may also have been influenced by pollination. Both Gosz et al. (1972) and Bocock (1963) found flowers, pollen, and fruit were sources of increased N and P in decomposing leaves. When they were present, flowers were included in the processed samples collected during spring.

4.2.2 TP

Annual TP loads ranged from $1.48*10^{-2}$ to $35.20*10^{-2}$ lb ac^{-1} yr^{-1} (Table 4.14). For Burlington and Raleigh, the smallest and largest loads were collected from the high-density and downtown sites, respectively. Also, the largest loads from Greensboro and Wilmington were sampled from the low-density old and high-density land uses, respectively. With the exception of Wilmington, TP loads from the low-density old sites were larger than sites draining the low-density new land use. Similar to TN, the largest cumulative load was collected in Greensboro.

Table 4.14: Annual TP Loads from Collected Debris

Location	Land Use	TP Load*10^{-2} (lb/ac/yr)	Cumulative TP Load*10^{-2} (lb/ac/yr)
Burlington	High-Density	1.48	11.90
	Low-Density Old	3.01	
	Low-Density New	1.67	
	Downtown	5.77	
Greensboro	High-Density	1.99	54.60
	Low-Density Old	35.20	
	Low-Density New	5.08	
	Downtown	12.30	
Raleigh	High-Density	6.32	44.30
	Low-Density Old	11.70	
	Low-Density New	9.06	
	Downtown	17.20	
Wilmington	High-Density	11.90	38.30
	Low-Density Old	4.67	
	Low-Density New	6.63	
	Downtown	15.10	

Average annual TP loads for the land uses varied between $5.42*10^{-2}$ and $13.60*10^{-2}$ lb ac^{-1} yr^{-1} (Table 4.15). Average loads from the low-density old and downtown land uses were the largest. Loads sampled from the high-density and low-density new land covers were comparable; the similarity between loads from these land uses was attributed to the sites' lack of tree canopy (Table 4.10).

Table 4.15: Average Annual TP Load per Land Use

Land Use	**TP Load*10^{-2} (lb/ac/yr)**
High-Density	5.42
Low-Density Old	13.60
Low-Density New	5.61
Downtown	12.60

Figure 4.3 and Table 4.16 include predicted TP loads for the land uses in each location. Except for Greensboro, loads sampled from downtown sites were the largest. Similar to TN, loads from Wilmington's low-density new land use were larger than loads sampled from the low-density old site. Tables D.29 and D.44 show less debris was collected from site W-LDO compared to site W-LDN, respectively. Also for the Piedmont municipalities, loads collected from the high-density land use were the smallest among the residential land uses. The interaction between location and land use was significant (p-value < 0.05). Significant comparisons between LSMEANS are summarized in Table 4.17. For Burlington and Greensboro, loads sampled from the high-density and downtown land uses were statistically different. Also, loads sampled from Greensboro's low-density old and Burlington's low-density new land uses were significantly different from loads collected from the other locations. In Wilmington, loads sampled from the downtown site were statistically different from loads collected from the low-density sites. Differences in loads may have been influenced by variations in street sweeping frequencies and tree abundance that were previously discussed in Section 4.2.1.

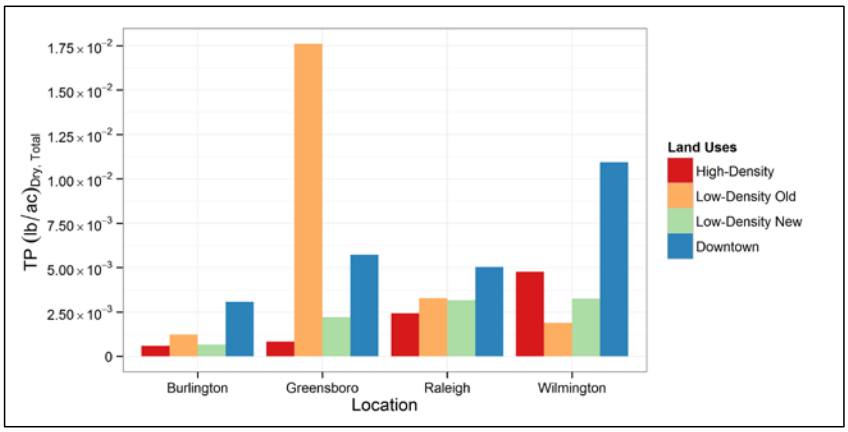

Figure 4.3: Predicted TP Loads for Location*Land Use Effect

Table 4.16: Predicted TP Loads per Location and Land Use

Location	Land Use	Predicted TP Load*10^{-3} (lb/ac)
Burlington	High-Density	0.60
	Low-Density Old	1.23
	Low-Density New	0.67
	Downtown	3.08
Greensboro	High-Density	0.84
	Low-Density Old	17.60
	Low-Density New	2.22
	Downtown	5.72
Raleigh	High-Density	2.42
	Low-Density Old	3.28
	Low-Density New	3.16
	Downtown	5.04
Wilmington	High-Density	4.76
	Low-Density Old	1.89
	Low-Density New	3.25
	Downtown	10.90

Table 4.17: Significant Differences between TP Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Raleigh	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	Low-Density Old	Raleigh	Low-Density Old	0.004
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	0.0007
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Downtown	Wilmington	Downtown	0.003
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**0.0273**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Raleigh	High-Density	0.0065
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	**Low-Density Old**	**Greensboro**	**Downtown**	**0.0033**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Greensboro	**Low-Density New**	**Greensboro**	**Downtown**	**0.0318**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.022**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0025**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

LSMEANS for the interaction between location and season are shown in Figure 4.4 and Table 4.18. For Burlington and Greensboro, the largest loads were sampled during spring and fall. In contrast, the largest loads collected in Wilmington were during summer and winter. This was expected considering trees begin to drop their leaves later in Wilmington. The interaction between location and season was significant (p-value < 0.05). Significant comparisons between LSMEANS are included in Table 4.19. Except for fall, loads collected from Burlington were statistically different from loads sampled from Greensboro and Wilmington. Also, loads collected during fall in Greensboro were significantly different from loads sampled during summer and winter.

Similar to TN, the results show which land uses and seasons the largest TP loads were collected from each location. Additionally, the results indicate there is potential to collect more TP in debris from certain land uses and during particular seasons. Refer to Section 4.2.1 for possible explanations regarding differences in loads. Appendix I includes details regarding TP loads normalized by street area while Appendix L summarizes predicted TN loads for each location's land use and season.

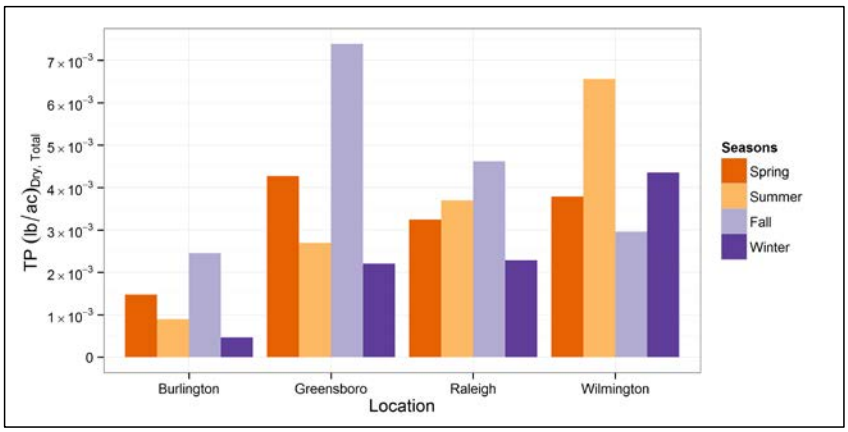

Figure 4.4: Predicted TP Loads for Location*Season Effect

Table 4.18: Predicted TP Loads per Location and Season

Location	Season	Predicted TP Load*10^{-3} (lb/ac)
Burlington	Spring	1.48
	Summer	0.90
	Fall	2.45
	Winter	0.47
Greensboro	Spring	4.27
	Summer	2.69
	Fall	7.38
	Winter	2.20
Raleigh	Spring	3.24
	Summer	3.70
	Fall	4.62
	Winter	2.28
Wilmington	Spring	3.79
	Summer	6.56
	Fall	2.96
	Winter	4.36

Table 4.19: Significant Differences between TP Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Summer**	**0.0226**
Burlington	Fall	Greensboro	Fall	0.0039
Burlington	**Spring**	**Burlington**	**Winter**	**0.0032**
Burlington	Spring	Greensboro	Spring	0.0123
Burlington	Spring	Wilmington	Spring	0.0361
Burlington	Summer	Greensboro	Summer	0.0104
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	**Fall**	**Greensboro**	**Summer**	**0.029**
Greensboro	**Fall**	**Greensboro**	**Winter**	**0.0005**
Greensboro	Fall	Wilmington	Fall	0.0396

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

To estimate TP loads in collected debris, TP concentrations were normalized by watershed area, and predicted concentration limits were found using the PROC GLIMMIX model described in Section 3.11 (Tables 4.20 and 4.21). Those who apply these concentrations must understand they are only 95% confident the collected debris' true or correct pollutant concentration is within the given interval. Note either predicted concentrations for each land use or season should be used to estimate pollutant loads in collected debris. Refer to Appendix J for an example illustrating how these concentration limits can be applied to estimate TP loads in collected debris. Also, details regarding the Excel tool incorporating these concentrations are discussed in Appendix M.

Table 4.20: TP Concentration Limits per Land Use

Land Use	Lower Limit TP (lb/lb/ac)	Upper Limit TP (lb/lb/ac)
High-Density	0.001685	0.001913
Low-Density Old	0.0008573	0.0009675
Low-Density New	0.002007	0.002268
Downtown	0.0006839	0.0007807

Table 4.21: TP Concentration Limits per Season

Season	Lower Limit TP (lb/lb/ac)	Upper Limit TP (lb/lb/ac)
Spring	0.001378	0.00156
Summer	0.001286	0.001468
Fall	0.001266	0.001432
Winter	0.0008843	0.0009989

Due to the influence of street sweeping, TP loads were also normalized by the watershed's curb length and duration between sampling events for each land use (Table 4.22) and season (Table 4.23). Similar to loads normalized by watershed area, these predicted concentration limits were also found using the PROC GLIMMIX model described in Section 3.11. Refer to Appendix K for an example illustrating how these concentration limits can be applied to estimate TN loads in street sweepings. Also, predicted TP concentrations in debris samples were found using the PROC GLIMMIX model and are included in Appendix J; these concentrations were also compared to unpublished data from Lockerman and Rubin (2015) and Stack et al. (2013). For details regarding the Excel tool incorporating these concentrations see Appendix M.

Table 4.22: Daily TP Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit TP (lb/lb/mile-day)	Upper Limit TP (lb/lb/mile-day)
High-Density	0.0007855	0.0009473
Low-Density Old	0.0005431	0.0006499
Low-Density New	0.0013015	0.0015599
Downtown	0.0006477	0.0007884

Table 4.23: Daily TP Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit TP (lb/lb/mile-day)	Upper Limit TP (lb/lb/mile-day)
Spring	0.0010636	0.0012788
Summer	0.0008715	0.0010607
Fall	0.0008241	0.0009886
Winter	0.000471	0.0005644

4.2.3 Labile Nutrient Loads and Stormwater Runoff

To compare loads in debris to thresholds established for nutrient sensitive watersheds (NCDENR, 2009), labile loads from collected debris were estimated using cumulative debris loads (Appendix D) and reported average TN and TP leaching rates of 0.000854 and 0.000657 g g^{-1} of dry leaf weight, respectively (Hobbie et al., 2014). These labile loads were also compared to annual aqueous loads in stormwater runoff in the monitored watersheds that neglected the presence of gross solids. Loads in runoff were estimated using the National EPA Stormwater Calculator, site characteristics such as percent impervious and soil type, Equation 4.1, and typical TN and TP runoff concentrations of 1.57 and 0.19 mg L^{-1}, respectively (Passeport and Hunt, 2009; US EPA, 2014a). The calculator incorporates the EPA's Stormwater Management Model (SWMM) to calculate average annual runoff, which is often used by jurisdictions to estimate pollutant loadings (US EPA, 2014a). Details regarding the estimations are included in Appendix G.

$$P = \frac{X * V * 10^{-6}}{A} * 0.89 \quad (4.1)$$

Where:
P= Annual pollutant load (lb/ac/yr)
X= Pollutant concentration (mg/L)
V= Annual runoff volume (L/yr)
A= Watershed area (ha)

Estimated aqueous TN loads in stormwater ranged from 5.23 to 13.50 lb ac^{-1} yr^{-1} while labile loads from organic matter varied between 0.01 to 0.27 lb ac^{-1} yr^{-1} (Table 4.24). Loads in runoff were larger than total gross solid (non-labile + labile) loads that ranged from 0.60 to 4.13 lb ac^{-1} yr^{-1}. Labile loads from debris were typically an order magnitude smaller than loads in stormwater. At a minimum, loads in stormwater accounted for 97.8% of a watershed's total aqueous (labile + stormwater) TN load, essentially the same conclusions drawn by Allison et al. (1998). Allison et al. (1998) applied leaching rates ranging from 5 to 20% and found labile loads in debris were approximately two orders of magnitude smaller than loads in runoff. Figure 4.5 summarizes the estimated TN loads for the downtown sites; plots showing the estimated loads for the remaining land uses are included in Appendix G.

Table 4.24: Estimated Stormwater and Labile Annual TN Loads

Land Use	Location	Debris Non-Labile + Labile TN Load (lb/ac/yr)	Labile[a] TN Load (lb/ac/yr)	Stormwater[b] TN Load (lb/ac/yr)
High-Density	Burlington	0.14	0.01	11.85
	Greensboro	0.19	0.02	11.99
	Raleigh	0.84	0.05	11.04
	Wilmington	1.41	0.11	5.70
Low-Density Old	Burlington	0.41	0.03	5.52
	Greensboro	4.13	0.27	13.07
	Raleigh	1.37	0.09	5.23
	Wilmington	0.60	0.04	5.35
Low-Density New	Burlington	0.20	0.01	7.30
	Greensboro	0.68	0.06	6.78
	Raleigh	0.91	0.07	5.23
	Wilmington	0.70	0.04	10.95
Downtown	Burlington	0.60	0.04	9.99
	Greensboro	1.62	0.12	11.80
	Raleigh	2.06	0.20	8.82
	Wilmington	1.09	0.10	13.50

[a] Estimated using leaching rates from Hobbie et al. (2014)
[b] Estimated annually using concentration from Passeport and Hunt (2009) and calculations from National EPA Stormwater Calculator (US EPA, 2014a)

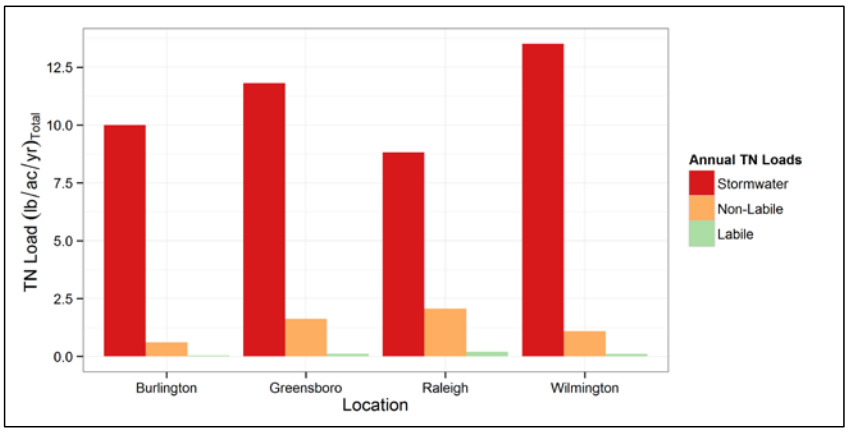

Figure 4.5: Estimated Annual TN Loads for Monitored Downtown Sites

Estimated labile TP loads varied from 0.01 to 0.21 lb ac^{-1} yr^{-1} while aqueous loads in stormwater that neglect the presence of gross solids ranged from 0.63 to 1.58 lb ac^{-1} yr^{-1} (Table 4.25). Comparable to TN, loads in runoff were an order of magnitude larger than labile loads from debris. At most, soluble TP loads from debris accounted for 12.7% of a watershed's total aqueous TP load. Additionally, loads in runoff were larger than total gross solid loads that ranged from 0.02 to 0.56 lb ac^{-1} yr^{-1} (Table 4.21). Figure 4.6 summarizes the estimated TP loads for the downtown sites; plots showing the estimated loads for the remaining land uses are included in Appendix G. Overall, Tables 4.24 and 4.25 suggest collecting debris from urban catch basins will only modestly reduce the nutrient concentration in downstream water bodies and or help municipalities comply with federal and state regulations.

Table 4.25: Estimated Stormwater and Labile Annual TP Loads

Land Use	Location	Debris Non-Labile + Labile TP Load (lb/ac/yr)	Labile[a] TP Load (lb/ac/yr)	Stormwater[b] TP Load (lb/ac/yr)
High-Density	Burlington	0.02	0.01	1.43
	Greensboro	0.03	0.01	1.45
	Raleigh	0.10	0.04	1.34
	Wilmington	0.20	0.08	0.69
Low-Density Old	Burlington	0.05	0.02	0.67
	Greensboro	0.56	0.21	1.58
	Raleigh	0.19	0.07	0.63
	Wilmington	0.08	0.03	0.65
Low-Density New	Burlington	0.02	0.01	0.88
	Greensboro	0.10	0.04	0.82
	Raleigh	0.14	0.05	0.63
	Wilmington	0.10	0.03	1.32
Downtown	Burlington	0.09	0.03	1.21
	Greensboro	0.22	0.10	1.43
	Raleigh	0.33	0.15	1.07
	Wilmington	0.23	0.08	1.63

[a] Estimated using leaching rates from Hobbie et al. (2014)
[b] Estimated annually using concentration from Passeport and Hunt (2009) and calculations from National EPA Stormwater Calculator (US EPA, 2014a)

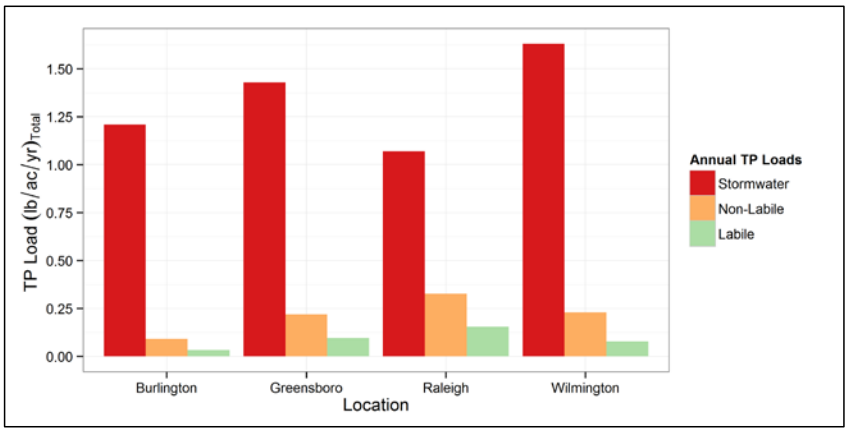

Figure 4.6: Estimated Annual TP Loads for Monitored Downtown Sites

4.3 TC and Metal Pollutant Loads

Similar to TN and TP, statistical analyses were performed for TC and metals including: Fe, Zn, Mn, Cu, Ni, and Pb. Details regarding the analyses for loads normalized by the watershed area and street area within the watershed are included in Appendix F and I, respectively. Also, pollutant concentrations normalized by the watershed area and the watershed's curb length are summarized in Appendix J and K, respectively. Information regarding pollutant loads are shown in Appendix L. For details regarding the Excel tool incorporating the pollutant concentrations see Appendix M.

Comparable to TN and TP, the statistical analyses found TC and metal loads were influenced by a location's land uses and seasons. Differences can be attributed to tree species (Gosz et al., 1972). Watershed characteristics that were previously discussed in Section 4.2.1 may also have affected these loads. Differences among loads were most likely caused by variations in typical metal sources including atmospheric deposition; road sediments; automobile's tires, oil, and brakes; and building rooftops, siding, and aging exterior paint (Davis et al., 2001; Beckwith et al., 1986; Gunawardena et al., 2013). Positive correlations have also been identified between metals and traffic volume and congestion (Gunawardena et al., 2013). Automatic traffic counters were not used during the study but NCDOT traffic maps and field observations typically found high-density and downtown sites received the least and most traffic, respectively (North Carolina Department of Transportation, 2015). However, vehicles were more frequent at Wilmington's high-density and Greensboro's low-density old sites compared to sites draining respective land uses.

4.4 Land Uses Yielding Largest Pollutant Loads

Land uses yielding the largest pollutant loads were found with the Gupta-Hsu method (Gupta and Hsu, 1984). For each pollutant, LSMEANS for the land covers were found using the PROC GLIMMIX model described in Section 3.11. Each land use's LSMEAN was treated a control and compared against the other land uses' LSMEANS using a Dunnett-Hsu adjustment. A positive and significant difference between a land use and control identified the control did not contribute the largest loads. Overall, the land use with the most positive and significant differences was identified as the largest pollutant contributor. For all inferences, significance was established at α=0.05. Appendix H provides more details regarding the Gupta-Hsu method.

For each pollutant, it was determined the downtown land use contributed the largest loads. Tables 4.26 and 4.27 show the predicted TN loads and the comparisons between land uses', respectively. Also Tables 4.28 and 4.29 include the predicted TP loads and the comparisons between land uses', respectively. Appendix H includes the predicted loads and comparisons for the remaining constituents. Note, the shown predicted loads were back-transformed from a gamma distribution while reported differences between the land uses' pollutants loads were not back-transformed.

Table 4.26: Predicted TN Load for Land Uses

Land Use	TN Load*10^{-2} (lb/ac)
High-Density	1.67
Low-Density Old	3.80
Low-Density New	2.15
Downtown	5.61

Table 4.27: Comparisons between TN Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.8193	<0.0001	Yes
Low-Density New	High-Density	0.2478	0.063	No
Downtown	High-Density	1.2092	<0.0001	Yes
High-Density	Low-Density Old	-0.8193	1.0	No
Low-Density New	Low-Density Old	-0.5716	1.0	No
Downtown	Low-Density Old	0.3899	0.0036	Yes
High-Density	Low-Density New	-0.2478	0.9985	No
Low-Density Old	Low-Density New	0.5716	<0.0001	Yes
Downtown	Low-Density New	0.9615	<0.0001	Yes
High-Density	Downtown	-1.2092	1.0	No
Low-Density Old	Downtown	-0.3899	1.0	No
Low-Density New	Downtown	-0.9615	1.0	No

[a] Significance established at α=0.05

Table 4.28: Predicted TP Load for Land Uses

Land Use	TP Load*10^{-3} (lb/ac)
High-Density	1.55
Low-Density Old	3.41
Low-Density New	1.98
Downtown	5.58

Table 4.29: Comparisons between TP Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.7855	<0.0001	Yes
Low-Density New	High-Density	0.2419	0.0754	No
Downtown	High-Density	1.2795	<0.0001	Yes
High-Density	Low-Density Old	-0.7855	1.0	No
Low-Density New	Low-Density Old	-0.5436	1.0	No
Downtown	Low-Density Old	0.494	0.0003	Yes
High-Density	Low-Density New	-0.2419	0.9979	No
Low-Density Old	Low-Density New	0.5436	<0.0001	Yes
Downtown	Low-Density New	1.0376	<0.0001	Yes
High-Density	Downtown	-1.2795	1.0	No
Low-Density Old	Downtown	-0.494	1.0	No
Low-Density New	Downtown	-1.0376	1.0	No

[a] Significance established at α=0.05

As expected, the downtown land use yielded the largest pollutant loads. Possible explanations for these results include downtown sites had the largest recorded AADT volumes and most tree variety and abundance (Table 4.30). Also, the largest cumulative debris loads were collected from the downtown land use in Burlington, Raleigh, and Wilmington. Refer to Appendix D for more details regarding estimated tree canopy loss, extent, and gain from 2000 to 2013 (Hansen et al., 2013).

Table 4.30: Site's Tree, Debris, and Traffic Characteristics

Location	Land Use[a]	Measured Tree Canopy (ft^2)	Tree Quantity	Estimated Tree Canopy[b]	Cumulative Debris Load (lb/ac)	AADT Volume Range[c]
Burlington	HD	-	3	Loss	12.58	-
	LDO	8.29	4	Extent	33.28	-
	LDN	-	3	Loss	11.69	-
	DT	236.38	9	-	58.08	5000-9999
Greensboro	HD	-	1	Loss	23.64	-
	LDO	-	8	Extent	358.12	-
	LDN	-	3	Loss	75.66	-
	DT	21.96	7	-	163.63	2000-4999
Raleigh	HD	4.31	4	Loss	64.24	-
	LDO	-	11	Extent	105.37	-
	LDN	-	5	Loss	90.02	-
	DT	160.60	21	-	217.78	5000-9999
Wilmington	HD	83.10	15	Extent	136.50	-
	LDO	74.59	37	Extent	49.69	-
	LDN	-	10	Loss	56.21	-
	DT	32.18	12	-	132.22	2000-4999

[a] High-density (HD), low-density old (LDO), low-density new (LDN), downtown (DT)
[b] Tree canopy gain, loss, and extent from 2000 to 2013 (Hansen et al., 2013)
[c] North Carolina Department of Transportation (2015)

SUMMARY AND RECOMMENDATIONS

5.1 Summary and Conclusions

The research successfully established baseline pollutant loads in gross solids draining from urban watersheds. Maximum cumulative annual TN, TP, and TC loads were 6.14, $54.60*10^{-2}$, and 206.12 lb ac^{-1} yr^{-1}, respectively. Maximum cumulative annual Fe, Zn, Mn, Cu, Ni, and Pb loads in collected debris were: $31.59*10^{-1}$, $14.68*10^{-2}$, $24.56*10^{-2}$, $16.68*10^{-3}$, $28.59*10^{-4}$, and $184.05*10^{-4}$ lb ac^{-1} yr^{-1}, respectively.

The PROC GLIMMIX model described in Section 3.11 was used to estimate pollutant loads for the debris collected from the monitored locations' land uses and seasons. For each constituent, the range in predicted loads for the studied land uses and seasons are summarized in Tables 5.1 and 5.2, respectively. As expected, nutrient and TC loads in the collected debris were larger than metal loads.

Table 5.1: Minimum and Maximum Predicted Pollutant Loads from Monitored Land Uses

Pollutant	Minimum Load (lb/ac)	Maximum Load (lb/ac)
$TN*10^{-2}$	0.57	19.10
$TP*10^{-3}$	0.60	17.60
TC	0.19	5.68
$Fe*10^{-2}$	0.19	10.40
$Zn*10^{-4}$	1.83	42.70
$Mn*10^{-4}$	2.04	56.70
$Cu*10^{-4}$	0.12	4.44
$Ni*10^{-5}$	0.47	1.38
$Pb*10^{-5}$	0.78	115.0

Table 5.2: Minimum and Maximum Predicted Pollutant Loads from Monitored Seasons

Pollutant	Minimum Load (lb/ac)	Maximum Load (lb/ac)
$TN*10^{-2}$	0.56	8.38
$TP*10^{-3}$	0.47	7.38
TC	0.21	3.22
$Zn*10^{-4}$	2.92	17.50
$Mn*10^{-4}$	2.70	44.30
$Cu*10^{-4}$	0.22	2.50
$Ni*10^{-5}$	0.31	8.16
$Pb*10^{-5}$	0.82	4.74

The calculated pollutant loads were used for statistical analyses. It was determined that where (land use) and when (season) organic debris was sampled from influenced the collected pollutant load for each location. Also, the results indicated that among locations and within municipalities loads were statistically different with respect to land uses and seasons. Differences between loads were attributed to variations in: basal area, lawn maintenance, rainfall, metal sources, leaf fall, and tree species. More importantly, the results suggested street sweeping frequencies and tree abundance influenced collected loads. Due to these influences, it does not appear the monitored sites are representative of all watersheds draining the four land uses. However, the reported results provide insight regarding pollutant loads that can be collected from debris. Moreover, this research suggests municipalities should consider allocating their resources to downtown streets with extensive overhanging tree canopy and abundance.

As expected, it was determined the downtown land use yielded the largest loads for all pollutants. Sites draining this land use typically had the most tree abundance, variety, and AADT volumes. In addition, previous research was used to estimate labile TN and TP loads from debris. Labile loads were then compared with typical aqueous nutrient loads in stormwater runoff. It was determined labile loads from debris contributed a maximum 12.7% of a watershed's total aqueous (stormwater + labile) pollutant load. As a result, collecting gross solids appears to only modestly improve downstream water quality.

5.2 Maintenance Recommendations for Gross Solids Collection

Results from the analyses were used to develop maintenance recommendations for gross solids collection. Street sweeping has been identified as an effective tool for removing solids from impervious surfaces (US EPA, 2014b; Marais et al., 2004, Kalinosky et al., 2014). These data suggest municipalities should continue to focus their street sweeping efforts on the downtown land use, as this land use contributed the largest pollutant and cumulative debris loads (Table 4.30). More importantly, municipalities should considering allocating more of their resources to downtown streets with extensive overhanging tree canopy and abundance. Field observations

herein and results from Kalinosky et al. (2014) found pollutant loads were larger from sites with large basal areas.

On average, samples from the downtown sites were collected every 15 days and had a daily volume draining solids ranging from ranging 0.06 to 0.09 ft^3 day^{-1} (Table D.60). Based on the analyses and current sweeping frequencies, it is recommended at a minimum downtown streets are swept weekly. However, factors including sweeper and operator efficiencies, overhanging tree canopy, and typical durations between storm events should also be considered (Selbig and Bannerman, 2007). Piedmont municipalities may also consider sweeping more frequently during autumn. In contrast, Coastal Plain municipalities may be better served if sweeping was more frequent during winter. For these ecoregions, leaf fall occurs during these seasons, and pollutant loads collected during these seasons at these locations were the largest. Nutrient loads in street sweepings can be estimated using the pollutant concentrations that were normalized by the watershed's curb length as well as the draft model discussed in Section 1.6 (Kalinosky et al., 2014) which could also be used to establish sweeping frequencies and optimize sweeping routes.

In addition to street sweeping, gross solids can be collected using proprietary units installed in catch basins. To decrease maintenance frequency, it is recommended devices utilizing the basin's volume be installed (Figure 5.1). With respect to maintenance, municipalities would trap the most gross solids with these devices in the low-density old land use (Table 4.30). When determining vacuuming frequencies, factors such as basin dimensions and the rate of draining gross solids should be considered. Using a conservative rate of 0.09 ft^3 day^{-1}, it was estimated the monitored basins would be full within two to 22 months.

Figure 5.1: Basin with Installed Gross Solids Collector (left) and Basin Vacuuming (right)

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APPENDIX A: LIST OF ABBREVATIONS

1. AADT: average annual daily traffic
2. ac: acre
3. B-DT: Burlington downtown site
4. B-HD: Burlington high-density site
5. B-LDN: Burlington low-density new site
6. B-LDO: Burlington low-density old site
7. Cu: copper
8. DT: downtown
9. Fe: iron
10. g: gram
11. G-DT: Greensboro downtown site
12. G-HD: Greensboro high-density site
13. G-LDN: Greensboro low-density new site
14. G-LDO: Greensboro low-density old site
15. HD: high-density
16. L: liter
17. lb: pound
18. LDN: low-density new
19. LDO: low-density old
20. mg: milligram
21. Mn: manganese
22. Ni: nickel
23. Pb: lead
24. R-DT: Raleigh downtown site
25. R-HD: Raleigh high-density site
26. R-LDN: Raleigh low-density new site
27. R-LDO: Raleigh low-density old site
28. TC: total carbon
29. TN: total nitrogen
30. TP: total phosphorus
31. µg: microgram
32. µm: micrometer
33. W-DT: Wilmington downtown site
34. W-HD: Wilmington high-density site
35. W-LDN: Wilmington low-density new site
36. W-LDO: Wilmington low-density old site
37. yr: year
38. Zn: zinc

APENDIX B: LIST OF PRODUCTS FROM PROJECT

Presentations and Publications:

- American Society of Agricultural and Biological Engineers International Meeting- Montreal Canada (July 2014)
- North Carolina American Public Works Association Conference- Winston-Salem, NC (September 2014)
- Water Resources Research Institute Annual Conference- Raleigh, NC (March 2015)
- World Environmental & Water Resources Congress- Austin, TX (May 2015)
- M.S. thesis: Gross Solids in Urban Catch Basins: A Pollutant Accounting Opportunity?
- *Journal of Environmental Engineering* article: Gross Solids in Urban Catch Basins: A Pollutant Accounting Opportunity? (currently being prepared for submission)

Data Sets:

- An Excel file containing all of the pollutant concentrations and loads from each collected debris sample has been created

Communication of Results:

- An abstract to present at the 2016 World Environmental & Water Resources Congress in West Palm Beach, FL has been submitted
- An abstract to present at the 2016 Water Resources Research Institute Annual Conference will be submitted
- An abstract to present at the 2016 North Carolina American Public Works Association Conference will be submitted
- In August 2015 the final results were presented to the City of Durham's Stormwater Group at a "Lunch and Learn" meeting
- An Excel tool was developed to help municipalities optimize maintenance regimens and estimate pollutant loads in collected debris and street sweeping using the results from this project

APPENDIX C: LEACHABLE TN AND TP FROM ORGANIC DEBRIS

Dorney (1986) simulated the effects of urban runoff on fallen leaves from 52 residential street trees in Milwaukee and Shorewood, Wisconsin, for leachable and TP analyses. Stormwater was simulated by soaking the leaves in distilled water for 2 hr. Dorney (1986) reported an average leachable P concentration of 148.1 µg g^{-1} of dry leaf weight with TP averaging 0.22% of the total dried leaf mass for all tree species (Table C.1). An average of 9.3% of TP was leached (0.004-0.026% of the total weight of leaves) during the 2 hr soaking. Additionally, only tree species had a significant effect on TP and leachable P.

Table C.1: Reported Leachable P, TP, and Leachable TP (Dorney, 1986)

Scientific Name	Common Name	Leachable P (µg/g of leaves)	TP (%)	Leachable TP (%)
Acer saccharum Marsh.	Sugar Maple	259.9	0.20	13.43
Acer saccharinum L.	Silver Maple	232.7	0.13	17.7
Fraxinus pensylvanica Fern.	Green Ash	188.4	0.24	7.0
Gleditsia tricanthos L.	Honey Locust	176.0	0.44	4.5
Fraxinus americana L.	White Ash	161.9	0.14	9.6
Ulmus americana L.	American Elm	158.5	-	-
Tilia americana L.	Basswood	95.7	0.15	7.8
Ulmus pumila L.	Chinese Elm	88.6	-	-
Tilia cordata L.	Little Leaf Linden	86.5	0.09	6.7
Quercus palustris Muenchh.	Pin Oak	81.5	-	-
Acer platanoides L.	Norway Maple	80.1	0.08	8.4
Fraxinus excelsior L.	Hessian Ash	66.1	-	-
Salix babylonica L.	Weeping Willow	38.1	-	-
Average		**148.1**	**0.22**	**9.3**

In a study comparable to Dorney (1986), Cowen and Lee (1973) collected oak and poplar leaves from Madison, Wisconsin, in October 1971. Oak leaves were also collected after storm events and along the shore and adjacent littoral zone of Lake Mendota in November 1971. To analyze for soluble P and soluble TP, leaves collected from Madison and Lake Mendota were soaked in distilled water for 1 hr and then subjected to 1.5 hr of percolation. Leaves collected after rainfall were washed with 300 mL of distilled water. Comparisons between the soluble P concentrations from oak and poplar leaves are described in Table C.2

Table C.2: Soluble P and TP from Oak and Poplar Leaves (Cowen and Lee, 1973)

Leaf Type	Source	TP (µg/g leaves)	Soluble Reactive P Leached (µg/g leaves)	Soluble Unreactive P Leached (µg/g leaves)	Total Soluble P Leached (µg/g leaves)
Oak[a]	Madison, Wisconsin	1000	44	10	54
Poplar[b]	Madison, Wisconsin	675	120	20	140

[a] Air-dry weight of leaves: 7.86 g, leachate volume: 960 mL
[b] Air-dry weight of leaves: 9.32 g, leachate volume: 950 mL

Leachable P was also determined for consecutive leachings as well as for intact and cut leaves. Cowen and Lee (1973) reported intact oak leaves leached less reactive soluble P (230 µg g^{-1} of leaves) than cut oak leaves (650 µg g^{-1} of leaves), and leaves soaked by rainfall only leached 23 µg g^{-1} of leaves of soluble reactive P. Similar to Dorney (1986), the amount of TP leached ranged from 0.005-0.023% of the total weight of leaves. More importantly, Cowen and Lee (1973) found soluble P concentrations varied with respect to the length and number of antecedent soaking periods (Table C.3).

Table C.3: Soluble P Concentrations from Consecutive Leachings (Cowen and Lee, 1973)

Leaching Period	Lake Mendota Zone	Leachate Volume (mL)	Soaking Period Prior to Percolation (hr)	Soluble Reactive P Leached (µg/g leaves)	Total Soluble P Leached (µg/g leaves)
1	Shoreline	1007	1	230	230
2	Littoral Zone	1055	2.5	160	160
3	Littoral Zone	1000	22.5	270	270
4	Littoral Zone	1000	1	74	74

Hobbie et al. (2014) further explored TN and TP leaching by first determining N and P decomposition rates for five deciduous tree species in St. Paul, Minnesota; leaf matter was collected from a parking lot's stormwater conveyance system. Decomposition was modeled using a double exponential model where it was separated as "fast" or "slow" (Equation C.1). The reported fractions of mass decomposed at each rate are summarized in Table C.4.

$$X = Me^{-k_{fast}t} + (1 - M)e^{-k_{slow}t} \quad \text{(C.1)}$$

Where:
X= Proportion of initial nutrient mass remaining at time t
M= Fraction of decomposing nutrient mass
k_{fast}= Fast decomposition rate
k_{slow}= Slow decomposition rate
t=Time

Table C.4: Decomposition Rates and Initial Nutrient Content (Hobbie et al., 2014)

Scientific Name	**Common Name**	**N (%Total Mass)**	**P (%Total Mass)**	**k_{fast} (y-1)**	**k_{slow} (y-1)**	**Fraction Fast (M)**	**Fraction Slow (1-M)**
Acer platanoides L.	Norway Maple	1.22	0.096	22.69	1.06	0.12	0.88
Acer x freemanii	Freeman Maple	1.57	0.134	36.89	1.04	0.22	0.78
Fraxinus pennsylvanica Marsh.	Green Ash	0.96	0.162	-	1.23	0	1
Quercus bicolor Willd.	Swamp White Oak	1.16	0.099	20.79	0.57	0.05	0.95
Tilia cordata Mill.	Little Leaf Linden	1.39	0.162	20.44	0.96	0.22	0.78

Hobbie et al. (2014) also reported the initial percent total masses of N and P as well as the forms of nutrients leached from leaves after soaking 0.5 hr (Table C.5) and 24 hr (Table C.6). Total dissolved nitrogen (TDN) was comprised of nitrate (NO_3^-N), ammonium (NH_4^+-N), and dissolved organic nitrogen; total dissolved phosphorus (TDP) consisted of soluble reactive phosphorus and dissolved organic phosphorus.

Table C.5: Forms of N and P Leached after 0.5 hr Soaking (Hobbie et al., 2014)

Scientific Name	Common Name	TDN (g/g leaves)	TDP (g/g leaves)
Acer platanoides L.	Norway Maple	0.000455	0.00025
Acer x freemanii	Freeman Maple	0.00027	0.00024
Fraxinus pennsylvanica Marsh.	Green Ash	0.000071	0.000151
Quercus bicolor Willd.	Swamp White Oak	0.000065	0.000198
Tilia cordata Mill.	Little Leaf Linden	0.000439	0.000284
Average Leached (g/g leaves)		0.00026	0.000225

Table C.6: Forms of N and P Leached after 24 hr Soaking (Hobbie et al., 2014)

Scientific Name	Common Name	TDN (g/g leaves)	TDP (g/g leaves)
Acer platanoides L.	Norway Maple	0.0012	0.000411
Acer x freemanii	Freeman Maple	0.001018	0.000373
Fraxinus pennsylvanica Marsh.	Green Ash	0.000477	0.000623
Quercus bicolor Willd.	Swamp White Oak	0.000241	0.000901
Tilia cordata Mill.	Little Leaf Linden	0.001334	0.000976
Average Leached (g/g leaves)		0.000854	0.000657

Allison et al. (1998) collected leaf matter in a hydrodynamic separator and compared estimated leachable TN and TP loads to water quality samples taken from the same watershed. They determined the loads from stormwater were two orders of magnitude larger than loads leached from leaves (Table C.7).

Table C.7: TP and TN Loads from Samples (Allison et al., 1998**)**

Sample	Runoff Event	Runoff (mL)	Organic Material (lb_{Dry})	TP[a] (%)	TN[a] (%)	Total TP (lb)	Total TN (lb)
1	1	3.65	88.18	0.08	0.70	0.07	0.62
2	1	0.85	29.54	0.09	1.40	0.03	0.4
3	1	0.40	5.29	0.09	1.30	0.01	0.07
4	1	1.70	42.55	0.28	1.90	0.12	0.81
5	1	14.30	142.64	0.20	2.20	0.29	3.14
6	3	3.95	135.14	0.11	1.00	0.15	1.35
7	1	1.10	24.69	0.10	1.00	0.02	0.25
8	1	1.85	37.70	0.10	1.20	0.04	0.45
9	1	1.65	20.72	0.11	1.30	0.02	0.27
10	2	9.05	97.0	0.14	1.60	0.14	1.55
Total	**13**	**38.50**	**623.47**	**-**	**-**	**0.88**	**8.92**

[a] Percentage of dry weight

APPENDIX D: SITE DESCRIPTIONS AND OBSERVED RAINFALL

D.1 High-Density

D.1.1 Site B-HD

Residential gutter systems were directly connected to the existing stormwater infrastructure, and lawns sloped from the front edges of houses to the asphalt road (Figure D.1). Vegetation species and litter details are included in Tables D.1 and D.2, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.2 and D.3 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.3 and Figure D.4. Basin dimensions are summarized in Table D.13. Table D.14 and Figure D.17 include the cumulative debris load collected from the site. Table D.15 summarizes the total volume of solids collected from the site. Note the transparency for all images from Hansen et al. (2014) were altered to show the map view.

Figure D.1: Aerial View of Site B-HD Watershed

Table D.1: Identified Vegetation Species at Site B-HD

Vegetation Type	Scientific Name[a,b]	Common Name
Grass	*Festuca arundinacea*	Tall Fescue
Tree	*Acer rubrum* L.	Red Maple
Tree	*Ilex x Nellie R. Stevens*	Nellie Stevens Holly
Tree	*Prunus serrulata*	Japanese Cherry
Plant	*Rosa xodorata* (Andrews) Sweet (pro sp.) [*chinensis x gigantea]*	Tea Rose
Plant	*Spiraea x vanhouttei*	Spirea

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

Figure D.2: Tree Canopy Loss/Extent/Gain at Site B-HD (Hansen et al., 2013)

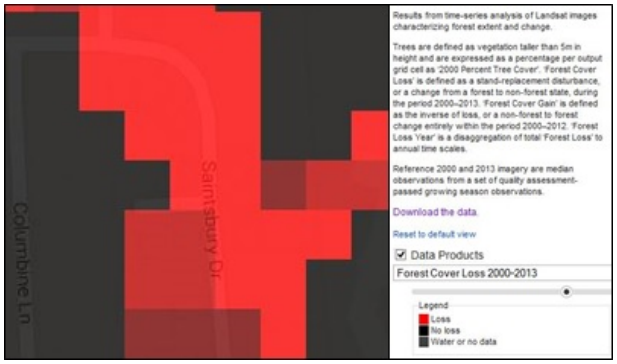

Figure D.3: Tree Canopy Loss at Site B-HD (Hansen et al., 2013)

Table D.2: Litter Types and Quantities Collected at Site B-HD

Litter Category	Quantity
Cigarette Butts	62
Styrofoam	2
Paper/Wrappers	21
Plastic	18
Stones/Pavement	538
Metal	3
Other	8

Table D.3: Total Rainfall between Sampling Events at Site B-HD

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.07	08/20/14	2.78
02/20/14	1.94	09/05/14	1.60
03/06/14	1.22	09/17/14	0.60
03/20/14	2.46	10/17/14	2.28
04/24/14	2.10	10/31/14	0.03
05/09/14	1.52	11/12/14	0.21
05/20/14	3.42	11/24/14	1.27
06/03/14	0.39	12/11/14	1.68
06/18/14	0.88	01/09/15	2.11
06/30/14	0.24	03/02/15	4.58
07/28/14	0.53		
Cumulative Rainfall (in)		31.94	

[a] Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

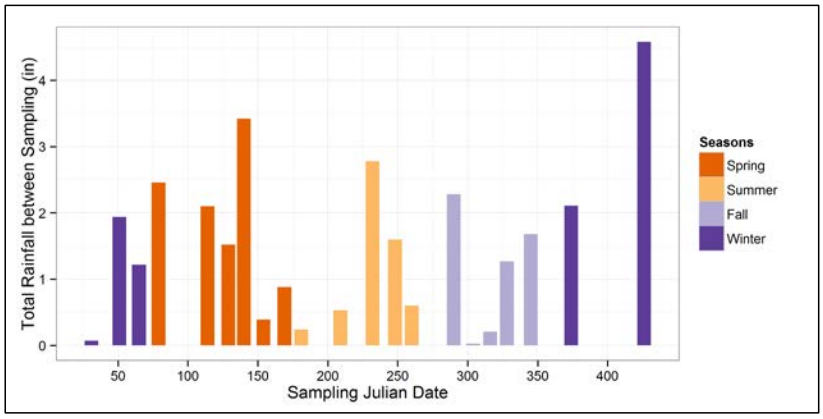

Figure D.4: Rainfall at Site B-HD, Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

D.1.2 Site G-HD

Residential gutter systems were directly connected to the asphalt street. Driveways and yards within the watershed also drained to the street (Figure D.5). Vegetation species and litter details are included in Tables D.4 and D.5, respectively ((NC Cooperative Extension, 2015; USDA-NRCS, 2015). Figures D.6 and D.7 show the estimated tree canopy loss, gain, and extent from 2000 to 2013 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.6 and Figure D.8. Basin dimensions are summarized in Table D.13. Table D.14 and Figure D.17 include the cumulative debris load collected from the site. Table D.15 summarizes the total volume of solids collected from the site.

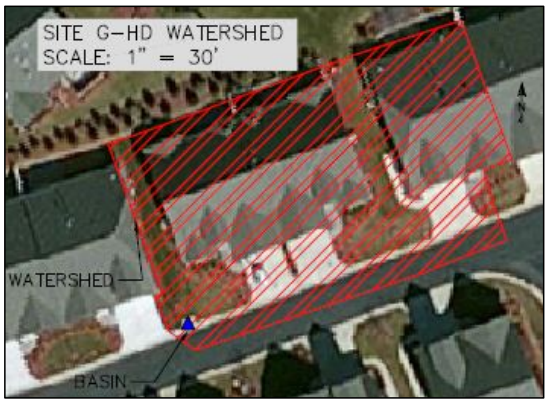

Figure D.5: Aerial View of Site G-HD Watershed

Table D.4: Identified Vegetation Species at Site G-HD

Vegetation Type	Scientific Name[a,b]	Common Name
Plant	*Buxus sempervirens*	Boxwood
Plant	*Nandina domestica*	Nandina
Tree	*Acer rubrum* L.	Red Maple
Grass	*Festuca arundinacea.*	Tall Fescue
Plant	*Catharanthus roseus*	Vinca

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

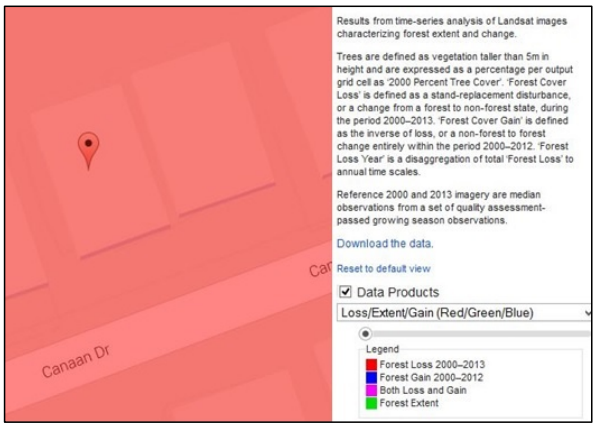

Figure D.6: Tree Canopy Loss/Extent/Gain at Site G-HD (Hansen et al., 2013)

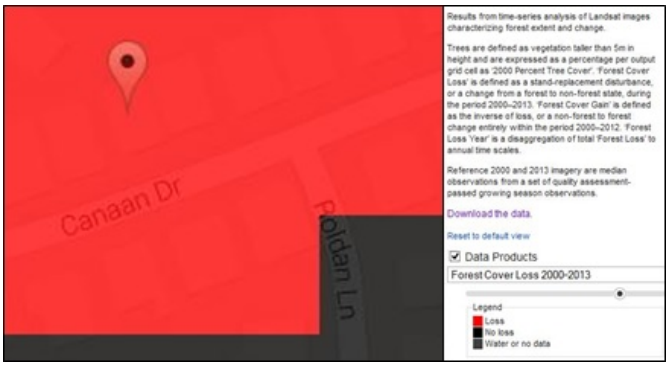

Figure D.7: Tree Canopy Loss at Site G-HD (Hansen et al., 2013)

Table D.5: Litter Types and Quantities Collected at Site G-HD

Litter Category	Quantity
Cigarette Butts	15
Styrofoam	10
Paper/Wrappers	4
Plastic	8
Stones/Pavement	171
Metal	0
Other	0

Table D.6: Total Rainfall between Sampling Events at Site G-HD

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.03	07/28/14	2.12
02/20/14	2.75	08/20/14	2.15
03/06/14	0.87	09/05/14	0.15
03/20/14	5.71	10/17/14	2.62
04/24/14	3.31	10/31/14	0.07
05/09/14	1.15	11/12/14	1.33
05/20/14	0.61	11/24/14	1.23
06/03/14	0.17	12/11/14	1.13
06/18/14	1.83	01/09/15	2.11
06/30/14	0.87	03/02/15	4.53
Cumulative Rainfall (in)		**34.74**	

[a] Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

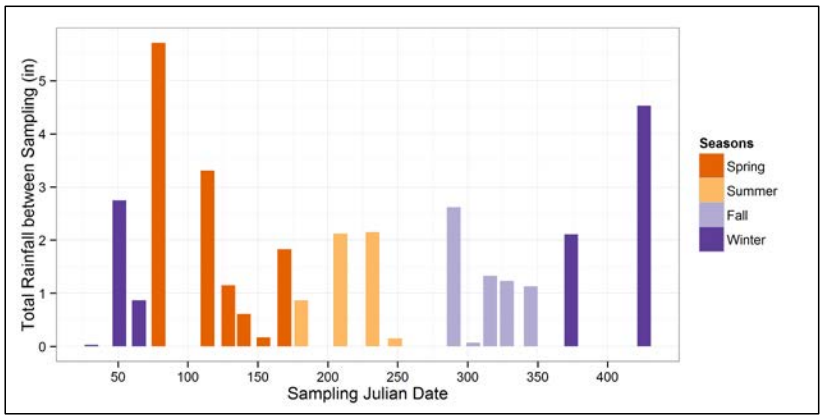

Figure D.8: Rainfall at Site G-HD, Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

D.1.3 Site R-HD

Residential gutter systems were directly connected to the existing conveyance network. Field observations found the lawns sloped from the front edge of homes to the asphalt road (Figure D.9). Vegetation species and litter details are included in Tables D.7 and D.8, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.10 and D.11 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.9 and Figure D.12. Basin dimensions are summarized in Table D.13. Table D.14 and Figure D.17 include the cumulative debris load collected from the site. Table D.15 summarizes the total volume of solids collected from the site.

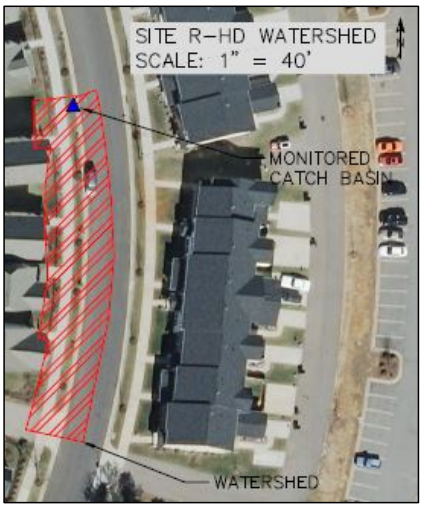

Figure D.9: Aerial View of Site R-HD Watershed

Table D.7: Identified Vegetation Species at Site R-HD

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Acer rubrum* L.	Red Maple
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Grass	*Festuca arundinacea*	Tall Fescue
Plant	*Hemerocallis* L.	Daylily
Vine	*Trachelospermum jasminoides* (Lindl.) Lem.	Confederate Jasmine
Tree	*Quercus alba* L.	White Oak
Plant	*Gardenia volkensii* K. Schum.	Common Gardenia
Plant	*Loropetalum chinese var. rubrum*	Loropetalum

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

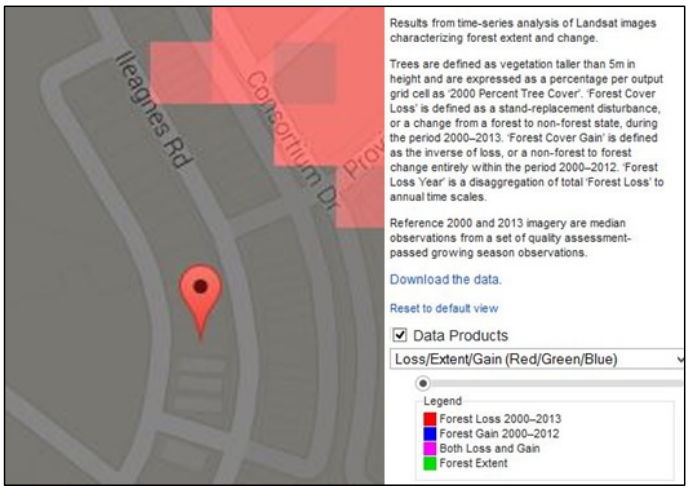

Figure D.10: Tree Canopy Loss/Extent/Gain at Site R-HD (Hansen et al., 2013)

Figure D.11: Tree Canopy Loss at Site R-HD (Hansen et al., 2013)

Table D.8: Litter Types and Quantities Collected at Site R-HD

Litter Category	Quantity
Cigarette Butts	33
Styrofoam	6
Paper/Wrappers	31
Plastic	33
Stones/Pavement	344
Metal	1
Other	0

Table D.9: Total Rainfall between Sampling Events at Site R-HD

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/17/14	1.43	08/19/14	4.76
01/24/14	0.02	09/03/14	0.06
02/07/14	0.38	09/12/14	4.63
02/27/14	2.59	10/09/14	1.19
03/19/14	3.81	10/23/14	4.04
04/04/14	1.24	11/05/14	0.61
04/17/14	2.50	11/20/14	0.74
04/28/14	0.77	12/05/14	1.69
05/08/14	1.23	12/14/14	0.45
05/21/14	5.70	01/05/15	4.46
06/17/14	1.20	01/31/15	3.73
06/27/14	1.96	02/12/15	1.11
07/11/14	1.30	02/28/15	2.90
08/04/14	6.53		
Cumulative Rainfall (in)		**61.03**	

[a] Station: LAKE-ECONET (State Climate Office of North Carolina, 2015)

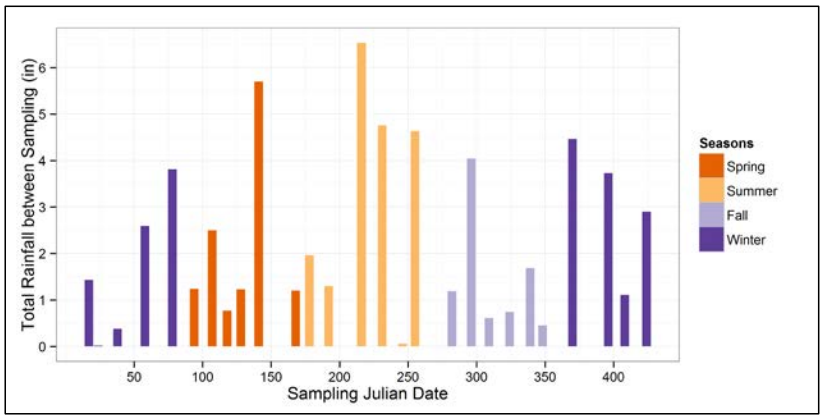

Figure D.12: Rainfall at Site R-HD, Station: LAKE-ECONET (State Climate Office of North Carolina, 2015)

D.1.4 Site W-HD

Field observations found lawns, driveways, and roofs drained to the mixed asphalt and brick road (Figure D.13). Vegetation species and litter details are included in Tables D.10 and D.11, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.14 and D.15 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.12 and Figure D.16. Basin dimensions are summarized in Table D.13. Table D.14 and Figure D.17 include the cumulative debris load collected from the site. Table D.15 summarizes the total volume of solids collected from the site.

Figure D.13: Aerial View of Site W-HD

Table D.10: Identified Vegetation Species at Site W-HD

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Quercus laurifolia* Michx.	Laurel Oak
Tree	*Platanus* L.	Sycamore
Tree	*Prunus caroliniana*	Carolina Cherry Laurel
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Plant	*Ligustrum vulgare*	Ligustrum
Plant	*Camellia* L.	Camellia
Tree	*Robinia pseudoacacia*	Black Locust
Tree	*Catalpa speciosa*	Northern Catalpa
Vine	*Campsis radicans*	Trumpet Creeper
Tree	*Mangolia grandiflora*	Southern Magnolia
Plant	*Thuja* L.	Arborvitae
Shrub	*Rhododendron carolinianum* Rehder	Azalea
Shrub	*Nerium oleander*	Oleander
Plant	*Hydrangea* L.	Hydrangea
Plant	*Cornus controversa*	Dogwood
Tree	*Acer rubrum* L.	Red Maple
Vine	*Trachelospermum jasminoides* (Lindl.) Lem.	Confederate Jasmine
Tree	*Albizia julibrissin*	Mimosa
Tree	*Eriobotrya japonica*	Loquat
Tree	*Pinus palustris*	Longleaf Pine
Shrub	*Yucca filamentosa*	Yucca

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

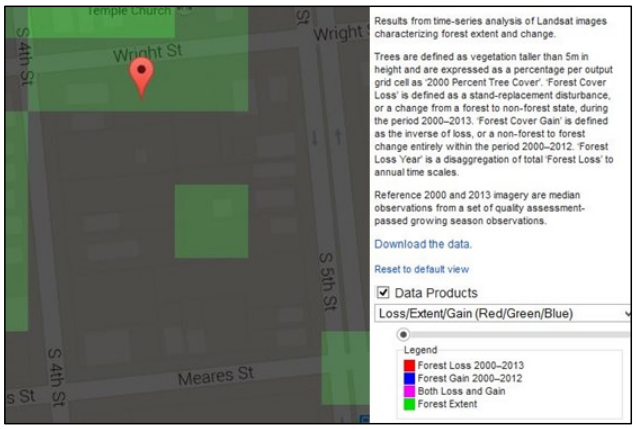

Figure D.14: Tree Canopy Loss/Extent/Gain at Site W-HD (Hansen et al., 2013)

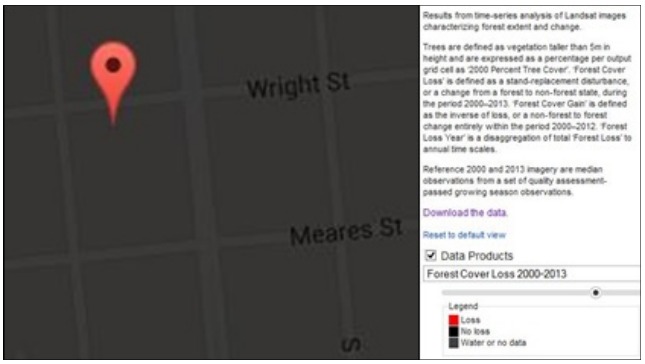

Figure D.15: Tree Canopy Loss at Site W-HD (Hansen et al., 2013)

Table D.11: Litter Types and Quantities Collected at Site W-HD

Litter Category	Quantity
Cigarette Butts	109
Styrofoam	28
Paper/Wrappers	344
Plastic	272
Stones/Pavement	1
Metal	12
Other	26

Table D.12: Total Rainfall between Sampling Events at Site W-HD

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
03/13/14	2.61	09/10/14	2.47
04/03/14	4.17	09/26/14	1.26
04/11/14	0.26	10/08/14	0.16
04/17/14	0.41	10/22/14	1.35
04/29/14	3.81	11/05/14	0.84
05/14/14	0.50	11/21/14	0.47
05/29/14	2.31	12/03/14	3.60
06/12/14	1.22	12/17/14	0.34
06/24/14	0.55	01/15/15	4.51
07/11/14	5.55	01/27/15	3.41
07/29/14	6.70	02/10/15	1.23
08/13/14	6.20	03/06/15	3.79
08/27/14	3.20	03/27/15	2.05
Cumulative Rainfall (in)		**63.01**	

[a] Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

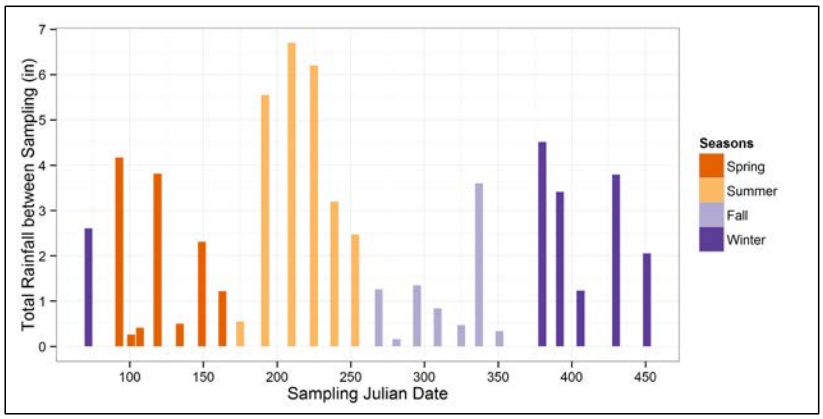

Figure D.16: Rainfall at Site W-HD, Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

Table D.13: Basin Dimensions at High-Density Sites

Dimension	**Site**			
	B-HD	G-HD	R-HD	W-HD
Basin Throat Height (ft)	0.69	0.39	0.49	0.56
Basin Throat Length (ft)	4.10	4.30	5.15	4.17
Basin Depth (ft)	2.89	3.31	-	2.00
Basin Width ft)	2.30	2.40	-	1.74
Basin Length (ft)	4.10	4.30	5.15	4.17
Basin Outlet Pipe (in)	21.65	14.96	-	11.81

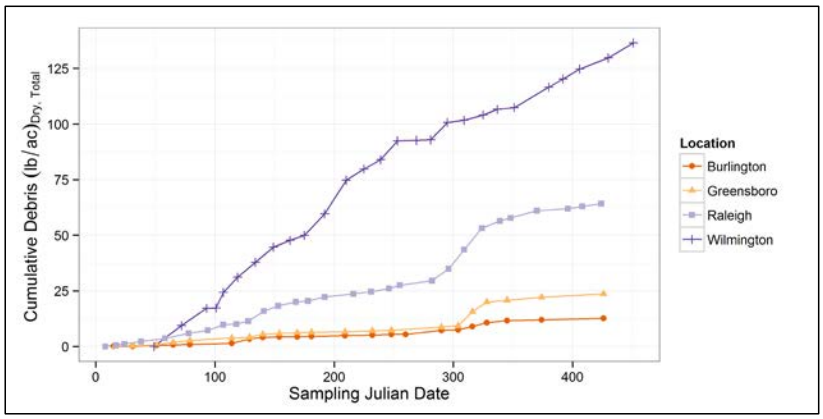

Figure D.17: High-Density Cumulative Debris Loads Normalized by Watershed Area

Table D.14: Debris Loads from High-Density Sites

Site	Cumulative Debris Load[a] (lb/ac)
B-HD	12.60
G-HD	23.65
R-HD	64.21
W-HD	136.47

[a] Normalized by watershed area

Table D.15: Gross Solids Volumes from High-Density Sites

Site	Cumulative Solids Volume (ft^3)	Average Solids Volume per Sample (ft^3)	Daily Average Solids Volume per Sample (ft^3/day)
B-HD	1.45	0.09	0.01
G-HD	3.24	0.20	0.02
R-HD	2.91	0.13	0.01
W-HD	24.77	1.03	0.07

D.2 Low-Density Old

D.2.1 Site B-LDO

Residential lawns, driveways, and roofs drained to the asphalt road (Figure D.18). Vegetation species and litter details are included in Tables D.16 and D.17, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.19 and D.20 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.18 and Figure D.21. Basin dimensions are summarized in Table D.28. Figure D.34 and Table D.29 include the cumulative debris load collected from the site. Table D.30 summarizes the total volume of solids collected from the site.

Figure D.18: Aerial View of Site B-LDO

Table D.16: Identified Vegetation Species at Site B-LDO

Vegetation Type	Scientific Name[a,b]	Common Name
Plant	*Hedera helix*	English Ivy
Grass	*Liriope spicata*	Creeping Liriope
Shrub	*Berberis candidula*	Paleleaf Barberry
Tree	*Betula nigra*	River Birch
Tree	*Acer rubrum* L.	Red Maple
Tree	*Acer saccharinum*	Silver Maple
Tree	*Quercus phellos* L.	Willow Oak
Grass	*Festuca arundinacea*	Tall Fescue

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

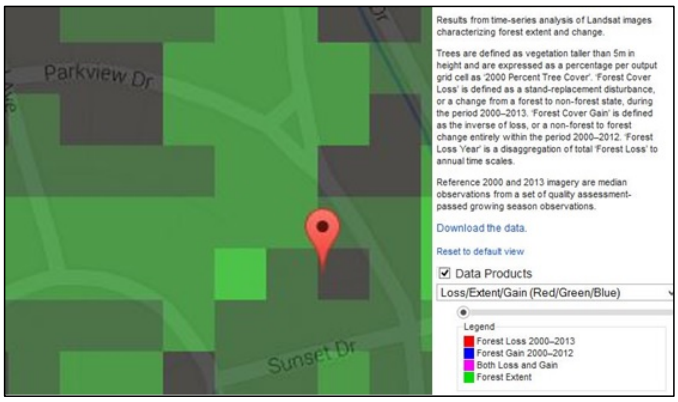

Figure D.19: Tree Canopy Loss/Extent/Gain at Site B-LDO (Hansen et al., 2013)

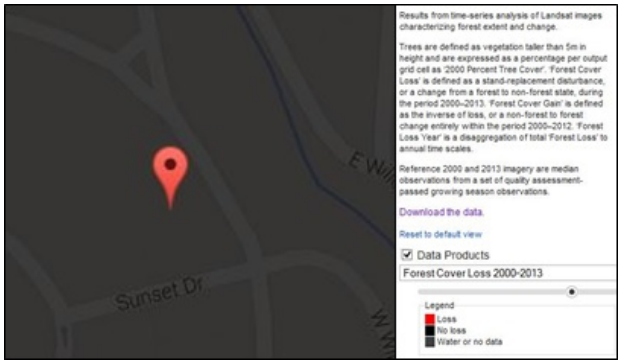

Figure D.20: Tree Canopy Loss at Site B-LDO (Hansen et al., 2013)

Table D.17: Litter Types and Quantities Collected at Site B-LDO

Litter Category	Quantity
Cigarette Butts	40
Styrofoam	10
Paper/Wrappers	10
Plastic	7
Stones/Pavement	39
Metal	1
Other	2

Table D.18: Total Rainfall between Sampling Events at Site B-LDO

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.07	09/05/14	1.60
02/20/14	1.94	09/17/14	0.60
03/20/14	2.46	09/29/14	0.27
04/24/14	1.52	10/17/14	2.01
05/09/14	1.52	10/31/14	0.03
05/20/14	3.42	11/12/14	0.21
06/03/14	0.39	11/24/14	1.27
06/18/14	0.88	12/11/14	1.68
06/30/14	0.24	01/09/15	2.11
07/28/14	0.53	01/20/15	0.92
08/05/14	1.17	01/30/15	0.77
08/20/14	1.61	03/02/15	2.88
Cumulative Rainfall (in)		**30.14**	

[a] Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

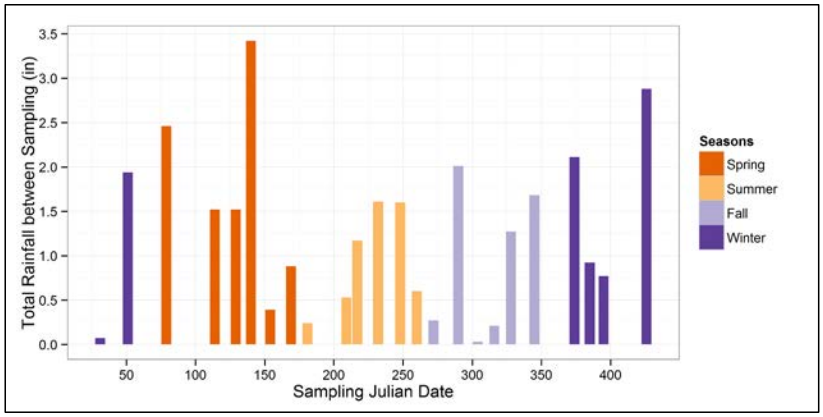

Figure D.21: Rainfall at Site B-LDO, Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

D.2.2 Site G-LDO

Field observations found lawns, driveways, and gutter systems drained away from the asphalt road (Figure D.22).Vegetation species and litter details are included in Tables D.19 and D.20, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.23 and D.24 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.21 and Figure D.25. Basin dimensions are summarized in Table D.28. Figure D.34 and Table D.29 include the cumulative debris load collected from the site. Table D.30 summarizes the total volume of solids collected from the site.

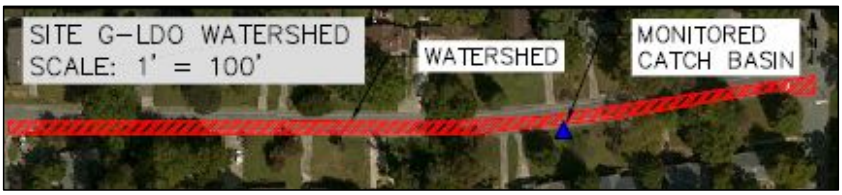

Figure D.22: Aerial View of Site G-LDO Watershed

Table D.19: Identified Vegetation Species at Site G-LDO

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Mangolia grandiflora*	Southern Magnolia
Grass	*Festuca arundinacea*	Tall Fescue
Plant	*Cornus controversa*	Dogwood
Tree	*Cercis canadensis var. canadensis*	Eastern Redbud
Plant	*Nandina domestica*	Nandina
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Tree	*Acer rubrum* L.	Red Maple
Vine	*Wisteria spp.*	Wisteria
Shrub	*Aucuba japonica*	Japanese Aucuba
Plant	*Ligustrum vulgare*	Ligustrum
Tree	*Magnolia acuminata*	Cucumber Tree
Plant	*Hedera helix*	English Ivy
Tree	*Fraxinus pennsylvanica*	Green Ash
Tree	*Ulmus americana*	American Elm
Tree	*Ilex opaca*	American Holly

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

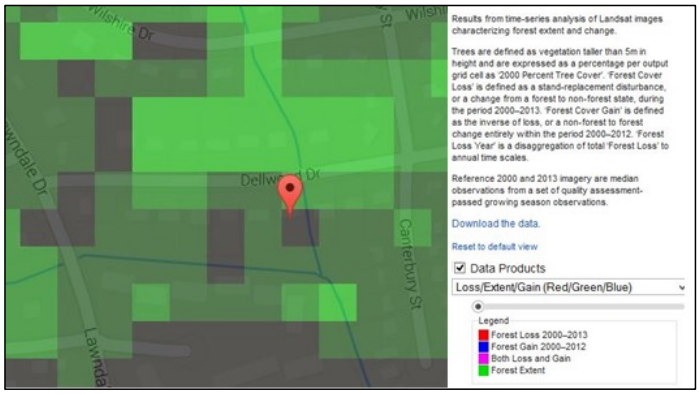

Figure D.23: Tree Canopy Loss/Extent/Gain at Site G-LDO (Hansen et al., 2013)

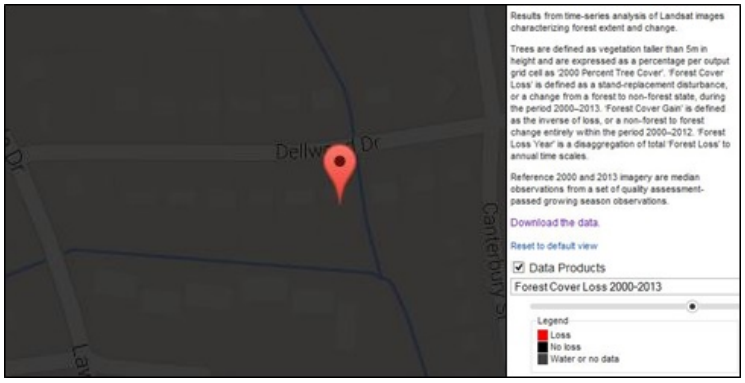

Figure D.24: Tree Canopy Loss at Site G-LDO (Hansen et al., 2013)

Table D.20: Litter Types and Quantities Collected at Site G-LDO

Litter Category	Quantity
Cigarette Butts	81
Styrofoam	9
Paper/Wrappers	41
Plastic	49
Stones/Pavement	3
Metal	8
Other	9

Table D.21: Total Rainfall between Sampling Events at Site G-LDO

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.03	09/05/14	0.15
02/20/14	2.75	09/17/14	0.89
03/20/14	5.71	10/17/14	1.73
04/24/14	1.46	10/31/14	0.07
05/09/14	1.15	11/12/14	1.33
06/03/14	0.17	11/24/14	1.23
06/18/14	1.83	12/11/14	1.13
06/30/14	0.87	01/09/15	2.11
07/28/14	2.12	01/20/15	0.60
08/05/14	0.95	01/30/15	0.54
08/20/14	1.20	03/02/15	3.39
Cumulative Rainfall (in)		**31.41**	

[a] Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

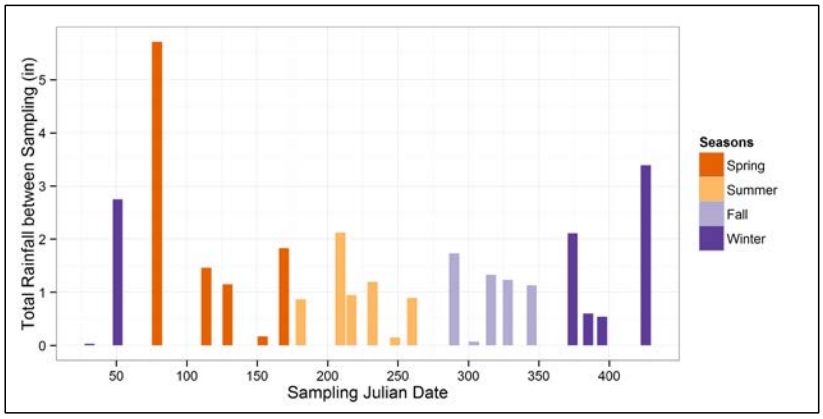

Figure D.25: Rainfall at Site G-LDO, Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

D.2.3 Site R-LDO

Surveys of the site found lawns drained from property's back edges or from the front edge of houses to the asphalt road. Disconnected downspouts managing the front halves of roofs drained onto driveways that were also graded towards the street (Figure D.26). Vegetation species and litter details are included in Tables D.22 and D.23, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.27 and D.28 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.24 and Figure D.29. Basin dimensions are summarized in Table D.28. Figure D.34 and Table D.29 include the cumulative debris load collected from the site. Table D.30 summarizes the total volume of solids collected from the site.

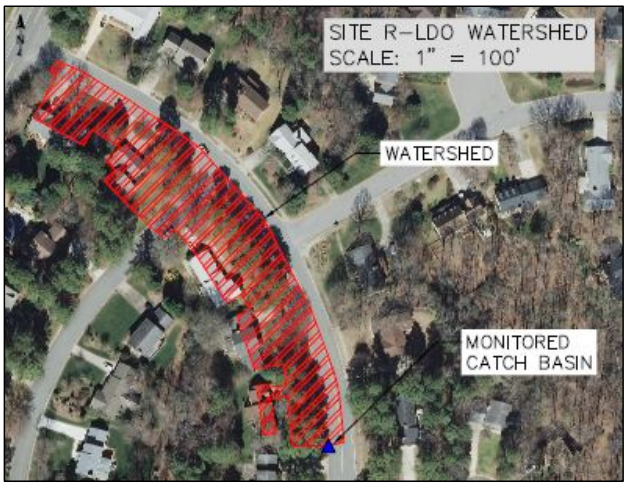

Figure D.26: Aerial View of Site R-LDO Watershed

Table D.22: Identified Vegetation Species at Site R-LDO

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Mangolia grandiflora*	Southern Magnolia
Tree	*Pinus taeda*	Loblolly Pine
Plant	*Cornus controversa*	Dogwood
Grass	*Festuca arundinacea*	Tall Fescue
Shrub	*Pyracantha coccinea*	Pyracantha
Tree	*Acer saccharum*	Sugar Maple
Plant	*Rosa* x*odorata* (Andrews) Sweet (pro sp.) [*chinensis* x *gigantea]*	Tea Rose
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Shrub	*Ligustrum sinense*	Chinese Privet
Tree	*Ulmus americana*	American Elm
Tree	*Quercus alba* L.	White Oak
Tree	*Acer palmatum*	Japanese Maple
Tree	*Cornus kousa*	Kousa Dogwood
Grass	*Liriope spicata*	Creeping Liriope
Tree	*Prunus serotina*	Wild Cherry
Tree	*Juniperus virginiana*	Eastern Red Cedar
Tree	*Morus* L.	Mulberry Tree
Shrub	*Ilex cornuta burfordii*	Burford Holly

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

Figure D.27: Tree Canopy Loss/Extent/Gain at Site R-LDO (Hansen et al., 2013)

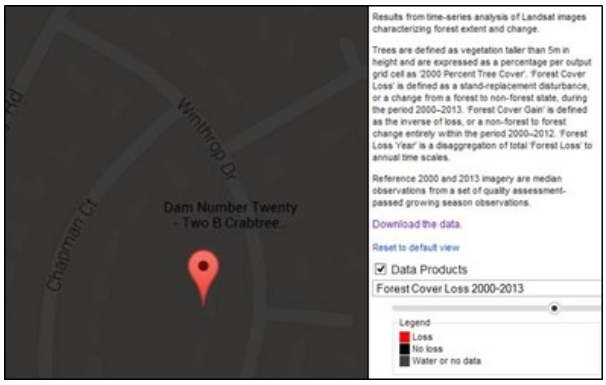

Figure D.28: Tree Canopy Loss at Site R-LDO (Hansen et al., 2013)

Table D.23: Litter Types and Quantities Collected at Site R-LDO

Litter Category	Quantity
Cigarette Butts	7
Styrofoam	4
Paper/Wrappers	7
Plastic	10
Stones/Pavement	27
Metal	1
Other	2

Table D.24: Total Rainfall between Sampling Events at Site R-LDO

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
04/04/14	2.03	08/04/14	1.18
04/07/14	0.85	08/19/14	5.05
04/14/14	0.09	09/03/14	0.18
04/18/14	1.12	09/12/14	1.20
04/25/14	0.50	09/28/14	1.23
04/28/14	0.48	10/09/14	0.08
04/30/14	0.13	10/16/14	3.00
05/08/14	1.18	11/05/14	0.67
05/16/14	4.81	11/20/14	0.76
05/29/14	0.18	12/05/14	1.84
06/10/14	1.31	12/14/14	0.55
06/17/14	0.92	01/05/15	4.19
06/27/14	3.29	01/22/15	2.20
07/11/14	1.75	01/31/15	0.75
07/21/14	2.88	02/12/15	0.99
07/23/14	0.23	03/12/15	3.64
Cumulative Rainfall (in)		**49.26**	

[a] Station: REED-ECONET (State Climate Office of North Carolina, 2015)

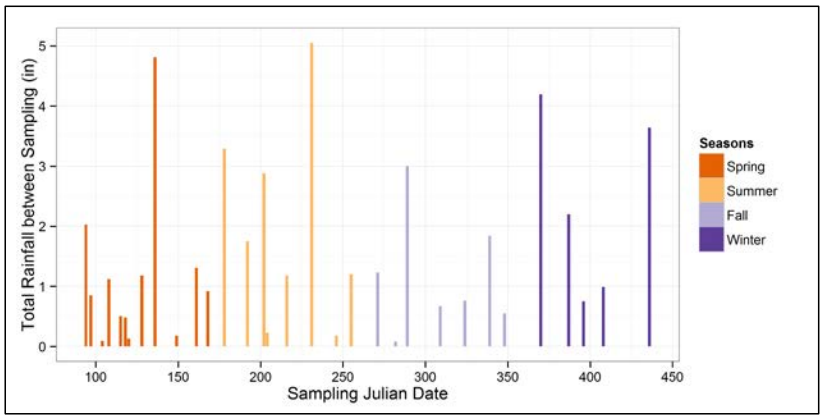

Figure D.29: Rainfall at Site R-LDO, Station: REED-ECONET (State Climate Office of North Carolina, 2015)

D.2.4 Site W-LDO

Field observations found front lawns, sidewalks, and front halves of roofs drained to the asphalt street (Figure D.30). Vegetation species and litter details for the site are included in Tables D.25 and D.26, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.31 and D.32 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.27 and Figure D.33. Basin dimensions are summarized in Table D.28. Figure D.34 and Table D.29 include the cumulative debris load collected from the site. Table D.30 summarizes the total volume of solids collected from the site.

Figure D.30: Aerial View of Site W-LDO Watershed

Table D.25: Identified Vegetation Species at Site W-LDO

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Pinus palustris*	Longleaf Pine
Tree	*Liquidambar styraciflua*	Sweetgum
Tree	*Acer rubrum* L.	Red Maple
Tree	*Prunus caroliniana*	Carolina Cherry Laurel
Tree	*Juniperus virginiana*	Eastern Red Cedar
Grass	*Liriope spicata*	Creeping Liriope
Shrub	*Rhododendron carolinianum* Rehder	Azalea
Grass	*Stenotaphrum* Trin.	St. Augustine Grass
Plant	*Hydrangea* L.	Hydrangea
Plant	*Loropetalum chinese var. rubrum*	Loropetalum
Tree	*Mangolia grandiflora*	Southern Magnolia
Tree	*Ilex opaca*	American Holly
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Tree	*Prunus serotina*	Wild Cherry
Plant	*Parthenocissus quinquefolia*	Virginia Creeper
Plant	*Camellia* L.	Camellia
Plant	*Hedera helix*	English Ivy
Plant	*Ligustrum vulgare*	Ligustrum
Tree	*Quercus nigra*	Water Oak
Plant	*Cornus controversa*	Dogwood
Tree	*Betula nigra*	River Birch
Tree	*Quercus virginiana*	Live Oak
Tree	*Quercus phellos* L.	Willow Oak

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

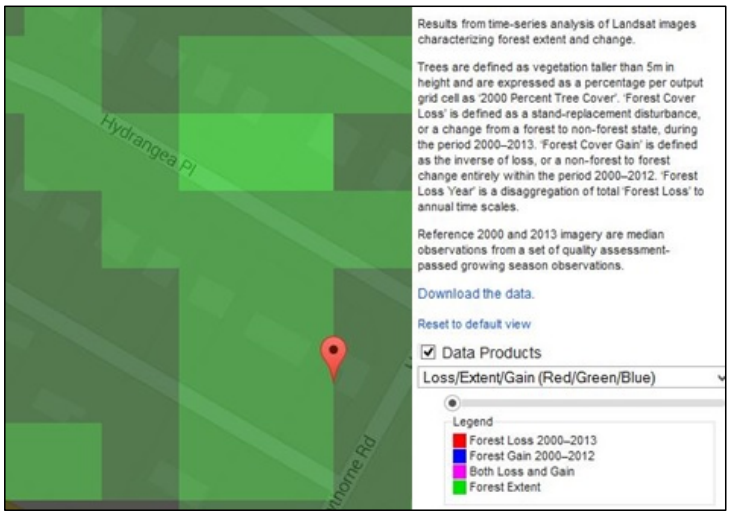

Figure D.31: Tree Canopy Loss/Extent/Gain at Site W-LDO (Hansen et al., 2013)

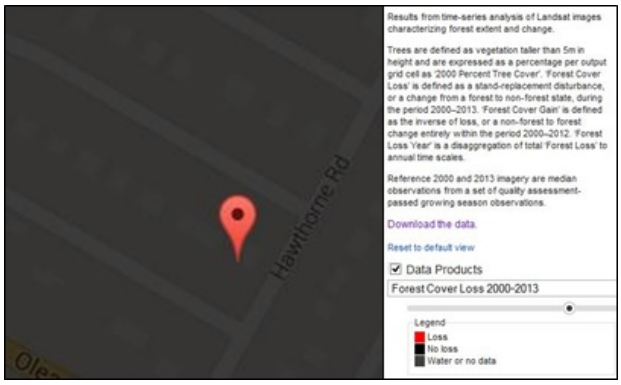

Figure D.32: Tree Canopy Loss at Site W-LDO (Hansen et al., 2013)

Table D.26: Litter Types and Quantities Collected at Site W-LDO

Litter Category	Quantity
Cigarette Butts	4
Styrofoam	0
Paper/Wrappers	0
Plastic	2
Stones/Pavement	1
Metal	0
Other	0

Table D.27: Total Rainfall between Sampling Events at Site W-LDO

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
03/13/14	2.61	09/26/14	1.26
04/03/14	4.17	10/08/14	0.16
04/17/14	0.67	10/22/14	1.35
04/29/14	3.81	11/05/14	0.84
05/14/14	0.50	11/21/14	0.47
05/29/14	2.31	12/03/14	3.60
06/12/14	1.22	12/17/14	0.34
06/24/14	0.60	01/15/15	4.51
07/11/14	5.50	01/27/15	3.41
07/29/14	6.70	02/10/15	1.23
08/13/14	6.20	03/06/15	3.79
08/27/14	3.20	03/27/15	2.05
09/10/14	2.47		
Cumulative Rainfall (in)		**63.01**	

[a] Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

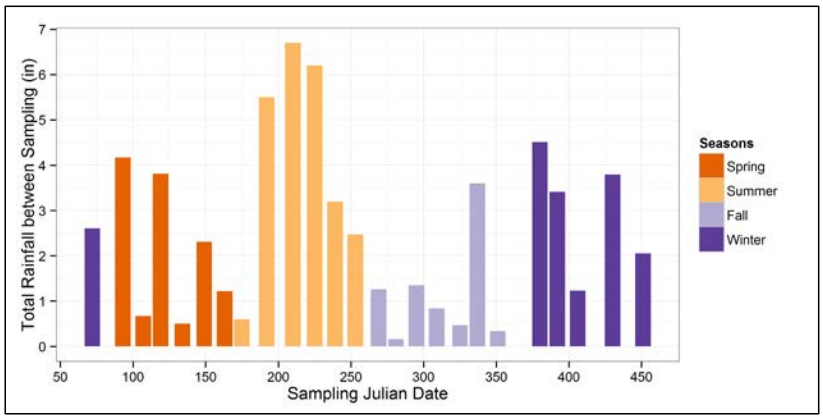

Figure D.33: Rainfall at Site W-LDO, Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

Table D.28: Basin Dimensions at Low-Density Old Sites

Dimension	Site			
	B-LDO	G-LDO	R-LDO	W-LDO
Basin Throat Height (ft)	0.56	0.69	-	0.59
Basin Throat Length (ft)	4.99	3.71	-	4.07
Basin Depth (ft)	4.20	2.30	-	1.51
Basin Width (ft)	2.10	5.51	-	1.84
Basin Length (ft)	4.00	3.71	-	4.07
Basin Outlet Pipe (in)	16.14	16.14	-	11.81

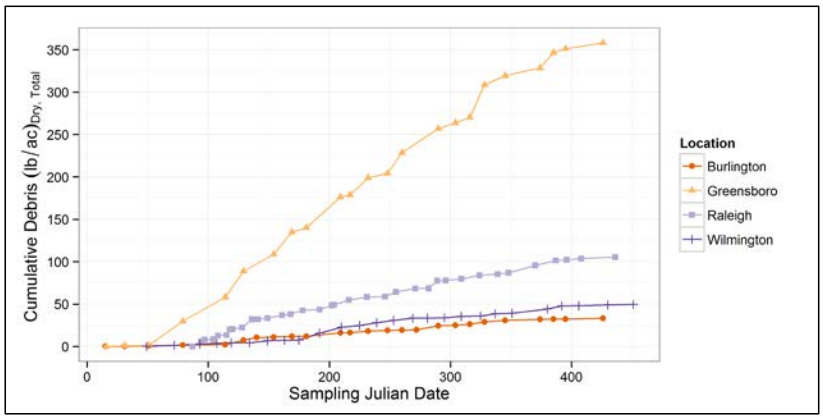

Figure D.34: Low-Density Old Cumulative Debris Loads Normalized by Watershed Area

Table D.29: Debris Loads from Low-Density Old Sites

Site	Cumulative Debris Load[a] (lb/ac)
B-LDO	33.27
G-LDO	358.11
R-LDO	105.36
W-LDO	49.69

[a] Normalized by watershed area

Table D.30: Gross Solids Volumes from Low-Density Old Sites

Site	Cumulative Solids Volume (ft^3)	Average Solids Volume per Sample (ft^3)	Daily Average Solids Volume per Sample (ft^3/day)
B-LDO	11.49	0.55	0.04
G-LDO	13.20	0.70	0.05
R-LDO	13.92	0.44	0.05
W-LDO	8.23	0.36	0.02

D.3 Low-Density New

D.3.1 Site B-LDN

Field observations found lawns sloped from the front edges of homes to the asphalt street. Driveways were also graded to drain onto the road, and gutter systems were directly connected to the conveyance network (Figure D.35). Vegetation species and litter details for the site are included in Tables D.31 and D.32, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.36 and D.37 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.33 and Figure D.38. Basin dimensions are summarized in Table D.43. Figure D.51 and Table D.44 include the cumulative debris load collected from the site. Table D.45 summarizes the total volume of solids collected from the site.

Figure D.35: Aerial View of Site B-LDN Watershed

Table D.31: Identified Vegetation Species at Site B-LDN

Vegetation Type	Scientific Name[a,b]	Common Name
Grass	*Festuca arundinacea*	Tall Fescue
Tree	*Acer rubrum* L.	Red Maple
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Tree	*Salix babylonica*	Weeping Willow

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

Figure D.36: Tree Canopy Loss/Extent/Gain at Site B-LDN (Hansen et al., 2013)

Figure D.37: Tree Canopy Loss at Site B-LDN (Hansen et al., 2013)

Table D.32: Litter Types and Quantities Collected at Site B-LDN

Litter Category	Quantity
Cigarette Butts	8
Styrofoam	4
Paper/Wrappers	15
Plastic	9
Stones/Pavement	15
Metal	0
Other	11

Table D.33: Total Rainfall between Sampling Events at Site B-LDN

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.07	08/05/14	1.17
02/20/14	1.94	08/20/14	1.61
03/06/14	1.22	09/05/14	1.60
03/20/14	2.46	09/29/14	0.87
04/24/14	2.10	10/17/14	2.01
05/09/14	1.52	10/31/14	0.03
05/20/14	3.42	11/12/14	0.21
06/03/14	0.39	11/24/14	1.27
06/18/14	0.88	12/11/14	1.68
06/30/14	0.24	01/09/15	2.11
07/28/14	0.53	03/02/15	4.58
Cumulative Rainfall (in)		**31.94**	

[a] Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

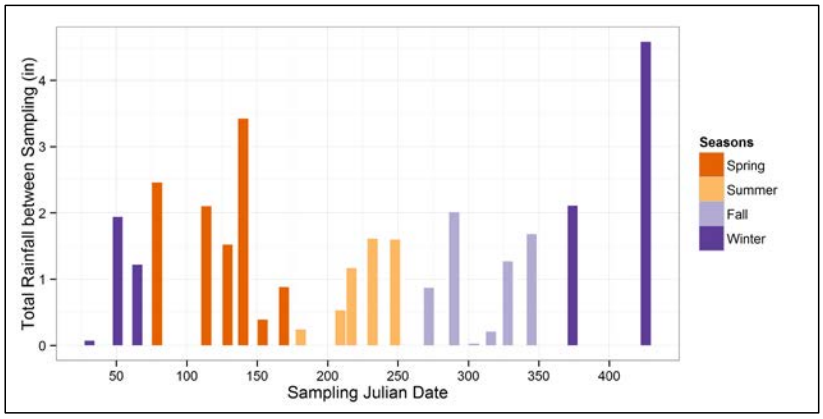

Figure D.38: Rainfall at Site B-LDN, Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

D.3.2 Site G-LDN

Surveys of the site found disconnected downspouts and lawns drained from the property's back edge to the asphalt road (Figure D.39). Vegetation species and litter details are included in Tables D.34 and D.35, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.40 and D.41 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.36 and Figure D.42. Basin dimensions are summarized in Table D.43. Figure D.51 and Table D.44 include the cumulative debris load collected from the site. Table D.45 summarizes the total volume of solids collected from the site.

Figure D.39: Aerial View of Site G-LDN Watershed

Table D.34: Identified Vegetation Species at Site G-LDN

Vegetation Type	Scientific Name[a,b]	Common Name
Grass	*Festuca arundinacea*	Tall Fescue
Tree	*Acer rubrum* L.	Red Maple
Tree	*Pyrus calleryana*	Bradford Pear
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Grass	*Liriope spicata*	Creeping Liriope
Shrub	*Ilex cornuta burfordii*	Burford Holly
Shrub	*Abelia x grandiflora*	Abelia

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

Figure D.40: Tree Canopy Loss/Extent/Gain at Site G-LDN (Hansen et al., 2013)

Figure D.41: Tree Canopy Loss at Site G-LDN (Hansen et al., 2013)

Table D.35: Litter Types and Quantities Collected at Site G-LDN

Litter Category	Quantity
Cigarette Butts	8
Styrofoam	4
Paper/Wrappers	15
Plastic	9
Stones/Pavement	15
Metal	0
Other	11

Table D.36: Total Rainfall between Sampling Events at Site G-LDN

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.03	09/05/14	0.15
02/20/14	2.75	09/17/14	0.89
03/06/14	0.87	09/29/14	0.22
03/20/14	5.71	10/17/14	1.51
04/24/14	3.31	10/31/14	0.07
05/09/14	1.15	11/12/14	1.33
05/20/14	0.61	11/24/14	1.23
06/03/14	0.17	12/11/14	1.13
06/18/14	1.83	01/09/15	2.11
06/30/14	0.87	01/20/15	0.60
07/28/14	2.12	01/30/15	0.54
08/05/14	0.95	03/02/15	3.39
08/20/14	1.20		
Cumulative Rainfall (in)		**34.74**	

[a] Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

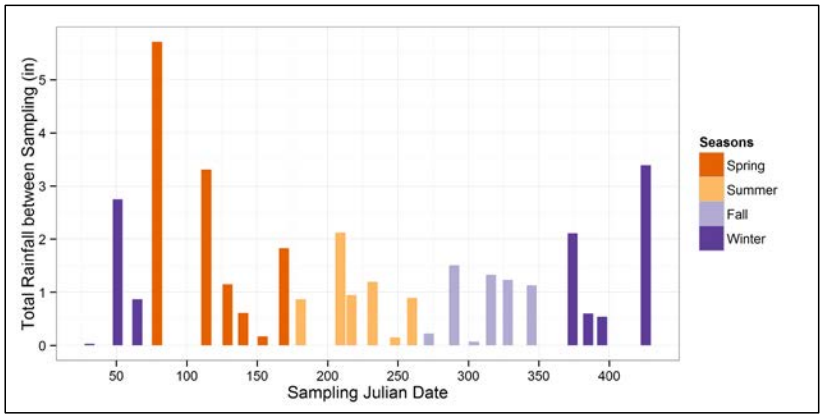

Figure D.42: Rainfall at Site G-LDN, Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

DB.3.3 Site R-LDN

Field observations found portions of lawns drained from the front edges of homes to the asphalt road. Additionally, one driveway was graded towards the street (Figure D.43). Vegetation species and litter details are included in Tables D.37 and D.38, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.44 and D.45 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.39 and Figure D.46. Basin dimensions are summarized in Table D.43. Figure D.51 and Table D.44 include the cumulative debris load collected from the site. Table D.45 summarizes the total volume of solids collected from the site.

Figure D.43: Aerial View of Site R-LDN Watershed

Table D.37: Identified Vegetation Species at Site R-LDN

Type	Scientific Name[a,b]	Common Name
Tree	*Prunus serrulata*	Japanese Cherry
Shrub	*Rhododendron carolinianum* Rehder	Azalea
Grass	*Cynodon dactylon* (L.) Pers.	Bermuda grass
Grass	*Festuca arundinacea*	Tall Fescue
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Tree	*Juniperus virginiana*	Eastern Red Cedar
Tree	*Acer rubrum* L.	Red Maple
Plant	*Lupinus spp.*	Lupine
Tree	*Ilex opaca*	American Holly
Shrub	*Ligustrum sinense*	Chinese Privet
Plant	*Dianthus chinensis*	Dianthus

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

Figure D.44: Tree Canopy Loss/Extent/Gain at Site R-LDN (Hansen et al., 2013)

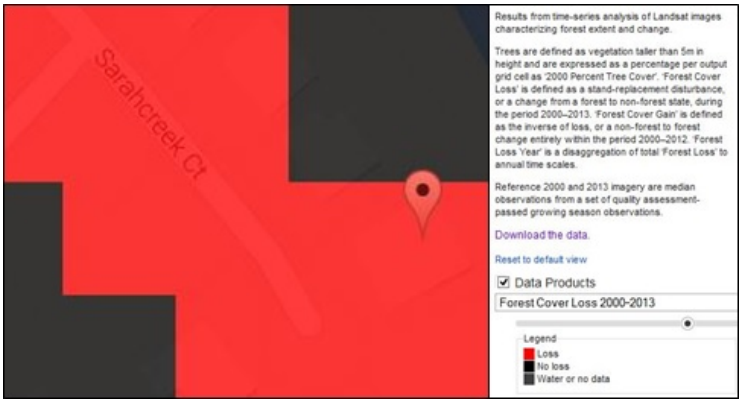

Figure D.45: Tree Canopy Loss at Site R-LDN (Hansen et al., 2013)

Table D.38: Litter Types and Quantities Collected at Site R-LDN

Litter Category	Quantity
Cigarette Butts	7
Styrofoam	8
Paper/Wrappers	11
Plastic	11
Stones/Pavement	221
Metal	0
Other	4

Table D.39: Total Rainfall between Sampling Events at Site R-LDN

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/17/14	1.38	08/19/14	5.05
01/24/14	0.02	09/03/14	0.18
02/07/14	0.35	09/12/14	1.20
02/27/14	2.75	09/28/14	1.23
03/19/14	3.65	10/09/14	0.08
04/04/14	2.14	10/23/14	3.00
04/14/14	0.94	11/05/14	0.67
04/28/14	2.10	11/20/14	0.76
05/08/14	1.31	12/05/14	1.84
05/21/14	4.81	12/14/14	0.55
06/02/14	0.18	01/05/15	4.19
06/17/14	2.23	01/22/15	2.20
06/27/14	3.29	01/31/15	0.75
07/11/14	1.75	02/12/15	0.99
07/23/14	3.11	02/28/15	2.60
08/04/14	1.18		
Cumulative Rainfall (in)		**56.48**	

[a] Station: REED-ECONET (State Climate Office of North Carolina, 2015)

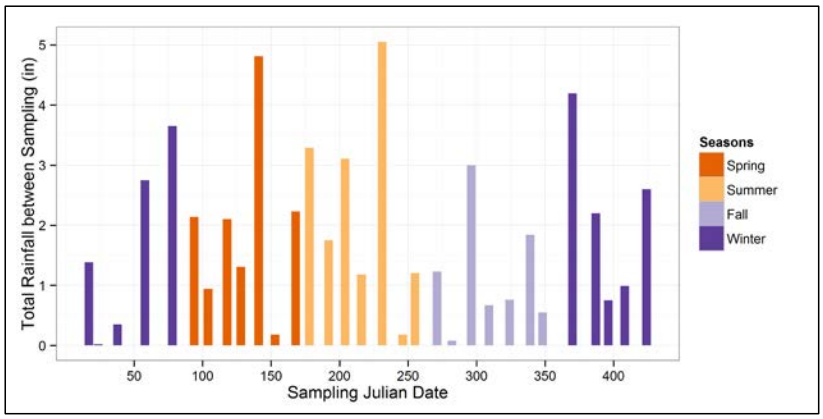

Figure D.46: Rainfall at Site R-LDN, Station: REED-ECONET (State Climate Office of North Carolina, 2015)

D.3.4 Site W-LDN

Surveys of the site found lawns drained from the front edges of homes to the asphalt road. Disconnected downspouts managing the front halves of roofs drained onto driveways that were also graded towards the street (Figure D.47). Vegetation species and litter details are included in Tables D.40 and D.41, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.48 and D.49 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.42 and Figure D.50. Basin dimensions are summarized in Table D.43. Figure D.51 and Table D.44 include the cumulative debris load collected from the site. Table D.45 summarizes the total volume of solids collected from the site.

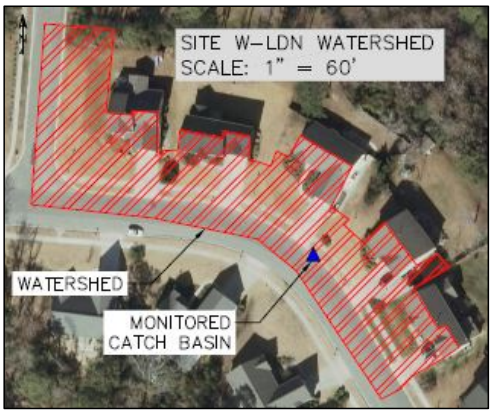

Figure D.47: Aerial View of Site W-LDN Watershed

Table D.40: Identified Vegetation Species at Site W-LDN

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Tree	*Acer rubrum* L.	Red Maple
Tree	*Acer saccharinum*	Silver Maple
Tree	*Betula nigra*	River Birch
Grass	*Eremochloa* Büse	Centipede Grass
Grass	*Cynodon dactylon* (L.) Pers.	Bermuda grass
Tree	*Pyrus calleryana*	Bradford Pear
Shrub	*Rhododendron carolinianum* Rehder	Azalea
Tree	*Trachycarpus fortunei*	Windmill Palm
Tree	*Acer palmatum*	Japanese Maple
Shrub	*Myrica cerifera*	Southern Waxmyrtle
Tree	*Liquidambar styraciflua*	Sweetgum
Tree	*Pinus taeda*	Loblolly Pine
Tree	*Morus* L.	Mulberry Tree
Plant	*Viburnum* L.	Viburnum

[a] NC Cooperative Extension (2015);
[b] USDA-NRCS (2015)

Figure D.48: Tree Canopy Loss/Extent/Gain at Site W-LDN (Hansen et al., 2013)

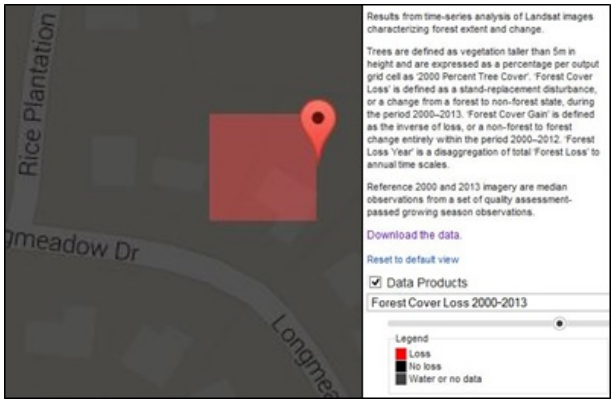

Figure D.49: Tree Canopy Loss at Site W-LDN (Hansen et al., 2013)

Table D.41: Litter Types and Quantities Collected at Site W-LDN

Litter Category	Quantity
Cigarette Butts	69
Styrofoam	2
Paper/Wrappers	32
Plastic	38
Stones/Pavement	0
Metal	2
Other	6

Table D.42: Total Rainfall between Sampling Events at Site W-LDN

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall[a] (in)
03/13/14	2.61	09/26/14	.26
04/03/14	4.17	10/08/14	0.16
04/17/14	0.67	10/22/14	1.35
04/29/14	3.81	11/05/14	0.84
05/14/14	0.50	11/21/14	0.47
05/29/14	2.31	12/03/14	3.60
06/12/14	1.22	12/17/14	0.34
06/24/14	0.55	01/15/15	4.51
07/11/14	5.55	01/27/15	3.41
07/29/14	6.70	02/10/15	1.23
08/27/14	3.20	03/06/15	3.79
09/10/14	2.47	03/27/15	2.05
Cumulative Rainfall (in)		**56.81**	

[a] Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

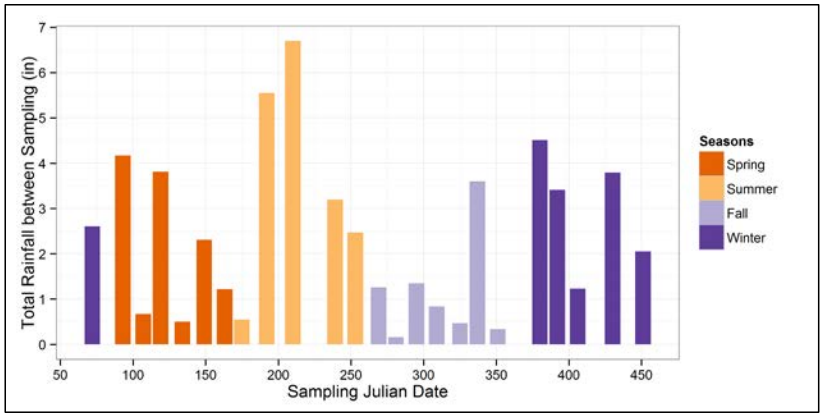

Figure D.50: Rainfall at Site W-LDN, Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

Table D.43: Basin Dimensions for Low-Density New Sites

Dimension	Site			
	B-LDN	G-LDN	R-LDN	W-LDN
Basin Throat Height (ft)	0.49	0.14	-	0.62
Basin Throat Length (ft)	4.10	1.25	-	3.90
Basin Depth (ft)	5.31	1.28	-	2.00
Basin Width (ft)	2.69	0.79	-	1.67
Basin Length (ft)	4.10	1.25	-	3.90
Basin Outlet Pipe (in)	29.92	0.76	-	11.81

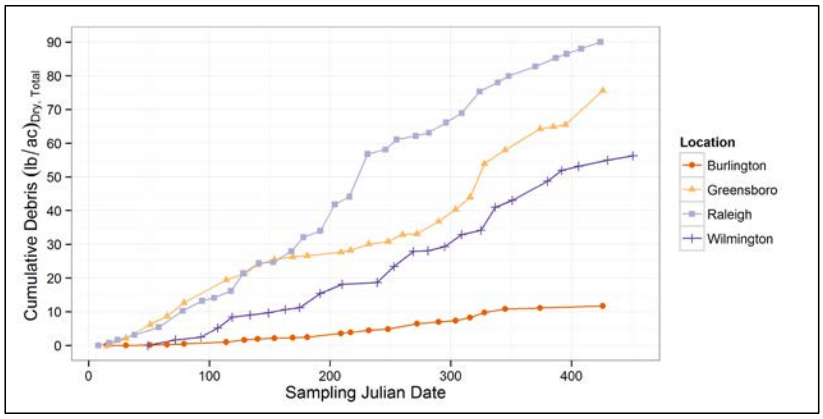

Figure D.51: Low-Density New Cumulative Debris Loads Normalized by Watershed Area

Table D.44: Debris Loads from Low-Density New Sites

Site	Cumulative Debris Load[a] (lb/ac)
B-LDN	11.72
G-LDN	75.63
R-LDN	90.04
W-LDN	56.24

[a] Normalized by watershed area

Table D.45: Gross Solids Volumes from Low-Density New Sites

Site	Cumulative Solids Volume (ft^3)	Average Solids Volume per Sample (ft^3)	Daily Average Solids Volume per Sample (ft^3/day)
B-LDN	1.43	0.08	0.01
G-LDN	18.36	0.87	0.05
R-LDN	3.16	0.13	0.01
W-LDN	6.94	0.32	0.02

D.4 Downtown

D.4.1 Site B-DT

Field observations found sidewalks, portions of driveways, and disconnected downspouts drained to the asphalt road. Portions of pervious areas were also graded to the street (Figure D.52). Vegetation species and litter details are included in Tables D.46 and D.47 respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.53 and D.54 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.48 and Figure D.55. Basin dimensions are summarized in Table D.58. Figure D.68 and Table D.59 include the cumulative debris load collected from the site. Table D.60 summarizes the total volume of solids collected from the site.

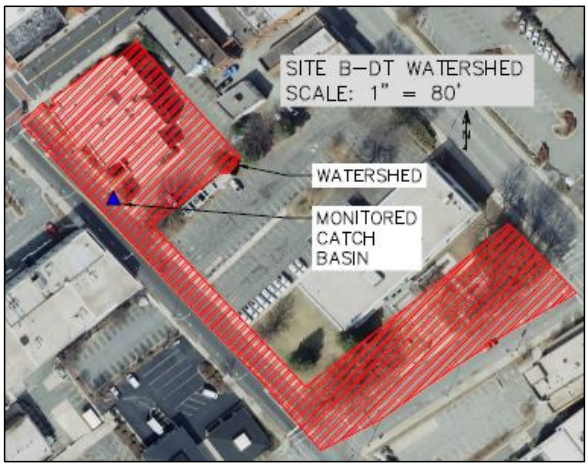

Figure D.52: Aerial View of Site B-DT Watershed

Table D.46: Identified Vegetation Species at Site B-DT

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Quercus phellos* L.	Willow Oak
Tree	*Tsuga caroliniana*	Carolina Hemlock
Tree	*Pyrus calleryana*	Bradford Pear
Grass	*Liriope spicata*	Creeping Liriope
Shrub	*Ligustrum sinense*	Chinese Privet
Shrub	*Juniperus horizontalis wiltonii*	Blue Rug Juniper
Plant	*Hemerocallis* L.	Daylily
Tree	*Osmanthus americanus*	Devilwood
Shrub	*Ilex cornuta burfordii*	Burford Holly
Plant	*Spiraea xvanhouttei*	Spirea
Plant	*Nandina domestica*	Nandina
Tree	*Ilex x attenuata fosteri*	Foster's Holly
Tree	*Acer rubrum* L.	Red Maple
Plant	*Hedera helix*	English Ivy
Grass	*Festuca arundinacea*	Tall Fescue
Shrub	*Berberis candidula*	Paleleaf Barberry

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

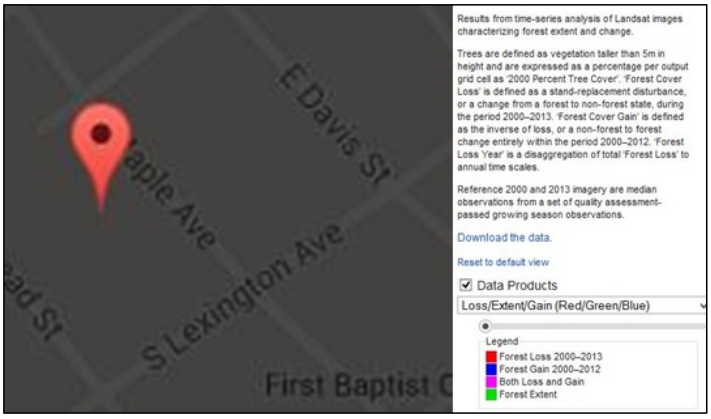

Figure D.53: Tree Canopy Loss/Extent/Gain at Site B-DT (Hansen et al., 2013)

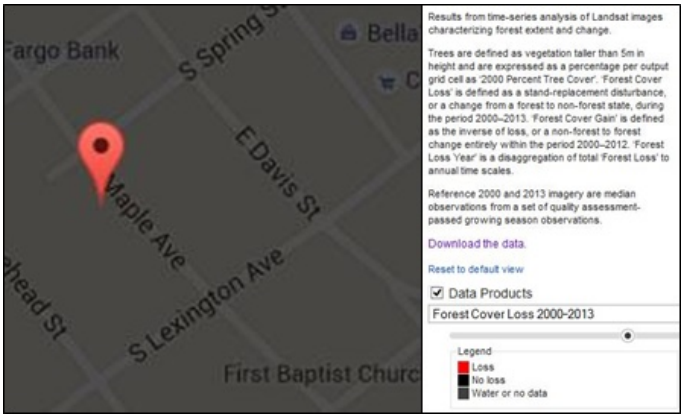

Figure D.54: Tree Canopy Loss at Site B-DT (Hansen et al., 2013)

Table D.47: Litter Types and Quantities Collected at Site B-DT

Litter Category	Quantity
Cigarette Butts	555
Styrofoam	25
Paper/Wrappers	139
Plastic	86
Stones/Pavement	119
Metal	2
Other	10

Table D.48: Total Rainfall between Sampling Events at Site B-DT

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.07	09/29/14	0.27
02/20/14	1.94	10/17/14	2.01
03/06/14	1.22	10/31/14	0.03
03/20/14	2.46	11/12/14	0.21
04/24/14	1.52	11/24/14	1.27
06/03/14	0.39	12/11/14	1.68
06/30/14	0.24	01/09/15	2.11
08/20/14	1.61	01/20/15	0.92
09/05/14	1.60	01/30/15	0.77
09/17/14	0.60	03/02/15	2.88
Cumulative Rainfall (in)		**23.83**	

[a] Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

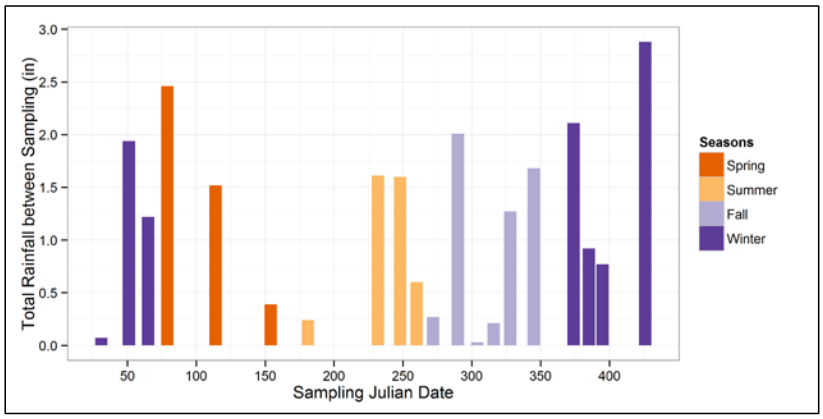

Figure D.55: Rainfall at Site B-DT, Station: KBUY-ASOS (State Climate Office of North Carolina, 2015)

D.4.2 Site G-DT

Surveys of the site found sidewalks and a portion of a nearby parking lot drained to the asphalt street (Figure D.56). Building gutter systems were directly connected to the conveyance system.

Vegetation species and litter details are included in Tables D.49 and D.50, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.57 and D.58 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.51 and Figure D.59. Basin dimensions are summarized in Table D.58. Figure D.68 and Table D.59 include the cumulative debris load collected from the site. Table D.60 summarizes the total volume of solids collected from the site.

Figure D.56: Aerial View of Site G-DT Watershed

Table D.49: Identified Vegetation Species at Site G-DT

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Fraxinus americana*	White Ash
Tree	*Prunus serrulata*	Japanese Cherry
Plant	*Hemerocallis* L.	Daylily
Grass	*Liriope spicata*	Creeping Liriope
Tree	*Quercus phellos* L.	Willow Oak
Shrub	*Juniperus horizontalis wiltonii*	Blue Rug Juniper
Tree	*Acer rubrum* L.	Red Maple
Plant	*Loropetalum chinese var. rubrum*	Loropetalum
Plant	*Nandina domestica*	Nandina
Tree	*Quercus spp.*	Oak

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

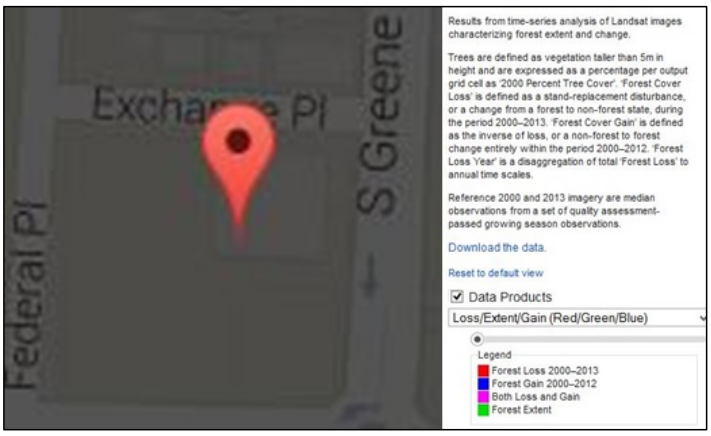

Figure D.57: Tree Canopy Loss/Extent/Gain at Site G-DT (Hansen et al., 2013)

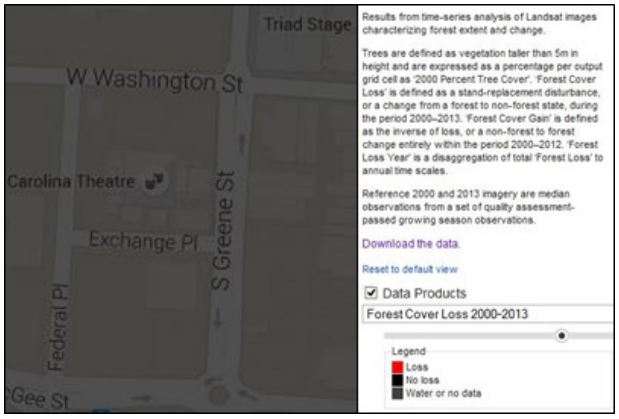

Figure D.58: Tree Canopy Loss at Site G-DT (Hansen et al., 2013)

Table D.50: Litter Types and Quantities Collected at Site G-DT

Litter Category	Quantity
Cigarette Butts	390
Styrofoam	25
Paper/Wrappers	227
Plastic	263
Stones/Pavement	85
Metal	5
Other	14

Table D.51: Total Rainfall between Sampling Events at Site G-DT

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall (in)
01/31/14	0.03	09/17/14	0.89
02/20/14	2.75	09/29/14	0.22
03/06/14	0.87	10/17/14	1.51
03/20/14	5.71	10/31/14	0.07
04/10/14	1.85	11/12/14	1.33
06/03/14	0.17	11/24/14	1.23
06/18/14	1.83	12/11/14	1.13
06/30/14	0.87	01/09/15	2.11
07/28/14	2.12	01/20/15	0.60
08/05/14	0.95	01/30/15	0.54
08/20/14	1.20	03/02/15	3.39
09/05/14	0.15		
Cumulative Rainfall (in)		31.52	

[a] Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

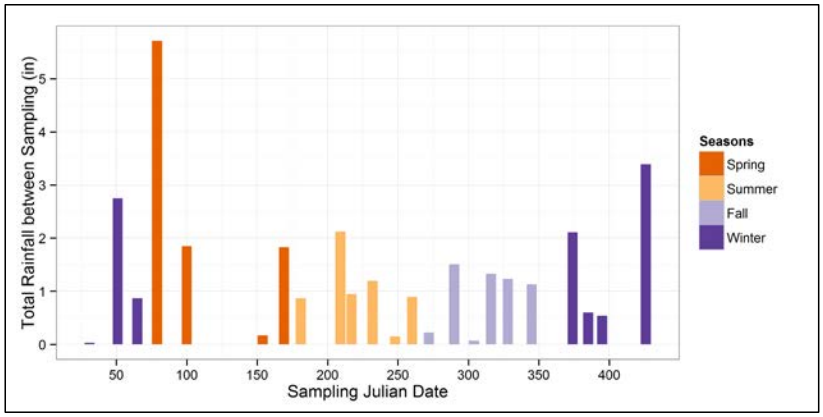

Figure D.59: Rainfall at G-DT, Station: NCAT-ECONET (State Climate Office of North Carolina, 2015)

D.4.3 Site R-DT

Field observations found sidewalks, parking lots, and pervious areas from building edges drained to the asphalt road (Figure D.60). A portion the gutter systems were directly connected to the conveyance network. Vegetation species and litter details are included in Tables D.52 and D.53, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.61 and D.62 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.54 and Figure D.63. Basin dimensions are summarized in Table D.58. Figure D.68 and Table D.59 include the cumulative debris load collected from the site. Table D.60 summarizes the total volume of solids collected from the site.

Figure D.60: Aerial View of Site R-DT Watershed

Table D.52: Identified Vegetation Species at Site R-DT

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Quercus phellos* L.	Willow Oak
Grass	*Festuca arundinacea*	Tall Fescue
Plant	*Buxus sempervirens*	Boxwood
Plant	*Nandina domestica*	Nandina
Tree	*Quercus rubra* L.	Northern Red Oak
Shrub	*Rhododendron carolinianum* Rehder	Azalea
Tree	*Morus* L.	Mulberry Tree
Tree	*Pyrus calleryana*	Bradford Pear
Grass	*Liriope spicata*	Creeping Liriope
Plant	*Cornus controversa*	Dogwood
Plant	*Hydrangea* L.	Hydrangea
Plant	*Juniperus* L.	Juniper
Tree	*Acer palmatum*	Japanese Maple
Tree	*Quercus alba* L.	White Oak
Tree	*Photinia davidiana*	Photinia
Shrub	*Yucca filamentosa*	Yucca
Shrub	*Ilex vomitoria nana*	Dwarf Yaupon Holly
Tree	*Ulmus americana*	American Elm
Tree	*Celtis laevigata*	Hackberry
Shrub	*Ligustrum sinense*	Chinese Privet

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

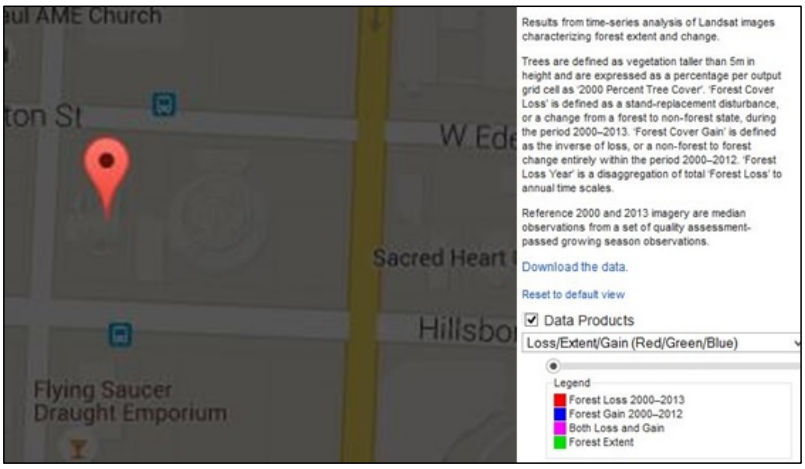

Figure D.61: Tree Canopy Loss/Extent/Gain at Site R-DT (Hansen et al., 2013)

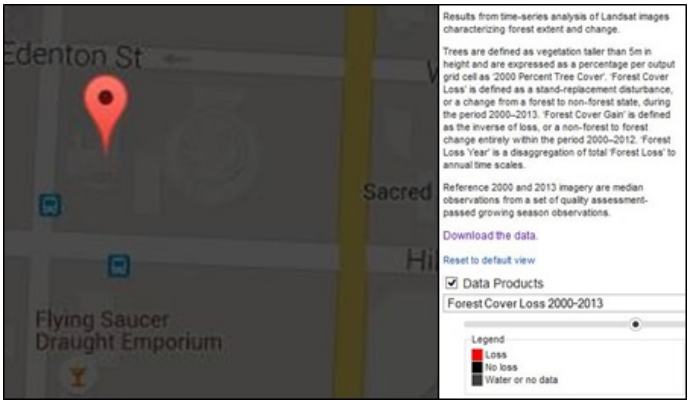

Figure D.62: Tree Canopy Loss at Site R-DT (Hansen et al., 2013)

Table D.53: Litter Types and Quantities Collected at Site R-DT

Litter Category	Quantity
Cigarette Butts	793
Styrofoam	19
Paper/Wrappers	181
Plastic	171
Stones/Pavement	649
Metal	5
Other	39

Table D.54: Total Rainfall between Sampling Events at Site R-DT

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall[a] (in)
04/14/14	0.03	09/12/14	4.63
04/18/14	1.70	09/28/14	0.47
04/25/14	0.37	10/09/14	0.72
04/28/14	0.40	10/16/14	4.04
04/30/14	0.39	11/05/14	0.61
05/08/14	0.84	11/20/14	0.74
05/16/14	5.70	12/05/14	1.69
06/10/14	0.54	12/14/14	0.45
06/17/14	0.66	01/05/15	4.46
06/27/14	1.96	01/22/15	3.10
07/11/14	1.30	01/31/15	0.63
07/23/14	2.07	02/12/15	1.11
08/04/14	4.46	02/28/15	2.90
08/19/14	4.76	03/12/15	1.01
09/03/14	0.06		
Cumulative Rainfall (in)		51.80	

[a] Station: LAKE-ECONET (State Climate Office of North Carolina, 2015)

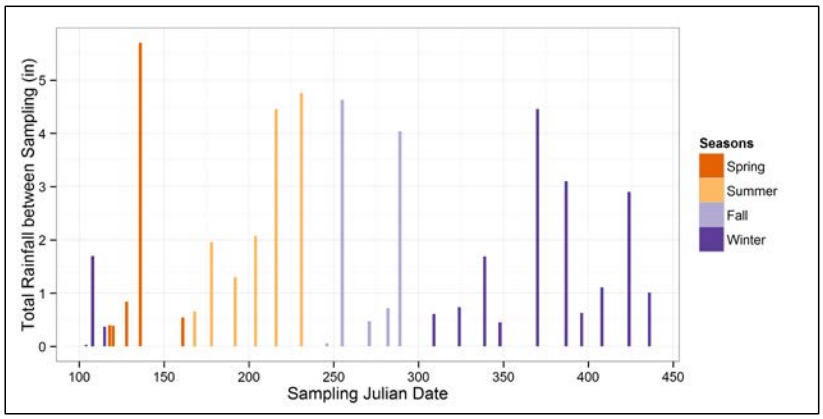

Figure D.63: Rainfall at Site R-DT, Station: LAKE-ECONET (State Climate Office of North Carolina, 2015)

D.4.4 Site W-DT

Surveys of the site found sidewalks, parking lots, disconnected downspouts, and pervious areas drained to the mixed asphalt and brick road (Figure D.64). Vegetation species and litter details are included in Tables D.55 and D.56, respectively (NC Cooperative Extension, 2015; USDA-NRCS, 2015). Estimated tree canopy loss, extent, and gain from 2000 to 2013 are shown in Figures D.65 and D.66 (Hansen et al., 2013). Rainfall data retrieved from the local weather station are shown in Table D.57 and Figure D.67. Basin dimensions are summarized in Table D.58. Figure D.68 and Table D.59 include the cumulative debris load collected from the site. Table D.60 summarizes the total volume of solids collected from the site.

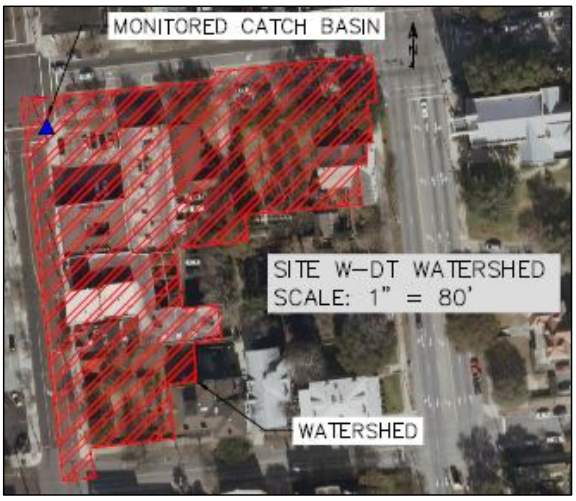

Figure D.64: Aerial View of Site W-DT Watershed

Table D.55: Identified Vegetation Species at Site W-DT

Vegetation Type	Scientific Name[a,b]	Common Name
Tree	*Quercus phellos* L.	Willow Oak
Tree	*Lagerstroemia indica* L.	Crape Myrtle
Tree	*Magnolia virginiana*	Sweetbay Magnolia
Grass	*Miscanthus sinensis gracillimus*	Maiden Grass
Tree	*Quercus virginiana*	Live Oak
Tree	*Acer palmatum*	Japanese Maple
Plant	*Buxus microphylla var. japonica*	Japanese Boxwood
Shrub	*Myrica cerifera*	Southern Waxmyrtle
Tree	*Quercus nigra*	Water Oak
Plant	*Gardenia volkensii* K. Schum.	Common Gardenia
Tree	*Mangolia grandiflora*	Southern Magnolia
Tree	*Morus* L.	Mulberry Tree
Shrub	*Podocarpus macrophyllus, Podocarpus spp.*	Podocarpus
Tree	*Ulmus parvifolia*	Lace Bark Elm
Tree	*Ilex opaca*	American Holly
Tree	*Prunus caroliniana*	Carolina Cherry Laurel
Plant	*Rosa xodorata* (Andrews) Sweet (pro sp.) [*chinensis* x *gigantea]*	Tea Rose
Vine	*Wisteria spp.*	Wisteria
Vine	*Campsis radicans*	Trumpet Creeper
Plant	*Camellia* L.	Camellia

[a] NC Cooperative Extension (2015)
[b] USDA-NRCS (2015)

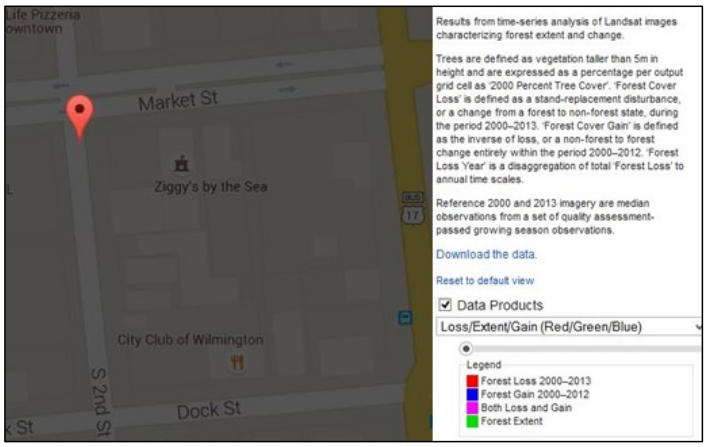

Figure D.65: Tree Canopy Loss/Extent/Gain at Site W-DT (Hansen et al., 2013)

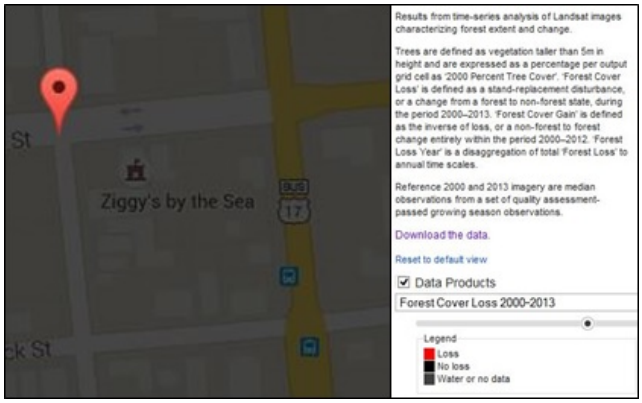

Figure D.66: Tree Canopy Loss at Site W-DT (Hansen et al., 2013)

Table D.56: Litter Types and Quantities Collected at Site W-DT

Litter Category	Quantity
Cigarette Butts	435
Styrofoam	26
Paper/Wrappers	260
Plastic	240
Stones/Pavement	56
Metal	12
Other	27

Table D.57: Total Rainfall between Sampling Events at Site W-DT

Date Sample Collected	Total Rainfall[a] (in)	Date Sample Collected	Total Rainfall[a] (in)
03/13/14	2.61	11/21/14	0.47
04/17/14	0.41	12/03/14	3.6
04/29/14	3.81	12/17/14	0.34
05/14/14	0.50	01/15/15	4.51
05/29/14	2.31	01/27/15	3.41
06/12/14	1.22	02/10/15	1.23
06/24/14	0.55	03/06/15	3.79
10/22/14	1.35	03/27/15	2.05
11/05/14	0.84		
Cumulative Rainfall (in)		33.02	

[a] Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

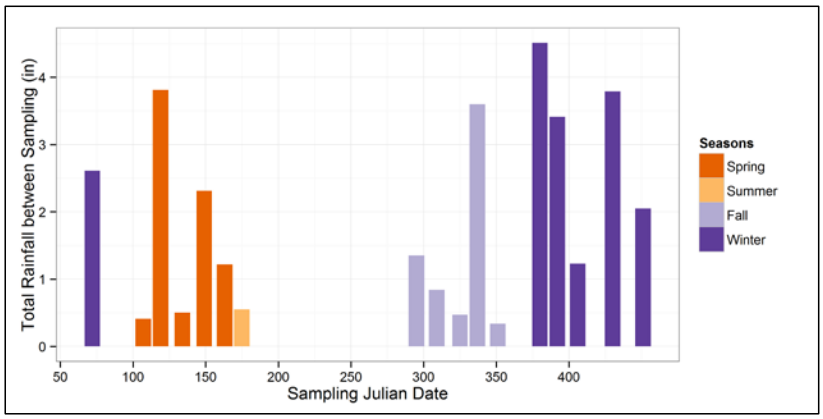

Figure D.67: Rainfall at Site W-DT, Station: KILM-ASOS (State Climate Office of North Carolina, 2015)

Table D.58: Basin Dimensions for Downtown Sites

Dimension	Site			
	B-DT	G-DT	R-DT	W-DT
Basin Throat Height (ft)	0.30	0.39	0.75	0.66
Basin Throat Length (ft)	5.81	6.00	4.79	4.00
Basin Depth (ft)	5.51	2.20	-	2.76
Basin Width (ft)	2.69	2.30	-	2.10
Basin Length (ft)	5.81	6.00	4.79	4.00
Basin Outlet Pipe (in)	24.02	11.81	-	11.81

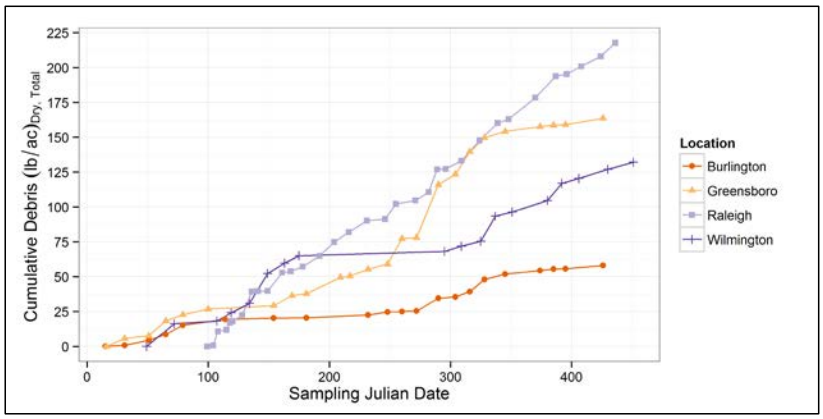

Figure D.68: Downtown Cumulative Debris Loads Normalized by Watershed Area

Table D.59: Debris Loads from Downtown Sites

Site	Cumulative Debris Load[a] (lb/ac)
B-DT	58.10
G-DT	163.62
R-DT	217.76
W-DT	132.19

[a] Normalized by watershed area

Table D.60: Gross Solids Volumes from Downtown New Sites

Site	Cumulative Solids Volume (ft^3)	Average Solids Volume per Sample (ft^3)	Daily Average Solids Volume per Sample (ft^3/day)
B-DT	13.46	0.84	0.06
G-DT	23.31	1.30	0.09
R-DT	27.40	0.90	0.08
W-DT	13.92	0.87	0.06

APPENDIX E: SAMPLE SORTING TECHNIQUE

Elements from Urban Water Resources Research Council Gross Solids (2009) and Roesner et al. (2007) were incorporated into the sorting technique developed specifically for this research project. The sorting steps for one collection are as followed:

1. Determine which size bin will contain the bagged sample and which scale will measure the sample's total weight (Figure E.1); bagged samples larger than the 3 gal bin will use scale A (CPWplus 200; Adam Equipment) and all remaining samples will use scale B (PC-20001; Intelligent Weighing Technology).

Figure E.1: Clockwise from top: Scale A, 19 gal Bin, Scale B, 3 gal Bin

2. Tare the weight of the bin on the appropriate scale, and record the weight of an unused 40 gal bag; assume the weight of the sample bag is equivalent, and ensure the bin is clean to avoid cross contamination of samples.
3. Record the total weight of the collected sample (in lb); apply a correction factor of 1.008 to any measurements taken with scale A to ensure all weight measurements are in terms of scale B (Figure E.2).

Figure E.2: Sample Weight Measurement with Scale A

4. Label a clean and sealable 1 qt plastic bag (7.5 in x 7.87 in) using a permanent marker with the two-digit month, two-digit date, and two letters of the site's location to identify the date and site the sample was collected; only one composite sample bag will be created for each collection (Figure E.3).

Figure E.3: Labelled Composite Sample Bag

5. Place the measured sample on a level surface and remove the sample bag; document the composition of the sample (Figure E.4).

Figure E.4: Removing Sample Bag (left) and Documented Sample (right)

6. Evenly spread the sample across the bin, and use a tape measurer to find the average depth of the solids from each corner and middle of the bin (Figure E.5)

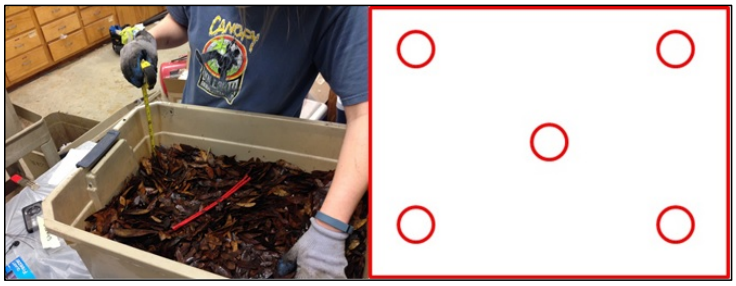

Figure E.5: Depth Measurement (left) and Plan View of Measurement Locations (right)

7. Multiply the average depth by the area of the bin (1.13 ft^2 for the 3 gal bin and 3.28 ft^2 for the 19 gal bin) to estimate the sample's volume; repeat as necessary.
8. Remove all litter from the sample; litter examples include: cigarette butts, Styrofoam, paper, wrappers, plastic, stones, pavement, metal, or other (Figure E.6).

Figure E.6: Clockwise from left: Wrapper, Paper, Metal, Stones, Cigarette Butts, Other, Styrofoam, and Plastic Examples

9. Toss the remaining debris seven times; if the 19 gal bin is used, remove a handful of the tossed debris from the top, and place into the 3 gal bin; otherwise place the handful of debris into the labelled composite bag (Figure E.7).

Figure E.7: Debris Sample Tossing (left) and Handful of Debris (right)

10. Repeat step 9 three more times if the 19 gal bin is used; otherwise repeat step 9 once for the 3 gal bin (Figure E.8).

11. If there are multiple bags, repeat step 9 three more times and place all handfuls of debris in another clean 19 gal bin; then repeat steps 1 through 11 until all of the bags have been processed. Follow steps 9 and 10 for the remaining 19 gal bin.
12. Toss the four handfuls of debris in the 3 gal bin seven times, remove a handful from the top, and place in the labelled composite bag; repeat once (Figure E.8).

Figure E.8: Handful of Debris in 3 gal bin (left) and Composite Sample (right)

13. Discard all remaining leaf debris and clean the 3 gal bin as necessary.
14. Tare the weight of the 3 gal bin on scale B and weigh the composite debris sample; Apply a correction factor of 1.008 ensure all weight measurements are in terms of scale B. Transfer to a refrigerator until the sample is taken to the NCDA&CS Agronomic Services Division Laboratory (Figure E.9).
15. Evenly spread the litter across the 3 gal bin and use a tape measurer to find the average length, width, and height of the litter (Figure E.9).
16. Multiply the average depth by the area of the bin (.13 ft^2 for the 3 gal bin and 3.28 ft^2 for the 19 gal bin) to estimate the volume of litter; repeat as necessary.
17. Categorize the litter as: cigarette butts, Styrofoam, paper and wrappers, plastic, stones and pavement, metal, or other (Figure E.6); Litter such as glass, rubber, wood, foam, and clothing were identified as other.
18. Tare the weight of the 3 gal bin on scale B and weigh each litter category separately (Figure E.9). Apply a correction factor of 1.008 ensure all weight measurements are in terms of scale B. Discard all litter when weighing is complete.

Figure E.9: Clockwise from top: Composite Debris Sample Weighing, Litter Volume Measurements, Paper and Wrapper Weighing, Plastic Weighing

APPENDIX F: POLLUTANT LOADS NORMALIZED BY WATERSHED AREA

Table F.1: Annual TC Loads from Collected Debris

Location	Land Use	TC Load (lb/ac/yr)	Cumulative TC Load (lb/ac/yr)
Burlington	High-Density	4.39	40.66
	Low-Density Old	10.31	
	Low-Density New	4.32	
	Downtown	21.64	
Greensboro	High-Density	9.43	206.12
	Low-Density Old	112.31	
	Low-Density New	25.46	
	Downtown	58.92	
Raleigh	High-Density	22.83	139.33
	Low-Density Old	34.88	
	Low-Density New	27.16	
	Downtown	54.47	
Wilmington	High-Density	33.32	90.94
	Low-Density Old	15.49	
	Low-Density New	16.50	
	Downtown	25.63	

Table F.2: Average Annual TC Load per Land Use

Land Use	TC Load (lb/ac/yr)
High-Density	17.49
Low-Density Old	43.25
Low-Density New	18.36
Downtown	40.16

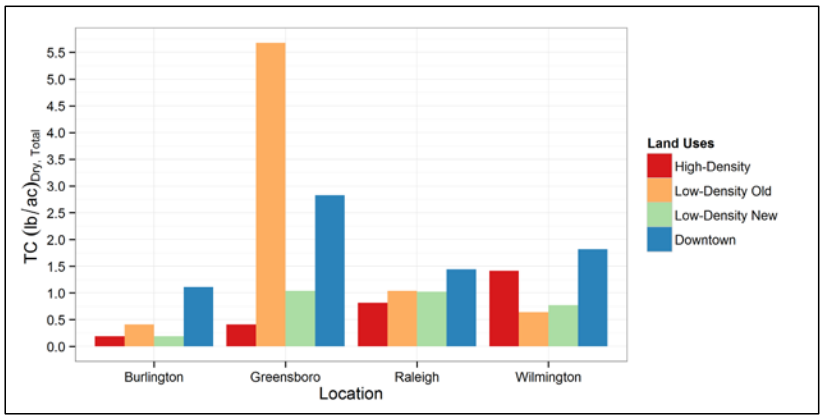

Figure F.1: Predicted TC Loads for Location*Land Use Effect

Table F.3: Predicted TC Loads per Location and Land Use

Location	Land Use	Predicted TC Load (lb/ac)
Burlington	High-Density	0.19
	Low-Density Old	0.41
	Low-Density New	0.19
	Downtown	1.11
Greensboro	High-Density	0.41
	Low-Density Old	5.68
	Low-Density New	1.04
	Downtown	2.83
Raleigh	High-Density	0.82
	Low-Density Old	1.04
	Low-Density New	1.03
	Downtown	1.45
Wilmington	High-Density	1.42
	Low-Density Old	0.64
	Low-Density New	0.77
	Downtown	1.82

Table F.4: Significant Differences between TC Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Raleigh	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Downtown**	**0.0077**
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	Low-Density Old	Raleigh	Low-Density Old	0.0025
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Downtown	Greensboro	Downtown	0.0218
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**0.0142**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Greensboro	**Low-Density New**	**Greensboro**	**Downtown**	**0.0046**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0489**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0076**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

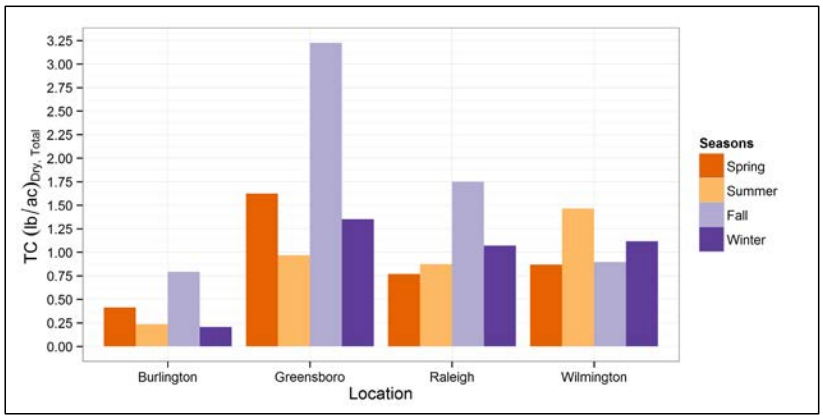

Figure F.2: Predicted TC Loads for Location*Season Effect

Table F.5: Predicted TC Loads per Location and Season

Location	Season	Predicted TC Load (lb/ac)
Burlington	Spring	0.42
	Summer	0.24
	Fall	0.79
	Winter	0.21
Greensboro	Spring	1.62
	Summer	0.97
	Fall	3.22
	Winter	1.35
Raleigh	Spring	0.77
	Summer	0.87
	Fall	1.75
	Winter	1.07
Wilmington	Spring	0.87
	Summer	1.47
	Fall	0.90
	Winter	1.12

Table F.6: Significant Differences between TC Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Summer**	**0.0002**
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	<0.0001
Burlington	Fall	Raleigh	Fall	0.043
Burlington	Spring	Greensboro	Spring	<0.0001
Burlington	Summer	Greensboro	Summer	<0.0001
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	**Fall**	**Greensboro**	**Summer**	**0.0003**
Greensboro	**Fall**	**Greensboro**	**Winter**	**0.0248**
Greensboro	Fall	Wilmington	Fall	<0.0001
Raleigh	**Fall**	**Raleigh**	**Spring**	**0.0056**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at $\alpha=0.05$

Table F.7: Annual Fe Loads from Collected Debris

Location	Land Use	Fe Load*10^{-1} (lb/ac/yr)	Cumulative Fe Load*10^{-1} (lb/ac/yr)
Burlington	High-Density	0.44	5.08
	Low-Density Old	1.91	
	Low-Density New	0.37	
	Downtown	2.36	
Greensboro	High-Density	0.52	31.59
	Low-Density Old	22.40	
	Low-Density New	2.91	
	Downtown	5.76	
Raleigh	High-Density	1.90	31.43
	Low-Density Old	8.14	
	Low-Density New	4.39	
	Downtown	17.0	
Wilmington	High-Density	5.11	15.84
	Low-Density Old	1.68	
	Low-Density New	2.06	
	Downtown	6.99	

Table F.8: Average Annual Fe Loads per Land Use

Land Use	Fe Load *10^{-1} (lb/ac/yr)
High-Density	1.99
Low-Density Old	8.53
Low-Density New	2.43
Downtown	8.03

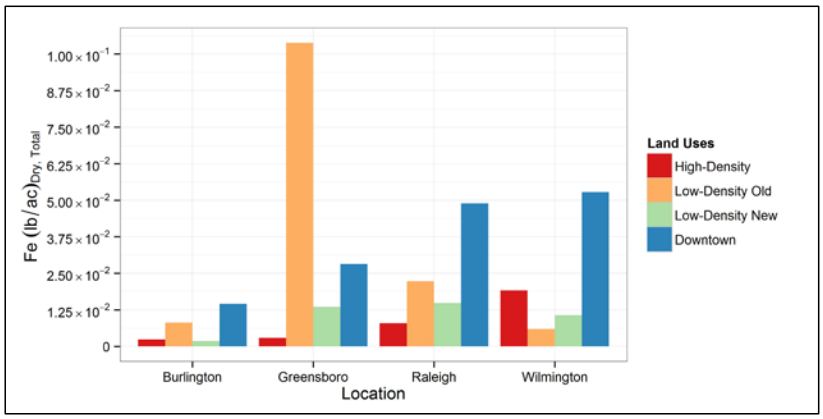

Figure F.3: Predicted Fe Loads for Location*Land Use Effect

Table F.9: Predicted Fe Loads per Location and Land Use

Location	Land Use	Predicted Fe Load*10^{-3} (lb/ac)
Burlington	High-Density	2.39
	Low-Density Old	8.09
	Low-Density New	1.85
	Downtown	14.50
Greensboro	High-Density	2.94
	Low-Density Old	104.0
	Low-Density New	13.60
	Downtown	28.20
Raleigh	High-Density	7.97
	Low-Density Old	22.30
	Low-Density New	14.80
	Downtown	48.90
Wilmington	High-Density	19.20
	Low-Density Old	5.95
	Low-Density New	10.70
	Downtown	52.80

Table F.10: Significant Differences between Fe Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Downtown**	**0.0001**
Burlington	High-Density	Raleigh	High-Density	0.0363
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**0.0033**
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Downtown	<0.0001
Burlington	Downtown	Raleigh	Downtown	0.0344
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**0.0015**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	**Low-Density Old**	**Greensboro**	**Downtown**	**0.0391**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	0.0004
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Low-Density Old**	**0.0465**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	Low-Density Old	Wilmington	Low-Density Old	0.0024
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**0.0056**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0398**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0029**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

Table F.11: Annual Zn Loads from Collected Debris

Location	Land Use	Zn Load*10^{-2} (lb/ac/yr)	Cumulative Zn Load *10^{-2} (lb/ac/yr)
Burlington	High-Density	0.60	3.68
	Low-Density Old	0.83	
	Low-Density New	0.35	
	Downtown	1.90	
Greensboro	High-Density	0.56	13.90
	Low-Density Old	8.73	
	Low-Density New	1.42	
	Downtown	3.19	
Raleigh	High-Density	1.45	14.68
	Low-Density Old	2.65	
	Low-Density New	2.86	
	Downtown	7.72	
Wilmington	High-Density	4.52	12.32
	Low-Density Old	1.07	
	Low-Density New	1.44	
	Downtown	5.29	

Table F.12: Average Annual Zn Loads per Land Use

Land Use	Zn Load*10^{-2} (lb/ac/yr)
High-Density	1.78
Low-Density Old	3.32
Low-Density New	1.52
Downtown	4.53

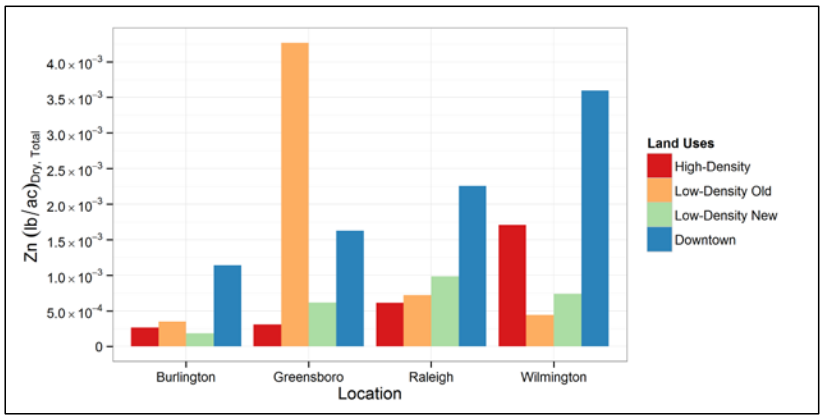

Figure F.4: Predicted Zn Loads for Location*Land Use Effect

Table F.13: Predicted Zn Loads per Location and Land Use

Location	Land Use	Predicted Zn Load*10^{-4} (lb/ac)
Burlington	High-Density	2.65
	Low-Density Old	3.49
	Low-Density New	1.83
	Downtown	11.40
Greensboro	High-Density	3.08
	Low-Density Old	42.70
	Low-Density New	6.18
	Downtown	16.30
Raleigh	High-Density	6.14
	Low-Density Old	7.20
	Low-Density New	9.83
	Downtown	22.60
Wilmington	High-Density	17.10
	Low-Density Old	4.40
	Low-Density New	7.38
	Downtown	36.0

Table F.14: Significant Differences between Zn Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Downtown**	**0.0001**
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Downtown**	**0.0049**
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	0.0011
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Downtown	Wilmington	Downtown	0.0256
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Greensboro	**Low-Density New**	**Greensboro**	**Downtown**	**0.0299**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	0.0063
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**0.0001**
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**0.0342**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

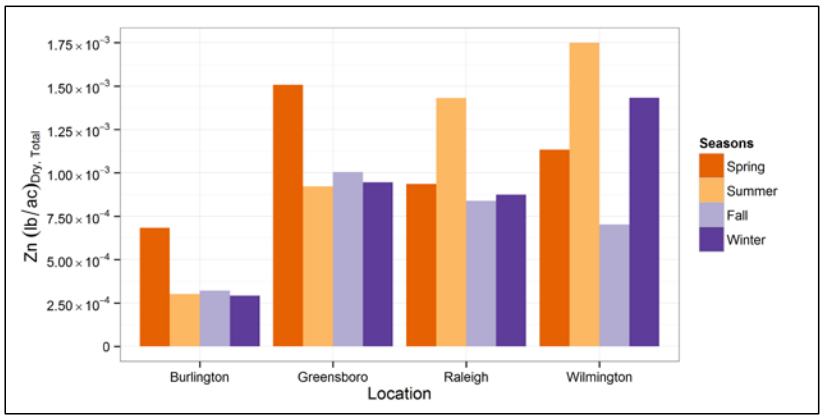

Figure F.5: Predicted Zn Loads for Location*Season Effect

Table F.15: Predicted Zn Loads per Location and Season

Location	Season	Predicted Zn Load*10^{-4} (lb/ac)
Burlington	Spring	6.83
	Summer	3.01
	Fall	3.21
	Winter	2.92
Greensboro	Spring	15.10
	Summer	9.22
	Fall	10.0
	Winter	9.47
Raleigh	Spring	9.36
	Summer	14.30
	Fall	8.39
	Winter	8.74
Wilmington	Spring	11.30
	Summer	17.50
	Fall	7.03
	Winter	14.30

Table F.16: Significant Differences between Zn Loads for Location*Season Effect

Location	Season	Location	Season	Adjusted p-value[a]
Burlington	Fall	Greensboro	Fall	0.0044
Burlington	Fall	Raleigh	Fall	0.0198
Burlington	Summer	Greensboro	Summer	0.0129
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	0.0019
Burlington	Winter	Raleigh	Winter	0.0029
Burlington	Winter	Wilmington	Winter	<0.0001

[a] Significance established at α=0.05

Table F.17: Annual Mn Loads from Collected Debris

Location	Land Use	Mn Load*10^{-2} (lb/ac/yr)	Cumulative Mn Load*10^{-2} (lb/ac/yr)
Burlington	High-Density	0.50	5.78
	Low-Density Old	1.90	
	Low-Density New	0.68	
	Downtown	2.70	
Greensboro	High-Density	1.02	22.12
	Low-Density Old	10.70	
	Low-Density New	5.03	
	Downtown	5.37	
Raleigh	High-Density	2.23	24.56
	Low-Density Old	3.28	
	Low-Density New	2.35	
	Downtown	16.70	
Wilmington	High-Density	1.39	5.37
	Low-Density Old	0.47	
	Low-Density New	0.75	
	Downtown	2.75	

Table F.18: Average Annual Mn Loads per Land Use

Land Use	Mn Load*10^{-2} (lb/ac/yr)
High-Density	1.29
Low-Density Old	4.09
Low-Density New	2.20
Downtown	6.88

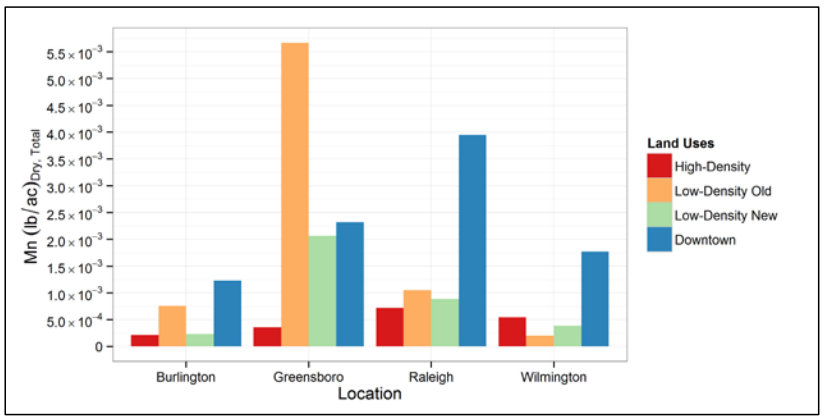

Figure F.6: Predicted Mn Loads for Location*Land Use Effect

Table F.19: Predicted Mn Loads per Location and Land Use

Location	Land Use	Predicted Mn Load*10^{-4} (lb/ac)
Burlington	High-Density	2.09
	Low-Density Old	7.56
	Low-Density New	2.31
	Downtown	12.30
Greensboro	High-Density	3.59
	Low-Density Old	56.70
	Low-Density New	20.60
	Downtown	23.2
Raleigh	High-Density	7.21
	Low-Density Old	10.50
	Low-Density New	8.86
	Downtown	39.50
Wilmington	High-Density	5.43
	Low-Density Old	2.04
	Low-Density New	3.89
	Downtown	17.70

Table F.20: Significant Differences between Mn Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**0.001**
Burlington	High-Density	Raleigh	High-Density	0.0008
Burlington	High-Density	Wilmington	High-Density	0.0494
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**0.0033**
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	Low-Density Old	Wilmington	Low-Density Old	0.0002
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Downtown	Raleigh	Downtown	0.0015
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**0.0414**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Greensboro	Low-Density New	Wilmington	Low-Density New	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**<0.0001**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0232**
Wilmington	**High-Density**	**Wilmington**	**Downtown**	**0.0118**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0004**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

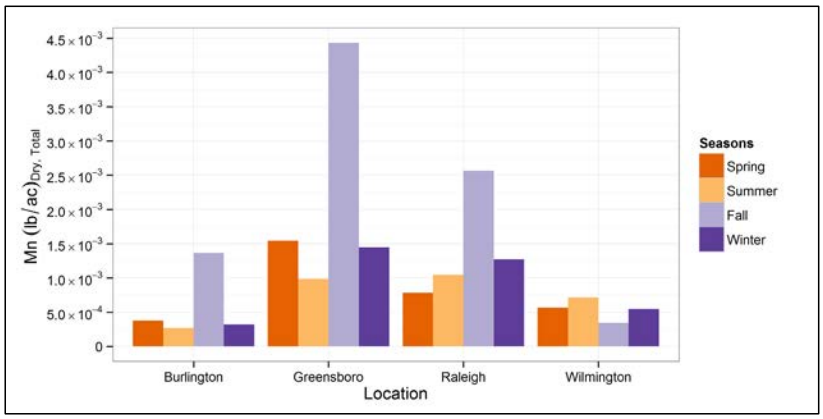

Figure F.7: Predicted Mn Loads for Location*Season Effect

Table F.21: Predicted Mn Loads per Location and Season

Location	Season	Predicted Mn Load*10^{-4} (lb/ac)
Burlington	Spring	3.77
	Summer	2.70
	Fall	13.70
	Winter	3.21
Greensboro	Spring	15.40
	Summer	9.87
	Fall	44.30
	Winter	14.50
Raleigh	Spring	7.80
	Summer	10.50
	Fall	25.60
	Winter	12.70
Wilmington	Spring	5.68
	Summer	7.13
	Fall	3.42
	Winter	5.48

Table F.22: Significant Differences between Mn Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Spring**	**0.001**
Burlington	**Fall**	**Burlington**	**Summer**	**<0.0001**
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	0.0037
Burlington	Fall	Wilmington	Fall	<0.0001
Burlington	Spring	Greensboro	Spring	0.0002
Burlington	Summer	Greensboro	Summer	0.0019
Burlington	Summer	Raleigh	Summer	0.0002
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Greensboro	**Fall**	**Greensboro**	**Spring**	**0.033**
Greensboro	**Fall**	**Greensboro**	**Summer**	**<0.0001**
Greensboro	**Fall**	**Greensboro**	**Winter**	**0.0078**
Greensboro	Fall	Wilmington	Fall	<0.0001
Greensboro	Spring	Wilmington	Spring	0.0469
Greensboro	Winter	Wilmington	Winter	0.0359
Raleigh	**Fall**	**Raleigh**	**Spring**	**0.0001**
Raleigh	**Fall**	**Raleigh**	**Summer**	**0.0405**
Raleigh	Fall	Wilmington	Fall	<0.0001

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

Table F.23: Annual Cu Loads from Collected Debris

Location	Land Use	Cu Load*10^{-3} (lb/ac/yr)	Cumulative Cu Load*10^{-3} (lb/ac/yr)
Burlington	High-Density	0.27	3.88
	Low-Density Old	1.13	
	Low-Density New	0.24	
	Downtown	2.25	
Greensboro	High-Density	1.11	16.68
	Low-Density Old	9.51	
	Low-Density New	2.07	
	Downtown	3.99	
Raleigh	High-Density	1.09	14.72
	Low-Density Old	3.13	
	Low-Density New	1.82	
	Downtown	8.68	
Wilmington	High-Density	4.43	12.78
	Low-Density Old	0.79	
	Low-Density New	1.20	
	Downtown	6.36	

Table F.24: Average Annual Cu Loads per Land Use

Land Use	Cu Load*10^{-3} (lb/ac/yr)
High-Density	1.72
Low-Density Old	3.64
Low-Density New	1.33
Downtown	5.32

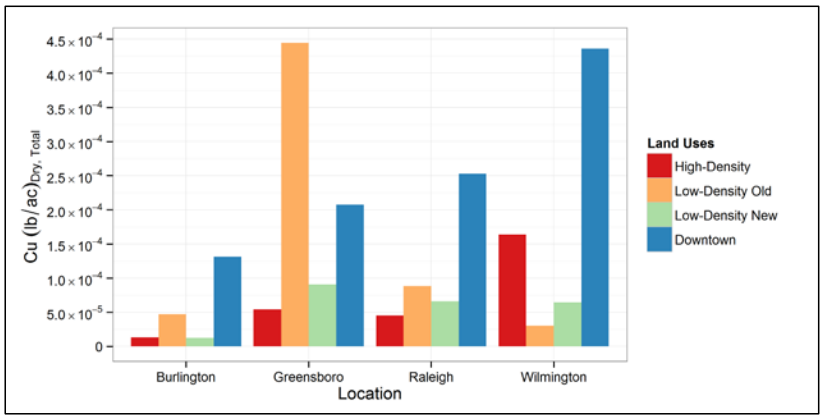

Figure F.8: Predicted Cu Loads for Location*Land Use Effect

Table F.25: Predicted Cu Loads per Location and Land Use

Location	Land Use	Predicted Cu Load*10^{-4} (lb/ac)
Burlington	High-Density	0.13
	Low-Density Old	0.47
	Low-Density New	0.12
	Downtown	1.31
Greensboro	High-Density	0.54
	Low-Density Old	4.44
	Low-Density New	0.91
	Downtown	2.08
Raleigh	High-Density	0.45
	Low-Density Old	0.88
	Low-Density New	0.66
	Downtown	2.53
Wilmington	High-Density	1.64
	Low-Density Old	0.30
	Low-Density New	0.65
	Downtown	4.36

Table F.26: Significant Differences between Cu Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**0.0041**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	0.0012
Burlington	High-Density	Raleigh	High-Density	0.0036
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**0.0013**
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Downtown	Wilmington	Downtown	0.0455
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.0027**
Greensboro	High-Density	Wilmington	High-Density	0.0261
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	0.0005
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**0.004**
Raleigh	Low-Density Old	Wilmington	Low-Density Old	0.008
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**<0.0001**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

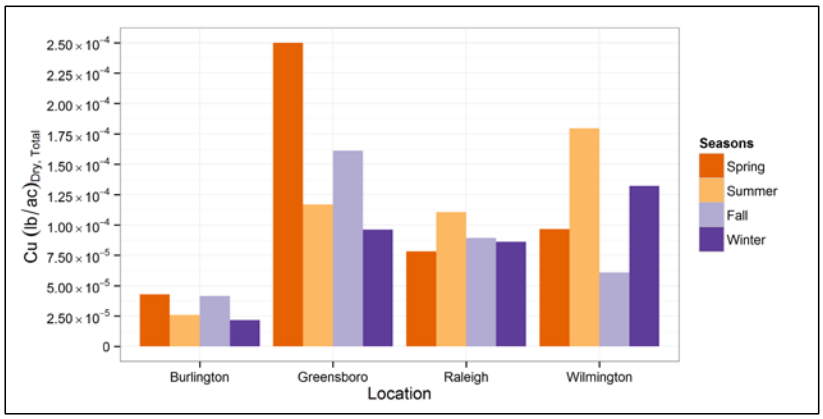

Figure F.9: Predicted Cu Loads for Location*Season Effect

Table F.27: Predicted Cu Loads per Location and Season

Location	Season	Predicted Cu Load*10^{-5} (lb/ac)
Burlington	Spring	4.27
	Summer	2.59
	Fall	4.16
	Winter	2.18
Greensboro	Spring	25.0
	Summer	11.70
	Fall	16.10
	Winter	9.62
Raleigh	Spring	7.83
	Summer	11.10
	Fall	8.94
	Winter	8.61
Wilmington	Spring	9.67
	Summer	18.0
	Fall	6.08
	Winter	13.20

Table F.28: Significant Differences between Cu Loads for Location*Season Effect

Location	Season	Location	Season	Adjusted p-value[b]
Burlington	Fall	Greensboro	Fall	0.0012
Burlington	Spring	Greensboro	Spring	<0.0001
Burlington	Summer	Greensboro	Summer	0.0005
Burlington	Summer	Raleigh	Summer	0.0003
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	0.0001
Burlington	Winter	Raleigh	Winter	0.0002
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	Spring	Raleigh	Spring	0.0038

[a] Significance established at α=0.05

Table F.29: Annual Ni Loads from Collected Debris

Location	Land Use	Ni Load*10^{-4} (lb/ac/yr)	Cumulative Ni Load*10^{-4} (lb/ac/yr)
Burlington	High-Density	0.62	3.18
	Low-Density Old	0.64	
	Low-Density New	0.31	
	Downtown	1.61	
Greensboro	High-Density	0.63	19.87
	Low-Density Old	13.10	
	Low-Density New	2.18	
	Downtown	3.96	
Raleigh	High-Density	1.49	28.59
	Low-Density Old	7.18	
	Low-Density New	5.72	
	Downtown	14.20	
Wilmington	High-Density	6.57	18.24
	Low-Density Old	2.05	
	Low-Density New	3.27	
	Downtown	6.35	

Table F.30: Average Annual Ni Loads per Land Use

Land Use	Ni Load*10^{-4} (lb/ac/yr)
High-Density	2.33
Low-Density Old	5.74
Low-Density New	2.87
Downtown	6.53

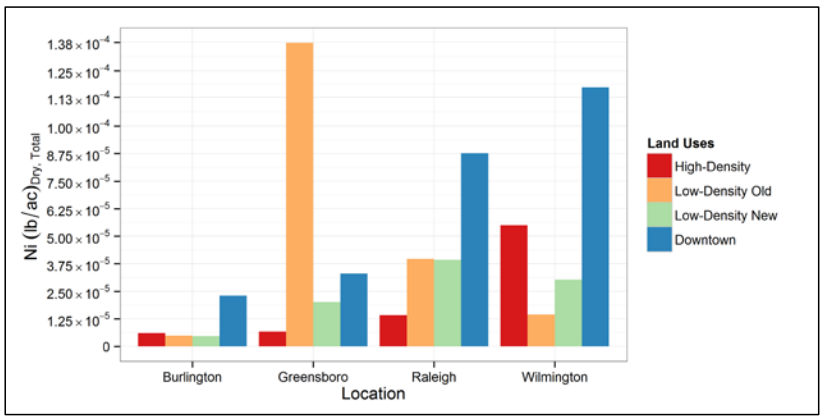

Figure F.10: Predicted Ni Loads for Location*Land Use Effect

Table F.31: Predicted Ni Loads per Location and Land Use

Location	Land Use	Predicted Ni Load*10^{-5} (lb/ac)
Burlington	High-Density	0.60
	Low-Density Old	0.49
	Low-Density New	0.47
	Downtown	2.30
Greensboro	High-Density	0.68
	Low-Density Old	13.80
	Low-Density New	2.01
	Downtown	3.31
Raleigh	High-Density	1.41
	Low-Density Old	3.97
	Low-Density New	3.93
	Downtown	8.77
Wilmington	High-Density	5.49
	Low-Density Old	1.45
	Low-Density New	3.03
	Downtown	11.80

Table F.32: Significant Differences between Ni Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	Low-Density Old	Raleigh	Low-Density Old	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	0.0024
Greensboro	**High-Density**	**Greensboro**	Low-Density Old	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.0273**
Greensboro	High-Density	Wilmington	High-Density	0.0002
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**0.0014**
Greensboro	Low-Density Old	Wilmington	Low-Density Old	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**0.0003**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0009**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

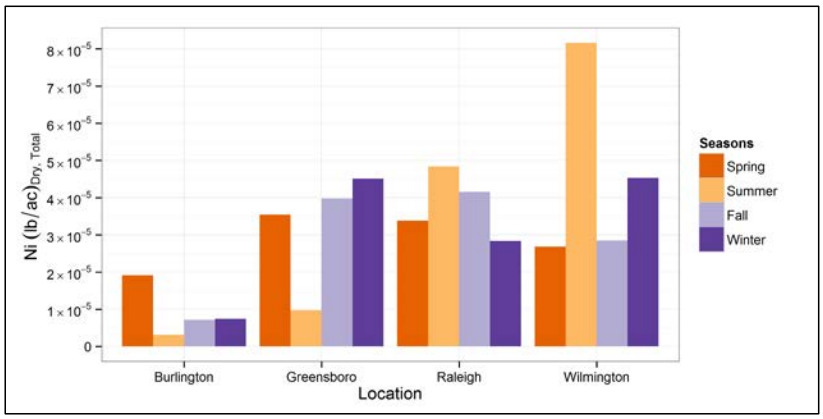

Figure F.11: Predicted Ni Loads for Location*Season Effect

Table F.33: Predicted Ni Loads per Location and Season

Location	Season	Predicted Ni Load*10^{-5} (lb/ac)
Burlington	Spring	1.91
	Summer	0.31
	Fall	0.71
	Winter	0.74
Greensboro	Spring	3.54
	Summer	0.98
	Fall	3.98
	Winter	4.51
Raleigh	Spring	3.38
	Summer	4.84
	Fall	4.16
	Winter	2.84
Wilmington	Spring	2.69
	Summer	8.16
	Fall	2.85
	Winter	4.53

Table F.34: Significant Differences between Ni Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	Fall	Greensboro	Fall	0.0046
Burlington	Fall	Raleigh	Fall	0.0018
Burlington	**Spring**	**Burlington**	**Summer**	**0.0356**
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	0.0097
Burlington	Winter	Wilmington	Winter	0.0058
Greensboro	**Summer**	**Greensboro**	**Winter**	**0.031**
Greensboro	Summer	Raleigh	Summer	0.0069
Greensboro	Summer	Wilmington	Summer	0.0008

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

Table F.35: Annual Pb Loads from Collected Debris

Location	Land Use	Pb Load*10^{-4} (lb/ac/yr)	Cumulative Pb Load*10^{-4} (lb/ac/yr)
Burlington	High-Density	1.20	8.96
	Low-Density Old	2.37	
	Low-Density New	0.83	
	Downtown	4.56	
Greensboro	High-Density	0.69	48.71
	Low-Density Old	34.40	
	Low-Density New	1.32	
	Downtown	12.30	
Raleigh	High-Density	1.99	73.34
	Low-Density Old	14.0	
	Low-Density New	8.65	
	Downtown	48.70	
Wilmington	High-Density	108.0	184.05
	Low-Density Old	12.60	
	Low-Density New	3.95	
	Downtown	59.50	

Table F.36: Average Annual Pb Loads per Land Use

Land Use	Pb Load*10^{-4} (lb/ac/yr)
High-Density	27.97
Low-Density Old	15.84
Low-Density New	3.69
Downtown	31.27

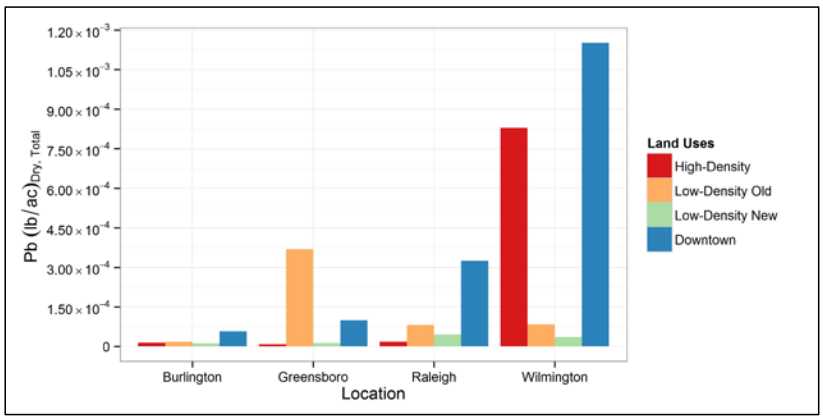

Figure F.12: Predicted Pb Loads for Location*Land Use Effect

Table F.37: Predicted Pb Loads per Location and Land Use

Location	Land Use	Predicted Pb Load*10^{-5} (lb/ac)
Burlington	High-Density	1.42
	Low-Density Old	1.79
	Low-Density New	1.19
	Downtown	5.76
Greensboro	High-Density	0.78
	Low-Density Old	36.90
	Low-Density New	1.35
	Downtown	9.93
Raleigh	High-Density	1.77
	Low-Density Old	8.10
	Low-Density New	4.47
	Downtown	32.50
Wilmington	High-Density	83.0
	Low-Density Old	8.35
	Low-Density New	3.65
	Downtown	115.0

Table F.38: Significant Differences between Pb Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	Low-Density Old	Greensboro	Low-Density Old	<0.0001
Burlington	Downtown	Raleigh	Downtown	0.0303
Burlington	Downtown	Wilmington	Downtown	<0.0001
Greensboro	**High-Density**	**Greensboro**	**Low-Density Old**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	**Low-Density New**	**Greensboro**	**Downtown**	**0.0033**
Greensboro	Downtown	Wilmington	Downtown	0.0006
Raleigh	**High-Density**	**Raleigh**	**Low-Density Old**	**0.0231**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**0.0309**
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**0.0009**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**<0.0001**
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

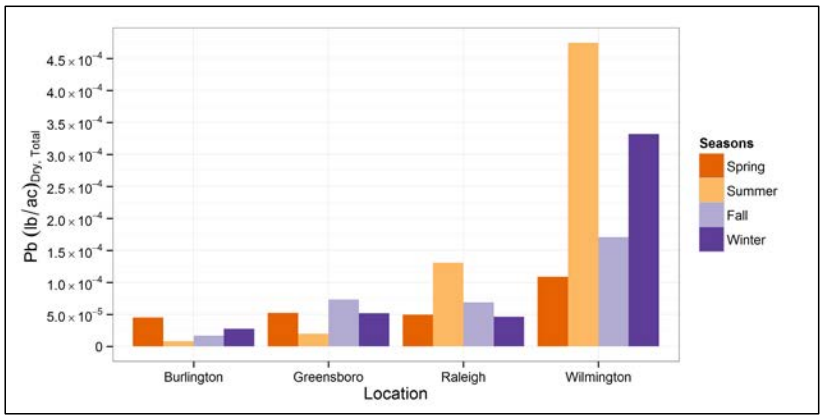

Figure F.12: Predicted Pb Loads for Location*Season Effect

Table F.39: Predicted Pb Loads per Location and Season

Location	Season	Predicted Pb Load*10^{-5} (lb/ac)
Burlington	Spring	4.25
	Summer	0.82
	Fall	1.70
	Winter	2.74
Greensboro	Spring	5.23
	Summer	1.95
	Fall	7.31
	Winter	5.18
Raleigh	Spring	4.96
	Summer	13.10
	Fall	6.91
	Winter	4.65
Wilmington	Spring	10.90
	Summer	47.40
	Fall	17.10
	Winter	33.20

Table F.40: Significant Differences between Pb Loads for Location*Season Effect

Location	Season	Location	Season	Adjusted p-value[s]
Burlington	Fall	Wilmington	Fall	0.0003
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Wilmington	Winter	0.0001
Greensboro	Summer	Raleigh	Summer	0.0029
Greensboro	Summer	Wilmington	Summer	<0.0001
Greensboro	Winter	Wilmington	Winter	0.0092
Raleigh	Winter	Wilmington	Winter	0.0013

[a] Significance established at α=0.05

APPENDIX G: ESTIMATING LABILE LOADS

Nutrient loads in stormwater runoff generated from the monitored watersheds were found using the National EPA Stormwater Calculator, site characteristics, and typical TN and TP runoff concentrations of 1.57 and 0.19 mg L^{-1}, respectively (Passeport and Hunt, 2009; US EPA, 2014a). The calculator incorporates the EPA's Stormwater Management Model (SWMM) to calculate average annual runoff. Climate change was not included in the calculations, and rainfall was analyzed over a 30 year period. Annual runoff depths were converted to annual volumes using Equation G.1; Equation G.2 was used to determine annual pollutant loads.

$$V = 102{,}790 * R * A \quad \text{(G.1)}$$

Where:
V= Annual runoff volume (L)
R= Annual runoff depth (in)
A= Watershed area (ac)

$$P = \frac{X * V * 10^{-6}}{A} * 0.89 \quad \text{(G.2)}$$

Where:
P= Annual pollutant load (lb/ac/yr)
X= Pollutant concentration (mg/L)
V= Annual runoff volume (L/yr)
A= Watershed area (ac)

Loads leached from gross solids were estimated by multiplying cumulative debris loads by average TN and TP leaching rates of 0.000854 and 0.000657 g g of $leaves^{-1}$, respectively (Hobbie et al., 2014).

APPENDIX H: LAND USES CONTRIBUTING LARGEST POLLUTANT LOADS

The Gupta-Hsu method uses Multiple Comparisons with the Best (MCB) and Ranking and Selection (RS) procedures to determine the best or largest treatments (Gupta and Hsu, 1984). It is applicable for unbalanced data and randomized complete block designs (RCBDs). For each pollutant, LSMEANS for the land covers were found using the PROC GLIMMIX model described in Section 3.11. Each land use's LSMEAN was treated a control and compared against the other land uses' LSMEANS using a Dunnett-Hsu adjustment, which has more power than a Tukey-Kramer adjustment. A positive and significant difference between a land use and control identified the control did not contribute the largest loads. Overall, the land use with the most positive and significant differences was identified as the largest pollutant contributor. For all inferences, significance was established at $\alpha=0.05$. For each pollutant, it was determined the downtown land use contributed the largest loads. The results shown below include the predicted pollutant loads for each land use and the respective comparisons between LSMEANS. Note the shown predicted loads were back-transformed from a gamma distribution while reported differences between the land uses' predicted loads were not back-transformed.

Table H.1: Predicted TC Loads per Land Use

Land Use	TC Load (lb/ac)
High-Density	0.54
Low-Density Old	1.12
Low-Density New	0.63
Downtown	1.70

Table H.2: Comparisons between TC Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.7192	<0.0001	Yes
Low-Density New	High-Density	0.1439	0.2393	No
Downtown	High-Density	1.1356	<0.0001	Yes
High-Density	Low-Density Old	-0.7192	1.0	No
Low-Density New	Low-Density Old	-0.5753	1.0	No
Downtown	Low-Density Old	0.4164	0.0008	Yes
High-Density	Low-Density New	-0.1439	0.9822	No
Low-Density Old	Low-Density New	0.5753	<0.0001	Yes
Downtown	Low-Density New	0.9917	<0.0001	Yes
High-Density	Downtown	-1.1356	1.0	No
Low-Density Old	Downtown	-0.4164	1.0	No
Low-Density New	Downtown	-0.9917	1.0	No

[a] Significance established at α=0.05

Table H.3: Predicted Fe Loads per Land Use

Land Use	Fe Load*10^{-3} (lb/ac)
High-Density	5.72
Low-Density Old	18.30
Low-Density New	7.94
Downtown	32.10

Table H.4: Comparisons between Fe Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	1.1615	<0.0001	Yes
Low-Density New	High-Density	0.3274	0.0686	No
Downtown	High-Density	1.7239	<0.0001	Yes
High-Density	Low-Density Old	-1.1615	1.0	No
Low-Density New	Low-Density Old	-0.8342	1.0	No
Downtown	Low-Density Old	0.5623	0.0025	Yes
High-Density	Low-Density New	-0.3274	0.9984	No
Low-Density Old	Low-Density New	0.8342	<0.0001	Yes
Downtown	Low-Density New	1.3965	<0.0001	Yes
High-Density	Downtown	-1.7239	1.0	No
Low-Density Old	Downtown	-0.5623	1.0	No
Low-Density New	Downtown	-1.3965	1.0	No

[a] Significance established at α=0.05

Table H.5: Predicted Zn Loads per Land Use

Land Use	Zn Load*10^{-4} (lb/ac)
High-Density	5.40
Low-Density Old	8.29
Low-Density New	5.36
Downtown	19.70

Table H.6: Comparisons between Zn Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.4276	0.0021	Yes
Low-Density New	High-Density	-0.00911	0.7727	No
Downtown	High-Density	1.2944	<0.0001	Yes
High-Density	Low-Density Old	-0.4276	1.0	No
Low-Density New	Low-Density Old	-0.4367	1.0	No
Downtown	Low-Density Old	0.8667	<0.0001	Yes
High-Density	Low-Density New	0.009114	0.7293	No
Low-Density Old	Low-Density New	0.4367	0.0014	Yes
Downtown	Low-Density New	1.3035	<0.0001	Yes
High-Density	Downtown	-1.2944	1.0	No
Low-Density Old	Downtown	-0.8667	1.0	No
Low-Density New	Downtown	-1.3035	1.0	No

[a] Significance established at α=0.05

Table H.7: Predicted Mn Loads per Land Use

Land Use	Mn Load*10^{-4} (lb/ac)
High-Density	4.14
Low-Density Old	9.79
Low-Density New	6.36
Downtown	21.10

Table H.8: Comparisons between Mn Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.8604	<0.0001	Yes
Low-Density New	High-Density	0.4298	0.0028	Yes
Downtown	High-Density	1.6286	<0.0001	Yes
High-Density	Low-Density Old	-0.8604	1.0	No
Low-Density New	Low-Density Old	-0.4306	1.0	No
Downtown	Low-Density Old	0.7683	<0.0001	Yes
High-Density	Low-Density New	-0.4298	1.0	No
Low-Density Old	Low-Density New	0.4306	0.0021	Yes
Downtown	Low-Density New	1.1989	<0.0001	Yes
High-Density	Downtown	-1.627	1.0	No
Low-Density Old	Downtown	-0.7683	1.0	No
Low-Density New	Downtown	-1.1989	1.0	No

[a] Significance established at α=0.05

Table H.9: Predicted Cu Loads per Land Use

Land Use	Cu Load*10^{-5} (lb/ac)
High-Density	4.80
Low-Density Old	8.64
Low-Density New	4.67
Downtown	23.40

Table H.10: Comparisons between Cu Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.589	0.0001	Yes
Low-Density New	High-Density	-0.02607	0.81	No
Downtown	High-Density	1.5848	<0.0001	Yes
High-Density	Low-Density Old	-0.589	1.0	No
Low-Density New	Low-Density Old	-0.6151	1.0	No
Downtown	Low-Density Old	0.9958	<0.0001	Yes
High-Density	Low-Density New	0.02607	0.686	No
Low-Density Old	Low-Density New	0.6151	<0.0001	Yes
Downtown	Low-Density New	1.6108	<0.0001	Yes
High-Density	Downtown	-1.5848	1.0	No
Low-Density Old	Downtown	-0.9958	1.0	No
Low-Density New	Downtown	-1.6108	1.0	No

[a] Significance established at α=0.05

Table H.11: Predicted Ni Loads per Land Use

Land Use	Ni Load*10^{-5} (lb/ac)
High-Density	1.33
Low-Density Old	2.49
Low-Density New	1.83
Downtown	5.29

Table H.12: Comparisons between Ni Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.6251	0.0038	Yes
Low-Density New	High-Density	0.3158	0.1572	No
Downtown	High-Density	1.3789	<0.0001	Yes
High-Density	Low-Density Old	-0.6251	1.0	No
Low-Density New	Low-Density Old	-0.3093	0.9926	No
Downtown	Low-Density Old	0.7538	0.0008	Yes
High-Density	Low-Density New	-0.3158	0.9919	No
Low-Density Old	Low-Density New	0.3093	0.1551	No
Downtown	Low-Density New	1.6031	<0.0001	Yes
High-Density	Downtown	-1.3789	1.0	No
Low-Density Old	Downtown	-0.7538	1.0	No
Low-Density New	Downtown	-1.0631	1.0	No

[a] Significance established at α=0.05

Table H.13: Predicted Pb Loads per Land Use

Land Use	Pb Load*10^{-5} (lb/ac)
High-Density	3.57
Low-Density Old	8.18
Low-Density New	2.26
Downtown	21.50

Table H.14: Comparisons between Pb Loads for Land Uses

Land Use	Land Use	Difference	Adjusted p-value	Significant[a]
Low-Density Old	High-Density	0.8281	0.0008	Yes
Low-Density New	High-Density	-0.4579	0.998	No
Downtown	High-Density	1.7953	<0.0001	Yes
High-Density	Low-Density Old	-0.8281	1.0	No
Low-Density New	Low-Density Old	-1.286	1.0	No
Downtown	Low-Density Old	0.9672	0.0002	Yes
High-Density	Low-Density New	0.4579	0.0726	No
Low-Density Old	Low-Density New	1.286	<0.0001	Yes
Downtown	Low-Density New	2.2532	<0.0001	Yes
High-Density	Downtown	-1.7953	1.0	No
Low-Density Old	Downtown	-0.9672	1.0	No
Low-Density New	Downtown	-2.2532	1.0	No

[a] Significance established at α=0.05

APPENDIX I: POLLUTANT LOADS NORMALIZED BY STREET AREA

As expected, pollutant loads normalized by street area were larger than loads normalized by the total watershed. Significant interactions and differences between loads were also similar. Differences in pollutant loads were attributed to variations in metal sources, tree abundance, rainfall, and street sweeping frequency; refer to Sections 4.2.1 and 4.3 for more possible explanations regarding differences between loads.

Table I.1: Annual TN, TP, and TC Loads from Collected Debris

Location	Land Use	TN Load[a]	TP Load[a]	TC Load[a]
Burlington	High-Density	0.36	0.04	12.28
	Low-Density Old	3.62	0.29	98.17
	Low-Density New	0.83	0.07	19.27
	Downtown	2.02	0.21	77.90
Greensboro	High-Density	1.85	0.22	102.20
	Low-Density Old	3.86	0.35	112.31
	Low-Density New	5.21	0.42	212.97
	Downtown	7.98	0.66	315.07
Raleigh	High-Density	2.08	0.17	59.84
	Low-Density Old	5.30	0.49	145.17
	Low-Density New	3.96	0.42	126.97
	Downtown	6.53	0.60	191.39
Wilmington	High-Density	10.14	0.92	258.99
	Low-Density Old	6.03	0.50	165.91
	Low-Density New	2.52	0.26	63.52
	Downtown	4.80	0.74	125.12

[a] Units of lb ac^{-1} yr^{-1}

Table I.2: Annual Fe, Zn, and Mn Loads from Collected Debris

Location	Land Use	Fe Load[a]	Zn Load[a]	Mn Load[a]
Burlington	High-Density	0.12	0.02	0.01
	Low-Density Old	1.82	0.08	0.18
	Low-Density New	0.16	0.02	0.03
	Downtown	0.85	0.07	0.10
Greensboro	High-Density	0.56	0.06	0.11
	Low-Density Old	2.24	0.09	0.11
	Low-Density New	2.44	0.12	0.42
	Downtown	3.08	0.17	0.29
Raleigh	High-Density	0.50	0.04	0.06
	Low-Density Old	3.39	0.11	0.14
	Low-Density New	2.05	0.13	0.11
	Downtown	5.97	0.27	0.59
Wilmington	High-Density	3.97	0.35	0.11
	Low-Density Old	1.80	0.11	0.05
	Low-Density New	0.79	0.06	0.03
	Downtown	3.41	0.26	0.13

[a] Units of lb ac^{-1} yr^{-1}

Table I.3: Annual Cu, Ni, and Pb Loads from Collected Debris

Location	Land Use	Cu Load*10^{-2} (lb/ac/yr)	Ni Load*10^{-4} (lb/ac/yr)	Pb Load*10^{-3} (lb/ac/yr)
Burlington	High-Density	0.07	1.73	0.34
	Low-Density Old	1.07	6.07	2.25
	Low-Density New	10.60	1.40	0.37
	Downtown	0.81	5.81	1.64
Greensboro	High-Density	1.21	6.81	0.75
	Low-Density Old	0.95	13.10	3.44
	Low-Density New	1.73	18.30	1.10
	Downtown	2.13	21.10	6.57
Raleigh	High-Density	0.29	3.90	0.52
	Low-Density Old	1.30	29.90	5.83
	Low-Density New	0.85	26.80	4.05
	Downtown	3.05	50.10	17.10
Wilmington	High-Density	3.44	51.0	84.10
	Low-Density Old	0.84	21.90	13.40
	Low-Density New	0.46	12.60	1.52
	Downtown	3.11	31.0	29.10

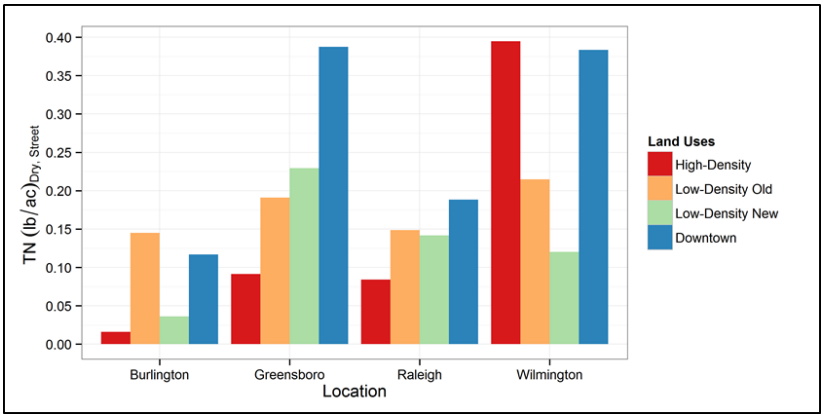

Figure I.1: Predicted TN Loads for Location*Land Use Effect

Table I.4: Predicted TN Loads for Location*Land Use Effect

Location	Land Use	Predicted TN Load (lb/ac)
Burlington	High-Density	0.02
	Low-Density Old	0.14
	Low-Density New	0.04
	Downtown	0.12
Greensboro	High-Density	0.09
	Low-Density Old	0.19
	Low-Density New	0.23
	Downtown	0.39
Raleigh	High-Density	0.08
	Low-Density Old	0.15
	Low-Density New	0.14
	Downtown	0.19
Wilmington	High-Density	0.39
	Low-Density Old	0.21
	Low-Density New	0.12
	Downtown	0.38

Table I.5: Significant Differences between TN Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	<0.0001
Burlington	High-Density	Raleigh	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**0.0035**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	0.0006
Burlington	Downtown	Greensboro	Downtown	0.0013
Burlington	Downtown	Wilmington	Downtown	0.006
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**0.0364**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**<0.0001**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**0.0322**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**0.0003**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0033**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

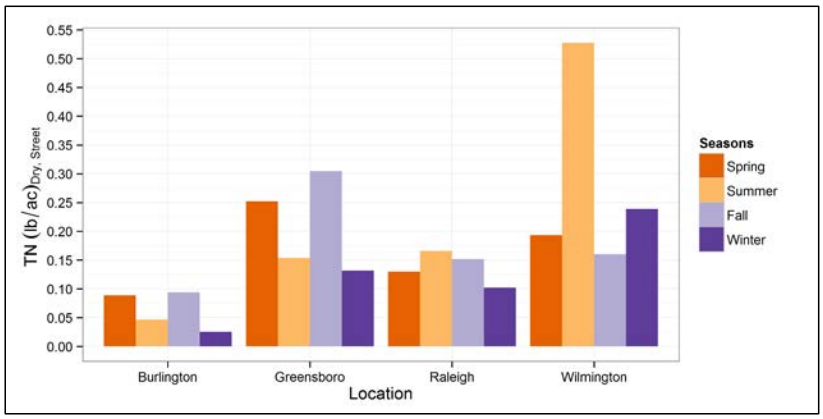

Figure I.2: Predicted TN Loads for Location*Season Effect

Table I.6: Predicted TN Loads for Location*Season Effect

Location	Season	Predicted TN Load (lb/ac)
Burlington	Spring	0.09
	Summer	0.05
	Fall	0.09
	Winter	0.03
Greensboro	Spring	0.25
	Summer	0.15
	Fall	0.30
	Winter	0.13
Raleigh	Spring	0.13
	Summer	0.17
	Fall	0.15
	Winter	0.10
Wilmington	Spring	0.19
	Summer	0.53
	Fall	0.16
	Winter	0.24

Table I.7: Significant Differences between TN Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	0.0007
Burlington	**Spring**	**Burlington**	**Winter**	**0.0004**
Burlington	Spring	Greensboro	Spring	0.0115
Burlington	Summer	Greensboro	Summer	0.002
Burlington	Summer	Raleigh	Summer	0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	Summer	Wilmington	Summer	0.0019
Raleigh	Summer	Wilmington	Summer	0.0021
Raleigh	Winter	Wilmington	Winter	0.0311
Wilmington	**Fall**	**Wilmington**	**Summer**	**0.0019**
Wilmington	**Spring**	**Wilmington**	**Summer**	**0.0287**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

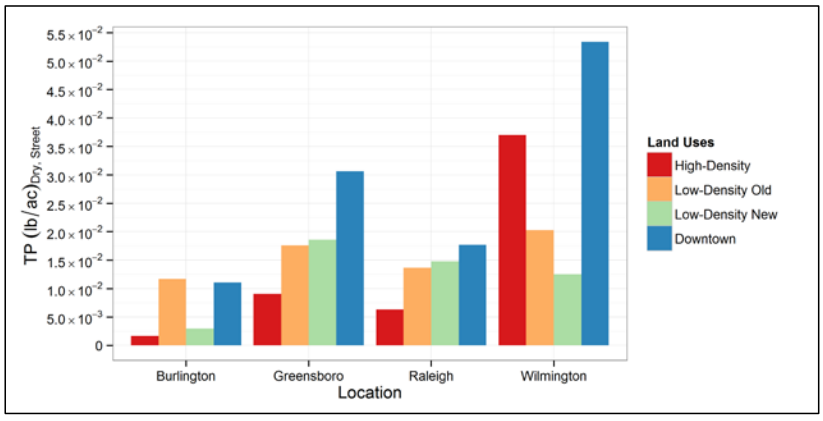

Figure I.3: Predicted TP Loads for Location*Land Use Effect

Table I.8: Predicted TP Loads for Location*Land Use Effect

Location	Land Use	Predicted TP Load*10^{-2} (lb/ac)
Burlington	High-Density	0.17
	Low-Density Old	1.17
	Low-Density New	0.30
	Downtown	1.11
Greensboro	High-Density	0.91
	Low-Density Old	1.76
	Low-Density New	1.86
	Downtown	3.06
Raleigh	High-Density	0.64
	Low-Density Old	1.37
	Low-Density New	1.48
	Downtown	1.77
Wilmington	High-Density	3.70
	Low-Density Old	2.03
	Low-Density New	1.25
	Downtown	5.34

Table I.9: Significant Differences between TP Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	<0.0001
Burlington	High-Density	Raleigh	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**0.0006**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Downtown	Greensboro	Downtown	0.0244
Burlington	Downtown	Wilmington	Downtown	<0.0001
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.0019**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Low-Density New**	**0.0272**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**0.0011**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Raleigh	Downtown	Wilmington	Downtown	0.0052
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**0.0028**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

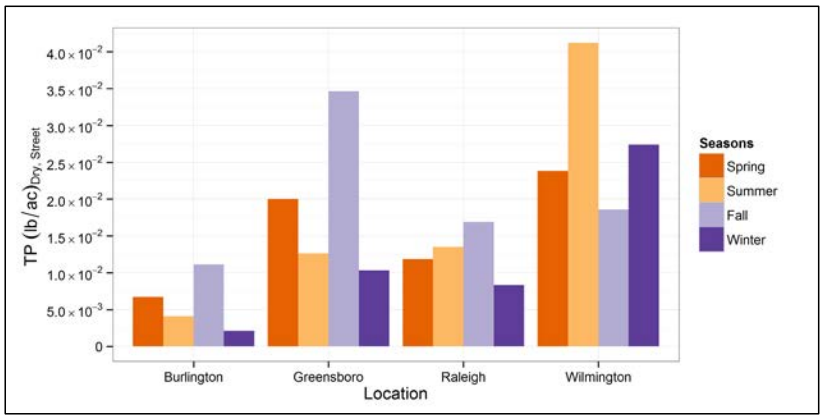

Figure I.4: Predicted TP Loads for Location*Season Effect

Table I.10: Predicted TP Loads for Location*Season Effect

Location	Season	Predicted TP Load*10^{-2} (lb/ac)
Burlington	Spring	0.67
	Summer	0.41
	Fall	1.12
	Winter	0.21
Greensboro	Spring	2.0
	Summer	1.26
	Fall	3.47
	Winter	1.03
Raleigh	Spring	1.19
	Summer	1.35
	Fall	1.69
	Winter	0.84
Wilmington	Spring	2.38
	Summer	4.12
	Fall	1.86
	Winter	2.74

Table I.11: Significant Differences between TP Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Summer**	**0.0225**
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	0.0024
Burlington	**Spring**	**Burlington**	**Winter**	**0.0032**
Burlington	Spring	Greensboro	Spring	0.0081
Burlington	Spring	Wilmington	Spring	0.0003
Burlington	Summer	Greensboro	Summer	0.0067
Burlington	Summer	Raleigh	Summer	0.0007
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	**Fall**	**Greensboro**	**Summer**	**0.029**
Greensboro	**Fall**	**Greensboro**	**Winter**	**0.0005**
Greensboro	Summer	Wilmington	Summer	0.006
Greensboro	Winter	Wilmington	Winter	0.0132
Raleigh	Summer	Wilmington	Summer	0.0055
Raleigh	Winter	Wilmington	Winter	0.0001

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

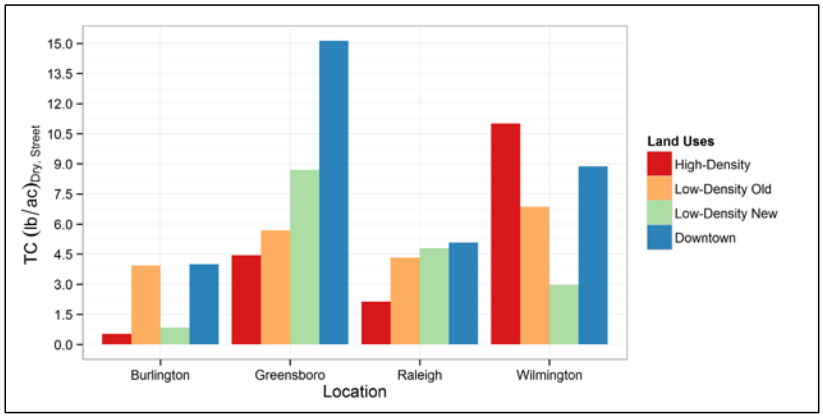

Figure I.5: Predicted TC Loads for Location*Land Use Effect

Table I.12: Predicted TC Loads for Location*Land Use Effect

Location	Land Use	Predicted TC Load (lb/ac)
Burlington	High-Density	0.52
	Low-Density Old	3.93
	Low-Density New	0.85
	Downtown	4.0
Greensboro	High-Density	4.44
	Low-Density Old	5.68
	Low-Density New	8.70
	Downtown	15.13
Raleigh	High-Density	2.14
	Low-Density Old	4.33
	Low-Density New	4.80
	Downtown	5.08
Wilmington	High-Density	11.0
	Low-Density Old	6.86
	Low-Density New	2.97
	Downtown	8.88

Table I.13: Significant Differences between TC Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	<0.0001
Burlington	High-Density	Raleigh	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	<0.0001
Burlington	Downtown	Greensboro	Downtown	<0.0001
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.0003**
Greensboro	High-Density	Wilmington	High-Density	0.0203
Greensboro	**Low-Density Old**	**Greensboro**	**Downtown**	**0.0072**
Greensboro	Low-Density New	Wilmington	Low-Density New	0.0007
Greensboro	Downtown	Raleigh	Downtown	0.0002
Raleigh	**High-Density**	**Raleigh**	**Low-Density New**	**0.0186**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**0.0043**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Low-Density New**	**0.0327**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0028**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

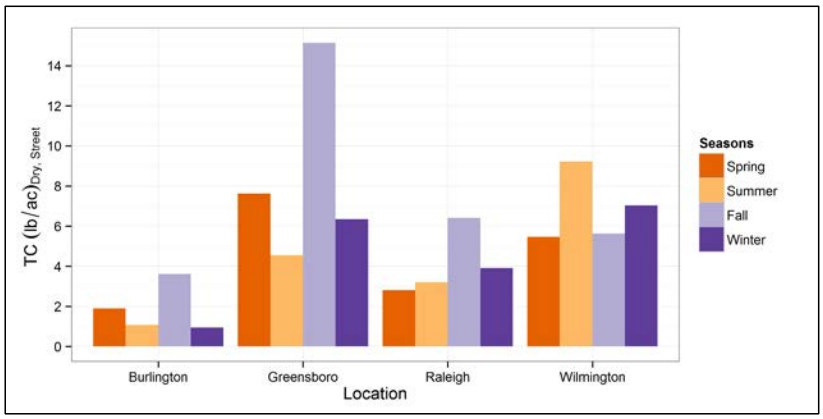

Figure I.6: Predicted TC Loads for Location*Season Effect

Table I.14: Predicted TC Loads for Location*Season Effect

Location	Season	Predicted TC Load (lb/ac)
Burlington	Spring	1.89
	Summer	1.08
	Fall	3.61
	Winter	0.94
Greensboro	Spring	7.61
	Summer	4.54
	Fall	15.13
	Winter	6.34
Raleigh	Spring	2.81
	Summer	3.20
	Fall	6.40
	Winter	3.91
Wilmington	Spring	5.46
	Summer	9.22
	Fall	5.63
	Winter	7.03

Table I.15: Significant Differences between TC Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Summer**	**0.0002**
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	<0.0001
Burlington	Spring	Greensboro	Spring	<0.0001
Burlington	Spring	Wilmington	Spring	0.0019
Burlington	Summer	Greensboro	Summer	<0.0001
Burlington	Summer	Raleigh	Summer	0.0009
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	**Fall**	**Greensboro**	**Summer**	**0.0003**
Greensboro	**Fall**	**Greensboro**	**Winter**	**0.0248**
Greensboro	Fall	Raleigh	Fall	0.0193
Greensboro	Fall	Wilmington	Fall	0.0034
Greensboro	Spring	Raleigh	Spring	0.001
Raleigh	**Fall**	**Raleigh**	**Spring**	**0.0056**
Raleigh	Summer	Wilmington	Summer	0.0033

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

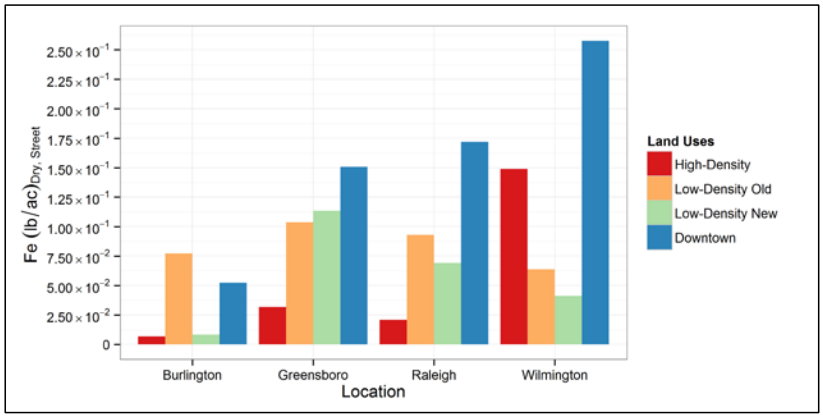

Figure I.7: Predicted Fe Loads for Location*Land Use Effect

Table I.16: Predicted Fe Loads for Location*Land Use Effect

Location	Land Use	Predicted Fe Load (lb/ac)
Burlington	High-Density	0.01
	Low-Density Old	0.08
	Low-Density New	0.01
	Downtown	0.05
Greensboro	High-Density	0.03
	Low-Density Old	0.10
	Low-Density New	0.11
	Downtown	0.15
Raleigh	High-Density	0.02
	Low-Density Old	0.09
	Low-Density New	0.07
	Downtown	0.17
Wilmington	High-Density	0.15
	Low-Density Old	0.06
	Low-Density New	0.04
	Downtown	0.26

Table I.17: Significant Differences between Fe Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	0.003
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	0.0007
Burlington	Downtown	Raleigh	Downtown	0.0433
Burlington	Downtown	Wilmington	Downtown	0.0072
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**0.0262**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.0022**
Greensboro	High-Density	Wilmington	High-Density	0.0015
Raleigh	**High-Density**	**Raleigh**	**Low-Density Old**	**<0.0001**
Raleigh	**High-Density**	**Raleigh**	**Low-Density New**	**0.0098**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**0.0207**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0245**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0002**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

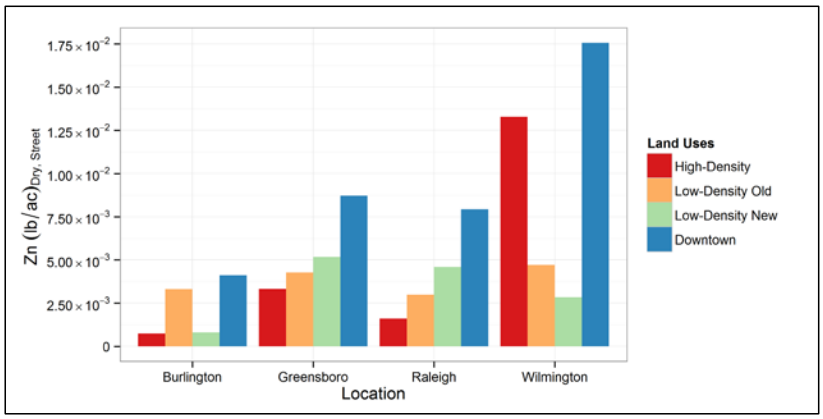

Figure I.8: Predicted Zn Loads for Location*Land Use Effect

Table I.18: Predicted Zn Loads for Location*Land Use Effect

Location	Land Use	Predicted Zn Load*10^{-3} (lb/ac)
Burlington	High-Density	0.74
	Low-Density Old	3.32
	Low-Density New	0.82
	Downtown	4.11
Greensboro	High-Density	3.33
	Low-Density Old	4.27
	Low-Density New	5.16
	Downtown	8.71
Raleigh	High-Density	1.61
	Low-Density Old	3.0
	Low-Density New	4.59
	Downtown	7.94
Wilmington	High-Density	13.3
	Low-Density Old	4.7
	Low-Density New	2.84
	Downtown	17.6

Table I.19: Significant Differences between Zn Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	<0.0001
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	0.001
Burlington	Downtown	Wilmington	Downtown	0.0006
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Low-Density New**	**0.0023**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**0.0028**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0072**
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0012**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

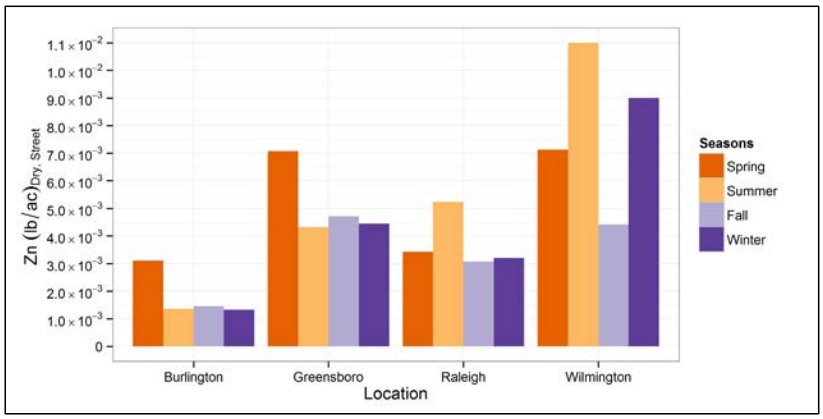

Figure I.9: Predicted Zn Loads for Location*Season Effect

Table I.20: Predicted Zn Loads for Location*Season Effect

Location	Season	Predicted Zn Load*10^{-3} (lb/ac)
Burlington	Spring	3.11
	Summer	1.37
	Fall	1.46
	Winter	1.33
Greensboro	Spring	7.07
	Summer	4.32
	Fall	4.71
	Winter	4.44
Raleigh	Spring	3.42
	Summer	5.24
	Fall	3.07
	Winter	3.20
Wilmington	Spring	7.13
	Summer	11.0
	Fall	4.42
	Winter	9.0

Table I.21: Significant Differences between Zn Loads for Location*Season Effect

Location	Season	Location	Season	Adjusted p-value[a]
Burlington	Fall	Greensboro	Fall	0.0028
Burlington	Fall	Wilmington	Fall	0.0042
Burlington	Summer	Greensboro	Summer	0.0087
Burlington	Summer	Raleigh	Summer	0.0002
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	0.0011
Burlington	Winter	Wilmington	Winter	<0.0001
Raleigh	Winter	Wilmington	Winter	0.0055

[a] Significance established at α=0.05

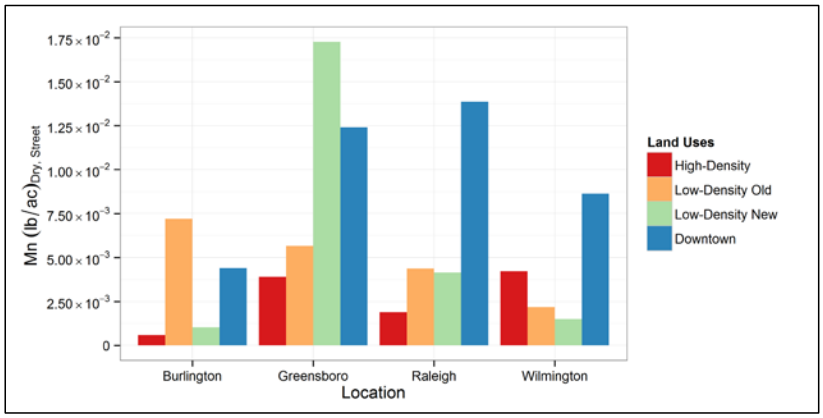

Figure I.10: Predicted Mn Loads for Location*Land Use Effect

Table I.22: Predicted Mn Loads for Location*Land Use Effect

Location	Land Use	Predicted Mn Load*10^{-3} (lb/ac)
Burlington	High-Density	0.58
	Low-Density Old	7.20
	Low-Density New	1.03
	Downtown	4.41
Greensboro	High-Density	3.90
	Low-Density Old	5.67
	Low-Density New	17.30
	Downtown	12.40
Raleigh	High-Density	1.89
	Low-Density Old	4.38
	Low-Density New	4.14
	Downtown	13.90
Wilmington	High-Density	4.22
	Low-Density Old	2.18
	Low-Density New	1.50
	Downtown	8.62

Table I.23: Significant Differences between Mn Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	<0.0001
Burlington	High-Density	Raleigh	High-Density	0.0022
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	Low-Density Old	Wilmington	Low-Density Old	0.0014
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Downtown	Greensboro	Downtown	0.0328
Burlington	Downtown	Raleigh	Downtown	0.0022
Greensboro	**High-Density**	**Greensboro**	**Low-Density New**	**<0.0001**
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.012**
Greensboro	**Low-Density Old**	**Greensboro**	**Low-Density New**	**0.0121**
Greensboro	Low-Density New	Raleigh	Low-Density New	<0.0001
Greensboro	Low-Density New	Wilmington	Low-Density New	<0.0001
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**0.0002**
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	Low-Density New	Wilmington	Low-Density New	0.0108
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**0.0198**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0025**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

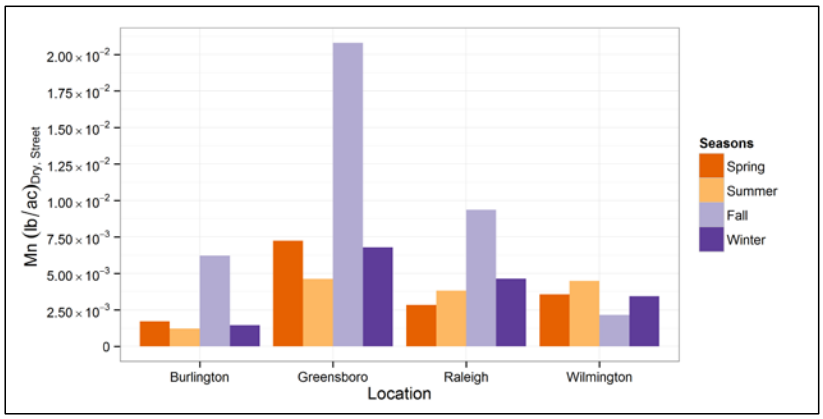

Figure I.11: Predicted Mn Loads for Location*Season Effect

Table I.24: Predicted Mn Loads for Location*Season Effect

Location	Season	Predicted Mn Load*10^{-3} (lb/ac)
Burlington	Spring	1.72
	Summer	1.23
	Fall	6.21
	Winter	1.46
Greensboro	Spring	7.24
	Summer	4.63
	Fall	20.80
	Winter	6.79
Raleigh	Spring	2.86
	Summer	3.83
	Fall	9.37
	Winter	4.65
Wilmington	Spring	3.57
	Summer	4.48
	Fall	2.15
	Winter	3.44

Table I.25: Significant Differences between Mn Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	**Fall**	**Burlington**	**Spring**	**0.001**
Burlington	**Fall**	**Burlington**	**Summer**	**<0.0001**
Burlington	**Fall**	**Burlington**	**Winter**	**<0.0001**
Burlington	Fall	Greensboro	Fall	0.0023
Burlington	Fall	Wilmington	Fall	0.0125
Burlington	Spring	Greensboro	Spring	0.0001
Burlington	Summer	Greensboro	Summer	0.0012
Burlington	Summer	Raleigh	Summer	0.0048
Burlington	Summer	Wilmington	Summer	0.0044
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	0.0011
Greensboro	**Fall**	**Greensboro**	**Spring**	**0.0332**
Greensboro	**Fall**	**Greensboro**	**Summer**	**<0.0001**
Greensboro	**Fall**	**Greensboro**	**Winter**	**0.0078**
Greensboro	Fall	Wilmington	Fall	<0.0001
Greensboro	Spring	Raleigh	Spring	0.0313
Raleigh	**Fall**	**Raleigh**	**Spring**	**0.0001**
Raleigh	**Fall**	**Raleigh**	**Summer**	**0.0404**
Raleigh	Fall	Wilmington	Fall	<0.0001

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

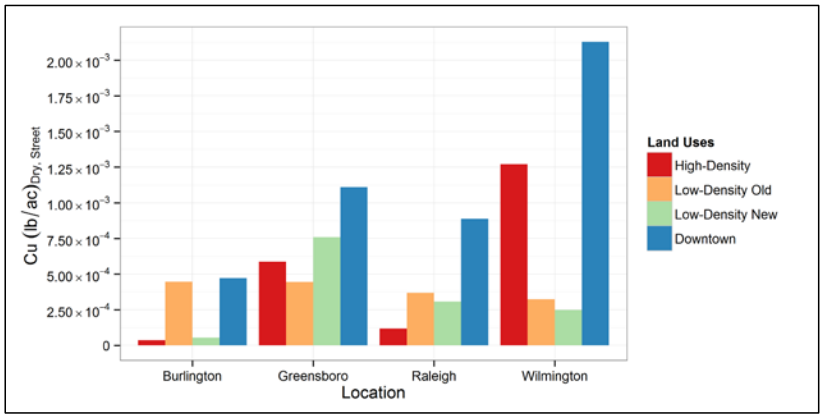

Figure I.12: Predicted Cu Loads for Location*Land Use Effect

Table I.26: Predicted Cu Loads for Location*Land Use Effect

Location	Land Use	Predicted Cu Load*10^{-4} (lb/ac)
Burlington	High-Density	0.37
	Low-Density Old	4.47
	Low-Density New	0.55
	Downtown	4.72
Greensboro	High-Density	5.87
	Low-Density Old	4.44
	Low-Density New	7.58
	Downtown	11.10
Raleigh	High-Density	1.19
	Low-Density Old	3.67
	Low-Density New	3.08
	Downtown	8.88
Wilmington	High-Density	12.70
	Low-Density Old	3.24
	Low-Density New	2.49
	Downtown	21.30

Table I.27: Significant Differences between Cu Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	**High-Density**	**Burlington**	**Low-Density Old**	**<0.0001**
Burlington	**High-Density**	**Burlington**	**Downtown**	**<0.0001**
Burlington	High-Density	Greensboro	High-Density	<0.0001
Burlington	High-Density	Raleigh	High-Density	0.0086
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	**Low-Density Old**	**Burlington**	**Low-Density New**	**<0.0001**
Burlington	**Low-Density New**	**Burlington**	**Downtown**	**<0.0001**
Burlington	Low-Density New	Greensboro	Low-Density New	<0.0001
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	0.0002
Burlington	Downtown	Wilmington	Downtown	0.0018
Greensboro	High-Density	Raleigh	High-Density	<0.0001
Greensboro	Low-Density New	Wilmington	Low-Density New	0.0209
Raleigh	**High-Density**	**Raleigh**	**Low-Density Old**	**0.0024**
Raleigh	**High-Density**	**Raleigh**	**Low-Density New**	**0.0351**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**Low-Density Old**	**Raleigh**	**Downtown**	**0.0436**
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**0.0044**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0002**
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**<0.0001**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at $\alpha=0.05$

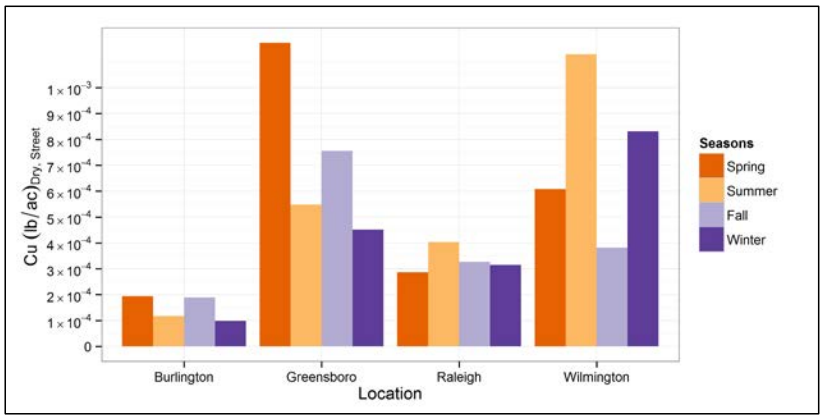

Figure I.13: Predicted Cu Loads for Location*Season Effect

Table I.28: Predicted Cu Loads for Location*Season Effect

Location	Season	Predicted Cu Load*10^{-4} (lb/ac)
Burlington	Spring	1.94
	Summer	1.18
	Fall	1.89
	Winter	0.99
Greensboro	Spring	11.70
	Summer	5.48
	Fall	7.56
	Winter	4.52
Raleigh	Spring	2.87
	Summer	4.04
	Fall	3.27
	Winter	3.15
Wilmington	Spring	6.08
	Summer	11.30
	Fall	3.82
	Winter	8.32

Table I.29: Significant Differences between Cu Loads for Location*Season Effect

Location	Season	Location	Season	Adjusted p-value[a]
Burlington	Fall	Greensboro	Fall	0.0008
Burlington	Spring	Greensboro	Spring	<0.0001
Burlington	Spring	Wilmington	Spring	0.0171
Burlington	Summer	Greensboro	Summer	0.0003
Burlington	Summer	Raleigh	Summer	0.0058
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	<0.0001
Burlington	Winter	Raleigh	Winter	0.006
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	Spring	Raleigh	Spring	<0.0001
Raleigh	Winter	Wilmington	Winter	0.0435

[a] Significance established at α=0.05

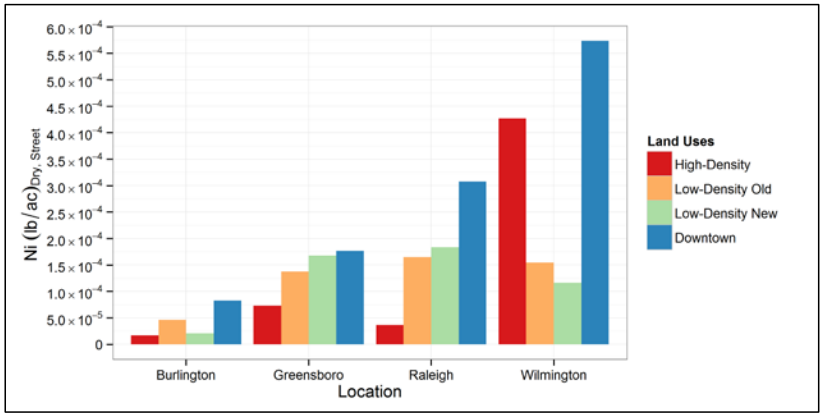

Figure I.14: Predicted Ni Loads for Location*Land Use Effect

Table I.30: Predicted Ni Loads for Location*Land Use Effect

Location	Land Use	Predicted Ni Load*10^{-4} (lb/ac)
Burlington	High-Density	0.17
	Low-Density Old	0.46
	Low-Density New	0.21
	Downtown	0.83
Greensboro	High-Density	0.74
	Low-Density Old	1.38
	Low-Density New	1.68
	Downtown	1.77
Raleigh	High-Density	0.37
	Low-Density Old	1.65
	Low-Density New	1.84
	Downtown	3.08
Wilmington	High-Density	4.27
	Low-Density Old	1.55
	Low-Density New	1.17
	Downtown	5.74

Table I.31: Significant Differences between Ni Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	Low-Density New	Greensboro	Low-Density New	0.0004
Burlington	Low-Density New	Raleigh	Low-Density New	<0.0001
Burlington	Low-Density New	Wilmington	Low-Density New	0.0087
Burlington	Downtown	Wilmington	Downtown	0.0131
Greensboro	High-Density	Wilmington	High-Density	0.0051
Raleigh	**High-Density**	**Raleigh**	**Low-Density Old**	**0.0062**
Raleigh	**High-Density**	**Raleigh**	**Low-Density New**	**0.0082**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**0.0369**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

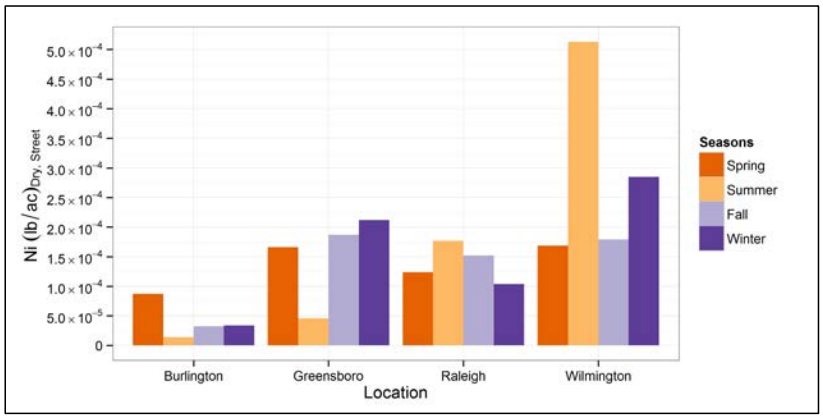

Figure I.15: Predicted Ni Loads for Location*Season Effect

Table I.32: Predicted Ni Loads for Location*Season Effect

Location	Season	Predicted Ni Load*10^{-4} (lb/ac)
Burlington	Spring	0.87
	Summer	0.14
	Fall	0.33
	Winter	0.34
Greensboro	Spring	1.66
	Summer	0.46
	Fall	1.87
	Winter	2.12
Raleigh	Spring	1.24
	Summer	1.77
	Fall	1.52
	Winter	1.04
Wilmington	Spring	1.69
	Summer	5.13
	Fall	1.79
	Winter	2.85

Table I.33: Significant Differences between Ni Loads for Location*Season Effect

Location[a]	Season	Location	Season	Adjusted p-value[b]
Burlington	Fall	Greensboro	Fall	0.0035
Burlington	Fall	Raleigh	Fall	0.0139
Burlington	Fall	Wilmington	Fall	0.0059
Burlington	**Spring**	**Burlington**	**Summer**	**0.0356**
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Greensboro	Winter	0.0075
Burlington	Winter	Wilmington	Winter	0.0003
Greensboro	**Summer**	**Greensboro**	**Winter**	**0.0309**
Greensboro	Summer	Wilmington	Summer	<0.0001

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

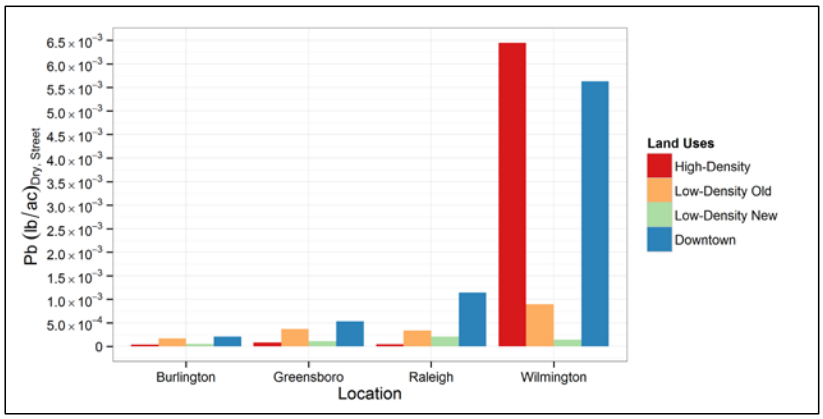

Figure I.16: Predicted Pb Loads for Location*Land Use Effect

Table I.34: Predicted Pb Loads for Location*Season Effect

Location	Land Use	Predicted Pb Load*10^{-4} (lb/ac)
Burlington	High-Density	0.40
	Low-Density Old	1.70
	Low-Density New	0.53
	Downtown	2.08
Greensboro	High-Density	0.85
	Low-Density Old	3.69
	Low-Density New	1.13
	Downtown	5.31
Raleigh	High-Density	0.46
	Low-Density Old	3.37
	Low-Density New	2.09
	Downtown	11.40
Wilmington	High-Density	64.50
	Low-Density Old	8.94
	Low-Density New	1.41
	Downtown	56.30

Table I.35: Significant Differences between Pb Loads for Location*Land Use Effect

Location[a]	Land Use	Location	Land Use	Adjusted p-value[b]
Burlington	High-Density	Wilmington	High-Density	<0.0001
Burlington	Downtown	Raleigh	Downtown	0.0358
Burlington	Downtown	Wilmington	Downtown	<0.0001
Greensboro	**High-Density**	**Greensboro**	**Downtown**	**0.0196**
Greensboro	High-Density	Wilmington	High-Density	<0.0001
Greensboro	Downtown	Wilmington	Downtown	0.0012
Raleigh	**High-Density**	**Raleigh**	**Low-Density Old**	**0.0003**
Raleigh	**High-Density**	**Raleigh**	**Downtown**	**<0.0001**
Raleigh	High-Density	Wilmington	High-Density	<0.0001
Raleigh	**Low-Density New**	**Raleigh**	**Downtown**	**0.0112**
Wilmington	**High-Density**	**Wilmington**	**Low-Density Old**	**0.0007**
Wilmington	**High-Density**	**Wilmington**	**Low-Density New**	**<0.0001**
Wilmington	**Low-Density Old**	**Wilmington**	**Low-Density New**	**0.0043**
Wilmington	**Low-Density Old**	**Wilmington**	**Downtown**	**0.0322**
Wilmington	**Low-Density New**	**Wilmington**	**Downtown**	**<0.0001**

[a] Boldfaced comparisons indicate differences within same location
[b] Significance established at α=0.05

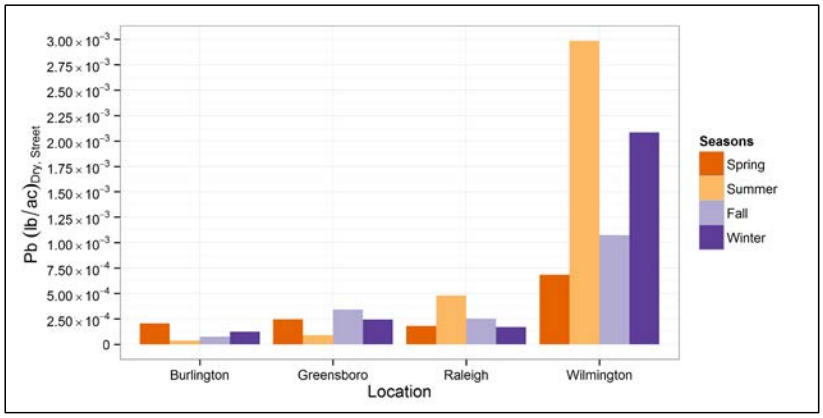

Figure I.17: Predicted Pb Loads for Location*Season Effect

Table I.36: Predicted Pb Loads for Location*Season Effect

Location	Season	Predicted Pb Load*10^{-4} (lb/ac)
Burlington	Spring	2.06
	Summer	0.37
	Fall	0.77
	Winter	1.25
Greensboro	Spring	2.45
	Summer	0.91
	Fall	3.43
	Winter	2.43
Raleigh	Spring	1.81
	Summer	4.80
	Fall	2.53
	Winter	1.70
Wilmington	Spring	6.84
	Summer	29.80
	Fall	10.70
	Winter	20.80

Table I.37: Significant Differences between Pb Loads for Location*Season Effect

Location	Season	Location	Season	Adjusted p-value[a]
Burlington	Fall	Wilmington	Fall	<0.0001
Burlington	Summer	Raleigh	Summer	<0.0001
Burlington	Summer	Wilmington	Summer	<0.0001
Burlington	Winter	Wilmington	Winter	<0.0001
Greensboro	Summer	Raleigh	Summer	0.0215
Greensboro	Summer	Wilmington	Summer	<0.0001
Greensboro	Winter	Wilmington	Winter	0.0008
Raleigh	Spring	Wilmington	Spring	0.0458
Raleigh	Summer	Wilmington	Summer	0.0284
Raleigh	Winter	Wilmington	Winter	<0.0001

[a] Significance established at α=0.05

APPENDIX J: POLLUTANT CONCENTRATIONS

J.1 Comparisons between TN and TP Concentrations

Limited published research exists on nutrient concentrations in leaf matter. However, some data has been reported for TN and TP concentrations in debris collected from proprietary units. Stack et al. (2013) analyzed leaf matter trapped by bags retrofitting four storm conveyance outfalls in the Tred Avon Watershed in Talbot County, Maryland. The outfalls drained four watersheds varying in land use (Table J.1). Reported TN and TP concentrations ranged from $4.18*10^{-3}$ to $20.20*10^{-3}$ lb lb^{-1} and from $3.37*10^{-4}$ to $17.30*10^{-4}$ lb lb^{-1} for TN and TP, respectively (Table J.2).

Table J.1: Land Use Percentages for Sites in Tred Avon Watershed (Stack et al., 2013)

Site	LDR[a] (%)	MDR[b] (%)	HDR[c] (%)	Commercial (%)	Institutional (%)	Forest (%)
Earle 48	3.9	47.2	17.2	10.9	20.7	0
Earle 60	1.9	52.6	17.4	25.2	1.3	1.7
Glenwood Elliptical	1.0	25.9	37.2	20.6	15.4	0
Glenwood Circular	1.1	39.8	4.3	8.8	46.0	0

[a] Low density residential
[b] Medium density residential
[c] High density residential

Table J.2: Reported TN and TP Concentrations (Stack et al., 2013)

Outfall	TN*10^{-3} (lb/lb)	TP*10^{-4} (lb/lb)
Earle 48	6.28	3.78
Earle 48	4.18	3.37
Glenwood Circular	5.90	3.88
Earle 48	6.16	4.23
Glenwood Elliptical	12.40	8.15
Earle 48	20.20	17.30
Earle 60	10.70	16.60
Earle 48	10.70	8.92
Earle 48	7.25	9.42
Earle 48	12.10	4.22

In contrast, Lockerman and Rubin (2015) studied debris trapped by a gross solids collector installed in catch basin draining a low-density old watershed in Raleigh, North Carolina. TN and TP concentrations were found by sub-sampling four sections of the collected debris. Concentrations ranged from $6.67*10^{-3}$ to $10.40*10^{-3}$ lb lb^{-1} and $5.98*10^{-4}$ to $7.77*10^{-4}$ lb lb^{-1} for TN and TP, respectively (Table J.3). In general nutrient concentrations reported by Lockerman and Rubin (2015) were similar to concentrations found by Stack et al. (2013).

Table J.3: Concentrations from Raleigh Watershed (Lockerman and Rubin, 2015)

Section	TN*10^{-3} (lb/lb)	TP*10^{-4} (lb/lb)
Top	7.94	5.98
Middle	10.40	6.07
Bottom 1	10.60	7.77
Bottom 2	6.67	6.88
Average	**8.90**	**6.68**

Nutrient concentrations for this study were found using methods described in Section 3.11. For comparison purposes, only concentrations for each land use were quantified. TN and TP concentrations ranged from $1.10*10^{-2}$ to $2.0*10^{-2}$ lb lb^{-1} and from $1.01*10^{-3}$ to $1.77*10^{-3}$ lb lb^{-1}, respectively (Table J.4). Overall, data from Lockerman and Rubin (2015) and Stack et al. (2013) were smaller; this is most likely due to differences between monitoring periods, sampling frequencies, and number of monitored sites.

Table J.4: Predicted TN and TP Concentrations from Gross Solids Study

Land Use	TN*10^{-2} (lb/lb)	TP*10^{-3} (lb/lb)
High-Density	1.10	1.01
Low-Density Old	2.0	1.77
Low-Density New	1.59	1.47
Downtown	1.53	1.45

J.2 Pollutant Concentrations Normalized by Watershed Area

Pollutant concentrations normalized by the watershed area were analyzed using methods discussed in Section 3.11. For practicality, concentrations were only determined for the monitored land uses and seasons. The tables listed below summarize the predicted concentrations and associated 95% confidence intervals. These values were calculated to help municipalities estimate pollutant loads from collected debris. It is important municipalities acknowledge these concentrations were influenced by location, and some concentrations were significantly different among land uses in the same location or among locations in comparable land uses.
More importantly, municipalities must understand they are only 95% confident the collected debris' true or correct pollutant concentration is within the given interval. Note either predicted concentrations for each land use or season should be used to estimate pollutant loads. See Section J.3 for examples applying these concentration limits. Also, the developed Excel tool accompanying the report can be used to estimate loads.

Table J.5: TC Concentration Limits per Land Use

Land Use	Lower Limit TC (lb/lb/ac)	Upper Limit TC (lb/lb/ac)
High-Density	0.60	0.68
Low-Density Old	0.32	0.36
Low-Density New	0.65	0.73
Downtown	0.23	0.26

Table J.6: TC Concentration Limits per Season

Season	Lower Limit TC (lb/lb/ac)	Upper Limit TC (lb/lb/ac)
Spring	0.41	0.46
Summer	0.36	0.41
Fall	0.47	0.53
Winter	0.42	0.47

Table J.7: Fe Concentration Limits per Land Use

Land Use	Lower Limit Fe (lb/lb/ac)	Upper Limit Fe (lb/lb/ac)
High-Density	0.005678	0.00746
Low-Density Old	0.003243	0.004213
Low-Density New	0.006811	0.008863
Downtown	0.002757	0.003671

Table J.8: Fe Concentration Limits per Season

Season	Lower Limit Fe (lb/lb/ac)	Upper Limit Fe (lb/lb/ac)
Spring	0.005148	0.006723
Summer	0.005911	0.007878
Fall	0.002724	0.003557
Winter	0.004173	0.005427

Table J.9: Zn Concentration Limits per Land Use

Land Use	Lower Limit Zn (lb/lb/ac)	Upper Limit Zn (lb/lb/ac)
High-Density	0.0005881	0.0007282
Low-Density Old	0.0002135	0.000262
Low-Density New	0.0005642	0.0006933
Downtown	0.0002341	0.000293

Table J.10: Zn Concentration Limits per Season

Season	Lower Limit Zn (lb/lb/ac)	Upper Limit Zn (lb/lb/ac)
Spring	0.000459	0.000566
Summer	0.0004425	0.0005539
Fall	0.0002146	0.0002642
Winter	0.0003805	0.0004678

Table J.11: Mn Concentration Limits per Land Use

Land Use	Lower Limit Mn (lb/lb/ac)	Upper Limit Mn (lb/lb/ac)
High-Density	0.000457	0.0005468
Low-Density Old	0.0002388	0.0002835
Low-Density New	0.0005892	0.0007002
Downtown	0.0002503	0.0003022

Table J.12: Mn Concentration Limits per Season

Season	Lower Limit Mn (lb/lb/ac)	Upper Limit Mn (lb/lb/ac)
Spring	0.0003085	0.0003676
Summer	0.0002847	0.0003437
Fall	0.0004652	0.0005538
Winter	0.0003941	0.0004686

Table J.13: Cu Concentration Limits per Land Use

Land Use	Lower Limit Cu (lb/lb/ac)	Upper Limit Cu (lb/lb/ac)
High-Density	0.00005065	0.00006222
Low-Density Old	0.00001909	0.00002326
Low-Density New	0.00004307	0.00005255
Downtown	0.00002463	0.00003056

Table J.14: Cu Concentration Limits per Season

Season	Lower Limit Cu (lb/lb/ac)	Upper Limit Cu (lb/lb/ac)
Spring	0.00004023	0.00004922
Summer	0.00003707	0.00004603
Fall	0.00002204	0.00002694
Winter	0.0000312	0.00003808

Table J.15: Ni Concentration Limits per Land Use

Land Use	Lower Limit Ni (lb/lb/ac)	Upper Limit Ni (lb/lb/ac)
High-Density	0.00001419	0.00001828
Low-Density Old	0.000006087	0.000007718
Low-Density New	0.00001603	0.00002042
Downtown	0.000006377	0.00000829

Table J.16: Ni Concentration Limits per Season

Season	Lower Limit Ni (lb/lb/ac)	Upper Limit Ni (lb/lb/ac)
Spring	0.00001037	0.00001336
Summer	0.00001079	0.00001392
Fall	0.000007567	0.000009649
Winter	0.0000104	0.00001335

Table J.17: Pb Concentration Limits per Land Use

Land Use	Lower Limit Pb (lb/lb/ac)	Upper Limit Pb (lb/lb/ac)
High-Density	0.00003366	0.00004974
Low-Density Old	0.00001769	0.00002561
Low-Density New	0.00001975	0.00002868
Downtown	0.00002336	0.00003504

Table J.18: Pb Concentrations per Season

Season	Lower Limit Pb (lb/lb/ac)	Upper Limit Pb (lb/lb/ac)
Spring	0.00002022	0.00002995
Summer	0.00002983	0.00004423
Fall	0.0000175	0.0000255
Winter	0.00002591	0.00003807

J.3 Examples Applying Concentration Limits

Land Use Example

Land Use: Downtown
Watershed area: 5 ac
Dry Weight of Collected Debris: 1000 lb
Pollutant of Interest: Zn
Lower Limit Zn Concentration: 0.0002341
Upper Limit Zn Concentration: 0.000293

Minimum amount of Zn collected:

$$1000\ lb\ of\ Debris * 5\ ac * \frac{0.0002341\ lb\ of\ Zn}{lb\ of\ Debris\ per\ ac} = 1.2\ lb\ of\ Zn$$

Maximum amount of Zn collected:

$$1000\ lb\ of\ Debris * 5\ ac * \frac{0.000293\ lb\ of\ Zn}{lb\ of\ Debris\ per\ ac} = 1.5\ lb\ of\ Zn$$

Season Example

Season: Summer
Watershed area: 5 ac
Dry Weight of Collected Debris: 1000 lb
Pollutant of Interest: Zn
Lower Limit Zn Concentration: 0.0004425
Upper Limit Zn Concentration: 0.0005539

Minimum amount of Zn collected:

$$1000\ lb\ of\ Debris * 5\ ac * \frac{0.0004425\ lb\ of\ Zn}{lb\ of\ Debris\ per\ ac} = 2.2\ lb\ of\ Zn$$

Maximum amount of Zn collected:

$$1000\ lb\ of\ Debris * 5\ ac * \frac{0.0005539\ lb\ of\ Zn}{lb\ of\ Debris\ per\ ac} = 2.8\ lb\ of\ Zn$$

APPENDIX K: DAILY POLLUTANT LOADS NORMALIZED BY CURB LENGTH

Pollutant concentrations normalized by the watershed area were analyzed using methods discussed in Section 3.11. For practicality, concentrations were only determined for the monitored land uses and seasons. The tables listed below summarize the predicted concentrations and associated 95% confidence intervals. These values were calculated to help municipalities estimate pollutant loads from street sweepings. It is important municipalities acknowledge these concentrations were influenced by location, and some concentrations were significantly different among land uses in the same location or among locations in comparable land uses.
More importantly, municipalities must understand they are only 95% confident the collected debris' true or correct pollutant concentration is within the given interval. Note either predicted concentrations for each land use or season should be used to estimate pollutant loads. See below for examples applying these concentration limits. Also, the developed Excel tool accompanying the report can be used to estimate loads.

Table K.1 Daily TC Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit TC (lb/lb/mile-day)	Upper Limit TC (lb/lb/mile-day)
High-Density	0.29	0.35
Low-Density Old	0.21	0.25
Low-Density New	0.42	0.50
Downtown	0.22	0.27

Table K.2: Daily TC Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit TC (lb/lb/mile-day)	Upper Limit TC (lb/lb/mile-day)
Spring	0.31	0.38
Summer	0.25	0.30
Fall	0.31	0.37
Winter	0.23	0.28

Table K.3: Daily Fe Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit Fe (lb/lb/mile-day)	Upper Limit Fe (lb/lb/mile-day)
High-Density	0.002535	0.003348
Low-Density Old	0.002003	0.002618
Low-Density New	0.004398	0.005756
Downtown	0.002596	0.003479

Table K.4: Daily Fe Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit Fe (lb/lb/mile-day)	Upper Limit Fe (lb/lb/mile-day)
Spring	0.00391	0.005138
Summer	0.00392	0.005253
Fall	0.001781	0.002337
Winter	0.002125	0.002781

Table K.5: Daily Zn Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit Zn (lb/lb/mile-day)	Upper Limit Zn (lb/lb/mile-day)
High-Density	0.0002709	0.0003491
Low-Density Old	0.000142	0.0001812
Low-Density New	0.0003714	0.0004747
Downtown	0.0002214	0.0002893

Table K.6: Daily Zn Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit Zn (lb/lb/mile-day)	Upper Limit Zn (lb/lb/mile-day)
Spring	0.0003463	0.0004445
Summer	0.0003182	0.0004155
Fall	0.0001401	0.0001794
Winter	0.0002049	0.0002622

Table K.7: Daily Mn Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit Mn (lb/lb/mile-day)	Upper Limit Mn (lb/lb/mile-day)
High-Density	0.0002227	0.0002794
Low-Density Old	0.0001527	0.0001897
Low-Density New	0.0003811	0.0004736
Downtown	0.0002293	0.0002907

Table K.8: Daily Mn Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit Mn (lb/lb/mile-day)	Upper Limit Mn (lb/lb/mile-day)
Spring	0.0002312	0.0002886
Summer	0.0001896	0.0002403
Fall	0.0003092	0.000385
Winter	0.0002195	0.0002732

Table K.9: Daily Cu Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit Cu (lb/lb/mile-day)	Upper Limit Cu (lb/lb/mile-day)
High-Density	0.00002401	0.00003086
Low-Density Old	0.00001263	0.00001607
Low-Density New	0.00002747	0.00003499
Downtown	0.00002333	0.00003029

Table K.10: Daily Cu Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit Cu (lb/lb/mile-day)	Upper Limit Cu (lb/lb/mile-day)
Spring	0.00003096	0.0000396
Summer	0.00002673	0.00003481
Fall	0.0000145	0.0000185
Winter	0.00001617	0.00002061

Table K.11: Daily Ni Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit Ni (lb/lb/mile-day)	Upper Limit Ni (lb/lb/mile-day)
High-Density	0.000006813	0.000009087
Low-Density Old	0.00000372	0.000004875
Low-Density New	0.000010544	0.000013905
Downtown	0.000006018	0.000008119

Table K.12: Daily Ni Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit Ni (lb/lb/mile-day)	Upper Limit Ni (lb/lb/mile-day)
Spring	0.000007572	0.000010098
Summer	0.000007669	0.000010264
Fall	0.000005343	0.000007042
Winter	0.000005169	0.000006872

Table K.13: Daily Pb Concentration Limits Normalized by Curb Length per Land Use

Land Use	Lower Limit Pb (lb/lb/mile-day)	Upper Limit Pb (lb/lb/mile-day)
High-Density	0.00001599	0.00002468
Low-Density Old	0.00001092	0.00001646
Low-Density New	0.00001335	0.00002028
Downtown	0.00002326	0.00003668

Table K.14: Daily Pb Concentration Limits Normalized by Curb Length per Season

Season	Lower Limit Pb (lb/lb/mile-day)	Upper Limit Pb (lb/lb/mile-day)
Spring	0.00001531	0.0000237
Summer	0.00002166	0.00003365
Fall	0.00001251	0.00001902
Winter	0.00001302	0.00001999

Examples Applying Concentration Limits

Land Use Example

Land Use: Downtown
Curb Length: 10 miles
Dry Weight of Collected Debris: 1000 lb
Days Between Street Sweeping: 3 days
Pollutant of Interest: Zn
Lower Limit Zn Concentration: 0.0002214
Upper Limit Zn Concentration: 0.0002893

Minimum amount of Zn collected:

$$1000\ lb\ of\ Debris * 10\ miles * 3\ days * \frac{0.0002214\ lb\ of\ Zn}{lb\ of\ Debris\ per\ mile\ per\ day} = 6.6\ lb\ of\ Zn$$

Maximum amount of Zn collected:

$$1000\ lb\ of\ Debris * 10\ miles * 3\ days * \frac{0.0002893\ lb\ of\ Zn}{lb\ of\ Debris\ per\ mile\ per\ day} = 8.7\ lb\ of\ Zn$$

Season Example

Season: Summer
Curb Length: 10 miles
Dry Weight of Collected Debris: 1000 lb
Days Between Street Sweeping: 3 days
Pollutant of Interest: Zn
Lower Limit Zn Concentration: 0.0003182
Upper Limit Zn Concentration: 0.0004155

Minimum amount of Zn collected:

$$1000\ lb\ of\ Debris * 10\ miles * 3\ days * \frac{0.0003182\ lb\ of\ Zn}{lb\ of\ Debris\ per\ mile\ per\ day} = 9.5\ lb\ of\ Zn$$

Maximum amount of Zn collected:

$$1000\ lb\ of\ Debris * 10\ miles * 3\ days * \frac{0.0004155\ lb\ of\ Zn}{lb\ of\ Debris\ per\ mile\ per\ day} = 12.7\ lb\ of\ Zn$$

APPENDIX L: POLLUTANT LOADS

Table L.1: Predicted TN Loads per Location and Land Use

Location	Land Use	TN Load*10^{-2} (lb)
Burlington	High-Density	0.31
	Low-Density Old	3.02
	Low-Density New	0.32
	Downtown	5.34
Greensboro	High-Density	0.30
	Low-Density Old	5.80
	Low-Density New	2.58
	Downtown	4.83
Raleigh	High-Density	0.57
	Low-Density Old	5.50
	Low-Density New	0.75
	Downtown	8.39
Wilmington	High-Density	15.20
	Low-Density Old	3.42
	Low-Density New	2.94
	Downtown	16.20

Table L.2: Predicted TN Loads per Land Use

Land Use	TN Load*10^{-2} (lb)
High-Density	4.09
Low-Density Old	4.44
Low-Density New	1.65
Downtown	8.69

Table L.3: Predicted TN Loads per Location and Season

Location	Season	TN Load*10^{-2} (lb)
Burlington	Spring	1.77
	Summer	0.93
	Fall	1.87
	Winter	0.51
Greensboro	Spring	2.74
	Summer	1.67
	Fall	3.31
	Winter	1.43
Raleigh	Spring	2.03
	Summer	2.59
	Fall	2.37
	Winter	1.59
Wilmington	Spring	5.46
	Summer	14.90
	Fall	4.53
	Winter	6.73

Table L.4: Predicted TN Loads per Season

Season	TN Load*10^{-2} (lb)
Spring	3.00
Summer	5.02
Fall	3.02
Winter	2.56

Table L.5: Predicted TP Loads per Location and Land Use

Location	Land Use	TP Load*10^{-3} (lb)
Burlington	High-Density	0.32
	Low-Density Old	2.44
	Low-Density New	0.26
	Downtown	5.06
Greensboro	High-Density	0.30
	Low-Density Old	5.35
	Low-Density New	2.09
	Downtown	3.82
Raleigh	High-Density	0.42
	Low-Density Old	5.09
	Low-Density New	0.79
	Downtown	7.88
Wilmington	High-Density	14.30
	Low-Density Old	3.22
	Low-Density New	3.05
	Downtown	22.60

Table L.6: Predicted TP Loads per Land Use

Land Use	TP Load*10^{-3} (lb)
High-Density	3.83
Low-Density Old	4.03
Low-Density New	1.55
Downtown	9.84

Table L.7: Predicted TP Loads per Location and Season

Location	Season	TP Load*10^{-3} (lb)
Burlington	Spring	1.34
	Summer	0.81
	Fall	0.43
	Winter	2.22
Greensboro	Spring	2.18
	Summer	1.37
	Fall	3.77
	Winter	1.12
Raleigh	Spring	1.85
	Summer	2.11
	Fall	2.64
	Winter	1.29
Wilmington	Spring	6.72
	Summer	11.60
	Fall	5.25
	Winter	7.73

Table L.8: Predicted TP Loads per Season

Season	TP Load*10^{-3} (lb)
Spring	3.02
Summer	3.97
Fall	3.02
Winter	3.09

Table L.9: Predicted TC Loads per Location and Land Use

Location	Land Use	TC Load (lb)
Burlington	High-Density	0.10
	Low-Density Old	0.82
	Low-Density New	0.07
	Downtown	1.82
Greensboro	High-Density	0.14
	Low-Density Old	1.73
	Low-Density New	0.98
	Downtown	1.89
Raleigh	High-Density	0.14
	Low-Density Old	1.62
	Low-Density New	0.25
	Downtown	2.26
Wilmington	High-Density	4.24
	Low-Density Old	1.09
	Low-Density New	0.73
	Downtown	3.76

Table L.10: Predicted TC Loads per Land Use

Land Use	TC Load (lb)
High-Density	1.16
Low-Density Old	1.31
Low-Density New	0.51
Downtown	2.43

Table L.11: Predicted TC Loads per Location and Season

Location	Season	TC Load (lb)
Burlington	Spring	0.38
	Summer	0.21
	Fall	0.72
	Winter	0.19
Greensboro	Spring	0.83
	Summer	0.49
	Fall	1.64
	Winter	0.69
Raleigh	Spring	0.44
	Summer	0.50
	Fall	1.0
	Winter	0.61
Wilmington	Spring	1.54
	Summer	2.60
	Fall	1.59
	Winter	1.98

Table L.12: Predicted TC Loads per Season

Season	TC Load (lb)
Spring	0.80
Summer	0.95
Fall	1.24
Winter	0.87

Table L.13: Predicted Fe Loads per Location and Land Use

Location	Land Use	Fe Load*10^{-3} (lb)
Burlington	High-Density	1.27
	Low-Density Old	16.0
	Low-Density New	0.72
	Downtown	23.90
Greensboro	High-Density	1.04
	Low-Density Old	31.50
	Low-Density New	12.80
	Downtown	18.80
Raleigh	High-Density	1.40
	Low-Density Old	34.70
	Low-Density New	3.68
	Downtown	76.40
Wilmington	High-Density	57.40
	Low-Density Old	10.10
	Low-Density New	10.10
	Downtown	109.0

Table L.14: Predicted Fe Loads per Land Use

Land Use	Fe Load*10^{-3} (lb)
High-Density	15.28
Low-Density Old	23.08
Low-Density New	6.83
Downtown	57.03

Table L.15: Predicted Fe Loads per Location and Season

Location	Season	Fe Load*10^{-3} (lb)
Burlington	Spring	5.06
	Summer	5.04
	Fall	4.48
	Winter	3.08
Greensboro	Spring	12.90
	Summer	8.85
	Fall	10.10
	Winter	6.83
Raleigh	Spring	10.70
	Summer	16.0
	Fall	8.40
	Winter	9.50
Wilmington	Spring	23.60
	Summer	56.20
	Fall	15.50
	Winter	30.80

Table L.16: Predicted Fe Loads per Season

Season	Fe Load*10^{-3} (lb)
Spring	13.07
Summer	21.52
Fall	9.62
Winter	12.55

Table L.17: Predicted Zn Loads per Location and Land Use

Location	Land Use	Zn Load*10^{-4} (lb)
Burlington	High-Density	1.41
	Low-Density Old	6.92
	Low-Density New	0.71
	Downtown	18.80
Greensboro	High-Density	1.09
	Low-Density Old	13.0
	Low-Density New	5.82
	Downtown	10.90
Raleigh	High-Density	1.08
	Low-Density Old	11.20
	Low-Density New	2.44
	Downtown	35.30
Wilmington	High-Density	51.10
	Low-Density Old	7.49
	Low-Density New	6.95
	Downtown	74.20

Table L.18: Predicted Zn Loads per Land Use

Land Use	Zn Load*10^{-4} (lb)
High-Density	13.67
Low-Density Old	9.65
Low-Density New	3.98
Downtown	34.80

Table L.19: Predicted Zn Loads per Location and Season

Location	Season	Zn Load*10^{-4} (lb)
Burlington	Spring	6.20
	Summer	2.73
	Fall	2.92
	Winter	2.65
Greensboro	Spring	7.69
	Summer	4.70
	Fall	5.12
	Winter	4.83
Raleigh	Spring	5.34
	Summer	8.18
	Fall	4.79
	Winter	4.99
Wilmington	Spring	20.10
	Summer	31.0
	Fall	12.50
	Winter	25.40

Table L.20: Predicted Zn Loads per Season

Season	Zn Load*10^{-4} (lb)
Spring	9.83
Summer	11.65
Fall	6.33
Winter	9.47

Table L.21: Predicted Mn Loads per Location and Land Use

Location	Land Use	Mn Load*10^{-3} (lb)
Burlington	High-Density	0.11
	Low-Density Old	1.50
	Low-Density New	0.09
	Downtown	2.02
Greensboro	High-Density	0.13
	Low-Density Old	1.72
	Low-Density New	1.94
	Downtown	1.55
Raleigh	High-Density	0.13
	Low-Density Old	1.63
	Low-Density New	0.22
	Downtown	6.17
Wilmington	High-Density	1.63
	Low-Density Old	0.35
	Low-Density New	0.37
	Downtown	3.65

Table L.22: Predicted Mn Loads per Land Use

Land Use	Mn Load*10^{-3} (lb)
High-Density	0.50
Low-Density Old	1.30
Low-Density New	0.65
Downtown	3.35

Table L.23: Predicted Mn Loads per Location and Season

Location	Season	Mn Load*10^{-3} (lb)
Burlington	Spring	0.34
	Summer	0.25
	Fall	1.24
	Winter	0.29
Greensboro	Spring	0.79
	Summer	0.51
	Fall	2.27
	Winter	0.74
Raleigh	Spring	0.45
	Summer	0.60
	Fall	1.46
	Winter	0.72
Wilmington	Spring	1.01
	Summer	1.27
	Fall	0.61
	Winter	0.97

Table L.24: Predicted Mn Loads per Season

Season	Mn Load*10^{-3} (lb)
Spring	0.65
Summer	0.65
Fall	1.39
Winter	0.68

Table L.25: Predicted Cu Loads per Location and Land Use

Location	Land Use	Cu Load*10^{-4} (lb)
Burlington	High-Density	0.07
	Low-Density Old	0.93
	Low-Density New	0.05
	Downtown	2.16
Greensboro	High-Density	0.19
	Low-Density Old	1.35
	Low-Density New	0.86
	Downtown	1.38
Raleigh	High-Density	0.08
	Low-Density Old	1.37
	Low-Density New	0.16
	Downtown	3.95
Wilmington	High-Density	4.90
	Low-Density Old	0.52
	Low-Density New	0.61
	Downtown	9.0

Table L.26: Predicted Cu Loads per Land Use

Land Use	Cu Load*10^{-4} (lb)
High-Density	1.31
Low-Density Old	1.04
Low-Density New	0.42
Downtown	4.12

Table L.27: Predicted Cu Loads per Location and Season

Location	Season	Cu Load*10^{-4} (lb)
Burlington	Spring	0.39
	Summer	0.24
	Fall	0.38
	Winter	0.20
Greensboro	Spring	1.27
	Summer	0.60
	Fall	0.82
	Winter	0.49
Raleigh	Spring	0.45
	Summer	0.63
	Fall	0.51
	Winter	0.49
Wilmington	Spring	1.72
	Summer	3.19
	Fall	1.08
	Winter	2.35

Table L.28: Predicted Cu Loads per Season

Season	Cu Load*10^{-4} (lb)
Spring	0.96
Summer	1.16
Fall	0.70
Winter	0.88

Table L.29: Predicted Ni Loads per Location and Land Use

Location	Land Use	Ni Load*10^{-6} (lb)
Burlington	High-Density	3.21
	Low-Density Old	9.64
	Low-Density New	1.82
	Downtown	37.90
Greensboro	High-Density	2.40
	Low-Density Old	41.80
	Low-Density New	18.90
	Downtown	22.0
Raleigh	High-Density	2.48
	Low-Density Old	61.70
	Low-Density New	9.76
	Downtown	137.0
Wilmington	High-Density	165.0
	Low-Density Old	24.60
	Low-Density New	28.50
	Downtown	243.0

Table L.30: Predicted Ni Loads per Land Use

Land Use	Ni Load*10^{-6} (lb)
High-Density	43.27
Low-Density Old	34.44
Low-Density New	14.75
Downtown	109.98

Table L.31: Predicted Ni Loads per Location and Season

Location	Season	Ni Load*10^{-6} (lb)
Burlington	Spring	17.30
	Summer	2.82
	Fall	6.48
	Winter	6.73
Greensboro	Spring	18.0
	Summer	4.97
	Fall	20.30
	Winter	23.0
Raleigh	Spring	19.30
	Summer	27.60
	Fall	23.70
	Winter	16.20
Wilmington	Spring	47.60
	Summer	145.0
	Fall	50.40
	Winter	80.40

Table L.32: Predicted Ni Loads per Season

Season	Ni Load*10^{-6} (lb)
Spring	25.55
Summer	45.10
Fall	25.22
Winter	31.58

Table L.33: Predicted Pb Loads per Location and Land Use

Location	Land Use	Pb Load*10^{-5} (lb)
Burlington	High-Density	0.76
	Low-Density Old	0.36
	Low-Density New	0.46
	Downtown	9.48
Greensboro	High-Density	0.28
	Low-Density Old	11.20
	Low-Density New	1.27
	Downtown	6.62
Raleigh	High-Density	0.31
	Low-Density Old	12.60
	Low-Density New	1.11
	Downtown	5.08
Wilmington	High-Density	248.0
	Low-Density Old	14.20
	Low-Density New	3.44
	Downtown	238.0

Table L.34: Predicted Pb Loads per Land Use

Land Use	Pb Load*10^{-5} (lb)
High-Density	62.34
Low-Density Old	9.59
Low-Density New	1.57
Downtown	64.80

Table L.35: Predicted Pb Loads per Location and Season

Location	Season	Pb Load*10^{-5} (lb)
Burlington	Spring	4.10
	Summer	0.75
	Fall	15.40
	Winter	24.90
Greensboro	Spring	26.80
	Summer	1.0
	Fall	3.73
	Winter	2.64
Raleigh	Spring	2.83
	Summer	7.49
	Fall	3.95
	Winter	2.56
Wilmington	Spring	19.30
	Summer	84.10
	Fall	30.30
	Winter	58.80

Table L.36: Predicted Pb Loads per Season

Season	Pb Load*10^{-5} (lb)
Spring	13.26
Summer	23.33
Fall	13.35
Winter	22.23

APPENDIX M: EXCEL TOOL ESTIMATING POLLUTANT LOADS

An Excel tool incorporating the identified pollutant concentrations was developed to help municipalities estimate pollutant loads and thus optimize maintenance regimens including street sweeping. Loads can be estimated with respect to land use or season. User inputs include: wet weight of the collected debris (lb), watershed area (ac), wet weight of the street sweepings (lb), length of curb swept (mi), and duration or number of days between street sweeping events (days). Note wet weight refers to the weight of the debris prior to any drying. The results from the tool will include an estimated moisture content, dry weight of the debris, and ranges of pollutant loads that were collected or swept.

It is crucial to recognize the estimated moisture contents and thus pollutant loads are not accurate. Statistical analyses determined knowing the wet weight of debris accurately predicted the moisture content at best 30% of the time. Moisture contents are needed to calculate the dry weight of debris without having to dry all of the collected debris. Therefore, it should be recognized the pollutant loads are not accurate but do provide some insight. More importantly, this tool should be used to optimize maintenance regimens including street sweeping and the installation of proprietary devices designed to collect debris. If possible, users should determine the dry weight of debris using other resources and apply this value to the reported pollutant concentrations to determine pollutant loads.

APPENDIX N: SAMPLE SAS CODE

```
/*Pollutant Analysis*/
options orientation= landscape;

proc import datafile="E:\Gross Solids\SAS\No Broken Traps Dry lb-lb-ac Total.csv"
/*proc import datafile="D:\SAS\No Broken Traps Dry lb-lb-ac Total.csv";*/
dbms=csv
out=a
replace;
getnames=yes;
GUESSINGROWS=100;
run;

proc sort data=a out=srtA;
by Location Land_Use Season Site Date;
run;

data srtA;
set srtA;
by Location Land_Use Season Site Date;
N_10=N*10;
P_10=P*100;
Fe_10=Fe*100;
Zn_10=Zn*1000;
Mn_10=Mn*1000;
Cu_10=Cu*10000;
run;

proc means min mean max std cv var n;
var N P C Fe Zn Mn Cu;
run;

proc print data =srtA (obs=50;
run;

proc freq data= srtA;
tables Location*Land_Use*Site*Season/list;
tables Location *Season/list;
run;

proc contents data=srtA;
run;
```

```
*ods pdf file="E:\Gross Solids\SAS\SAS Output No Broken Dry lb-lb-ac Total
NOVEMBER252015.pdf";
*run;

%LET IDVAR=N_10;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model N_10= Location Land_Use Location*Land_Use Season Season*Location
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;

proc export data=LSMNDS&IDVAR
outfile= "E:\N_10 No Broken Dry lb-lb-ac Total LSMNDS&IDVAR..CSV"
dbms=csv
replace;
run;

proc export data=DIFFDS&IDVAR
outfile= "E:\N_10 No Broken Dry lb-lb-ac Total DIFFDS&IDVAR..CSV"
dbms=csv
replace;
run;

PROC PRINT DATA = DIFFDS&IDVAR;
WHERE AdjP lE 0.05;
RUN;

ods csv file='E:\Gross Solids\SAS\N_10 No Broken Dry lb-lb-ac Total.csv';

ODS CSV CLOSE;

%LET IDVAR=P_10;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model P_10= Location Land_Use Location*Land_Use Season Season*Location
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
```

```
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;

proc export data=LSMNDS&IDVAR
outfile= "E:\P_10 No Broken Dry lb-lb-ac Total LSMNDS_&IDVAR..CSV"
dbms=csv
replace;
run;

proc export data=DIFFDS&IDVAR
outfile= "E:\P_10 No Broken Dry lb-lb-ac Total DIFFDS_&IDVAR..CSV"
dbms=csv
replace;
run;

ods csv file='E:\Gross Solids\SAS\P_10 No Broken Dry lb-lb-ac Total.csv';

PROC PRINT DATA = DIFFDS&IDVAR;
WHERE AdjP lE 0.05;
RUN;

ODS CSV CLOSE;

%LET IDVAR=Fe_10;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model Fe_10= Location Land_Use Location*Land_Use Season Season*Location
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;

proc export data=LSMNDS&IDVAR
  outfile= "E:\Fe_10 No Broken Dry lb-lb-ac Total LSMNDS_&IDVAR..CSV"
```

```
  dbms=csv
  replace;
run;

proc export data=DIFFDS&IDVAR
  outfile= "E:\Fe_10 No Broken Dry lb-lb-ac Total DIFFDS_&IDVAR..CSV"
  dbms=csv
  replace;
run;

ods csv file='E:\Gross Solids\SAS\Fe_10 No Broken Dry lb-lb-ac Total.csv';

PROC PRINT DATA = DIFFDS&IDVAR;
 WHERE AdjP lE 0.05;
 RUN;

ODS CSV CLOSE;

%LET IDVAR=Zn_10;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model Zn_10= Location Land_Use Location*Land_Use Season Season*Location
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;

proc export data=LSMNDS&IDVAR
  outfile= "E:\Zn_10 No Broken Dry lb-lb-ac Total LSMNDS_&IDVAR..CSV"
  dbms=csv
  replace;
run;

proc export data=DIFFDS&IDVAR
  outfile= "E:\Zn_10 No Broken Dry lb-lb-ac Total DIFFDS_&IDVAR..CSV"
  dbms=csv
  replace;
run;

ods csv file='E:\Gross Solids\SAS\Zn_10 No Broken Dry lb-lb-ac Total.csv';
```

```
PROC PRINT DATA = DIFFDS&IDVAR;
  WHERE AdjP lE 0.05;
  RUN;

ODS CSV CLOSE;

%LET IDVAR=Mn_10;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model Mn_10= Location Land_Use Location*Land_Use Season Season*Location
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;

proc export data=LSMNDS&IDVAR
   outfile= "E:\Mn_10 No Broken Dry lb-lb-ac Total LSMNDS_&IDVAR..CSV"
   dbms=csv
   replace;
run;

proc export data=DIFFDS&IDVAR
   outfile= "E:\Mn_10 No Broken Dry lb-lb-ac Total DIFFDS_&IDVAR..CSV"
   dbms=csv
   replace;
run;

ods csv file='E:\Gross Solids\SAS\Mn_10 No Broken Dry lb-lb-ac Total.csv';

PROC PRINT DATA = DIFFDS&IDVAR;
  WHERE AdjP lE 0.05;
  RUN;

ODS CSV CLOSE;

%LET IDVAR=Cu_10;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model Cu_10= Location Land_Use Location*Land_Use Season Season*Location
```

```
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;

proc export data=LSMNDS&IDVAR
   outfile= "E:\Cu_10 No Broken Dry lb-lb-ac Total LSMNDS_&IDVAR..CSV"
   dbms=csv
   replace;
run;

proc export data=DIFFDS&IDVAR
   outfile= "E:\Cu_10 No Broken Dry lb-lb-ac Total DIFFDS_&IDVAR..CSV"
   dbms=csv
   replace;
run;

ods csv file='E:\Gross Solids\SAS\Cu_10 No Broken Dry lb-lb-ac Total.csv';

PROC PRINT DATA = DIFFDS&IDVAR;
  WHERE AdjP lE 0.05;
  RUN;

ODS CSV CLOSE;

%LET IDVAR=C;
proc GLIMMIX data= srtA  plots=all;
class Location Land_Use Season Date;
model C= Location Land_Use Location*Land_Use Season Season*Location
/ dist=gamma link=log;
lsmeans Location Land_Use Season / ilink cl alpha=0.05 adjust=Tukey lines;
lsmeans Location*Land_Use   / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Land_Use);
lsmeans Season*Location / ilink  cl alpha=0.05 adjust=tukey  DIFF  slicediff= (Location
Season);
ods output lsmeans=lsmnds&IDVAR  DIFFS=DIFFDS&IDVAR;
run;

ODS LISTING CLOSE;
```

```
proc export data=LSMNDS&IDVAR
   outfile= "E:\C No Broken Dry lb-lb-ac Total LSMNDS_&IDVAR..CSV"
   dbms=csv
   replace;
run;

proc export data=DIFFDS&IDVAR
   outfile= "E:\C No Broken Dry lb-lb-ac Total DIFFDS_&IDVAR..CSV"
   dbms=csv
   replace;
run;

ods csv file='E:\Gross Solids\SAS\C No Broken Dry lb-lb-ac Total.csv';

PROC PRINT DATA = DIFFDS&IDVAR;
  WHERE AdjP lE 0.05;
  RUN;

ODS CSV CLOSE;

ODS PDF CLOSE;

/*Land Uses Contributing Largest Loads*/
options orientation= landscape;
*ODS LISTING GPATH = 'E:\Gross Solids\SAS';

proc import datafile="E:\Gross Solids\SAS\No Broken Traps Dry lb-ac Total.csv"
dbms=csv
out=a
replace;
getnames=yes;
GUESSINGROWS=100;
run;

proc sort data=a out=srtA;
by Location Land_Use Season Site Date;
run;

data srtA;
set srtA;
by Location Land_Use Season Site Date;
N_10=N*10;
P_10=P*100;
Fe_10=Fe*10;
Zn_10=Zn*1000;
Mn_10=Mn*1000;
```

```
Cu_10=Cu*10000;
run;

proc freq data=srtA;
tables land_use/list out=outluse nopercent nocum;
run;

proc print data= outluse;
run;

data _null_;
set outluse(keep=land_Use);
do land_Use= 1 to 4;
call symput( compress("LUSE"||land_Use), land_Use);
end;
run;
%put &luse1 &luse2 &luse3 &luse4;
run;

%macro hsumax(dataset, depvar, idvar);
proc GLIMMIX data=&dataset  plots=all;
class Location Land_Use Season Date;
model &depvar =   Location   Land_Use       Land_Use*Location Season Season*Location/
dist=gamma link=log;
lsmeans  Land_Use  / ilink  cl alpha=0.05 adjust=tukey  lines;
%do i = 1 %to 4;
lsmeans Land_Use / ilink  cl alpha=0.05 adjust=Dunnett   DIFF=Controlu("&i")   ;
%end;
ods output lsmeans=lsmnds&depVAR  DIFFS=DIFFDS&depVAR;
*ODS EXCLUDE DIFFS;
run;
%mend;

*ods tagsets.rtf  style=seaside  file="Best Treatment No Broken Traps Dry lb-ac Total
NOVEMBER252015.rtf";

ODS PDF file="E:\Gross Solids\SAS\Best Treatment No Broken Traps Dry lb-ac Total
NOVEMBER252015.pdf";
run;

%LET depVAR=N_10;
%hsumax( srtA , &depvar, H_&depvar);
quit;

%LET depVAR=P_10;
%hsumax( srtA , &depvar, H_&depvar);
```

```
quit;

%LET depVAR=Fe_10;
%hsumax( srtA , &depvar, H_&depvar);
quit;

%LET depVAR=Zn_10;
%hsumax( srtA , &depvar, H_&depvar);
quit;

%LET depVAR=Mn_10;
%hsumax( srtA , &depvar, H_&depvar);
quit;

%LET depVAR=Cu_10;
%hsumax( srtA , &depvar, H_&depvar);
quit;

%LET depVAR=C;
%hsumax( srtA , &depvar, H_&depvar);
quit;

ODS PDF CLOSE;
*ods tagsets.rtf close;
```