City of Seattle | Seattle Public Utilities

NPDES Phase I Municipal Stormwater Permit

Street Sweeping Water Quality Effectiveness Study Final Report

Prepared by

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1 Summary

1.1 Study Overview

From October 2014 through September 2016, Seattle Public Utilities (SPU) conducted water quality monitoring to evaluate the effectiveness of street sweeping on urban stormwater runoff. This study was designed to help add to the limited data available about modern street sweeping technology's effect on stormwater quality.

This study fulfilled a portion of the City of Seattle's (Seattle's) monitoring requirements listed in Special Condition S8.C.3 of the 2013-2018 National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permit (Permit), which allows a Permittee to independently conduct an effectiveness study in addition to paying into a collective fund to study stormwater quality at a regional level.

A paired Before/After-Control/Impact (BACI) design was used to test if stormwater quality differences can be detected between runoff from swept and unswept roadways. Specifically, this study assessed the ability of Seattle's current fleet of Schwarze® A9 Monsoon™ regenerative air street sweepers utilized on a weekly basis to reduce pollutant concentrations in stormwater runoff. This study sampled and analyzed stormwater samples only with the intent to directly measure the impact of street sweeping on water quality. No solids samples were collected, no street dirt yield was measured, and no mass balance estimates or modeling were performed as part of this study.

Stormwater monitoring was conducted at four sites located on the same arterial street in south Seattle, Washington. Two sites served as Control sites (swept on a weekly basis, which is the normal condition for Seattle arterial roadways) and two sites served as Impact sites (not swept during the second year). The four sites were monitored over a two-year period where Year 1 (2014-2015) represented *Before* conditions (all four sites swept on a weekly basis) and Year 2 (2015-2016) represented *After* conditions (two Control sites swept weekly, two Impact sites not swept). Sweeping was discontinued at the Impact sites approximately three months before Year 2 sampling commenced to allow for street dirt accumulation and equilibration to unswept conditions at the Impact sites.

Note on study design and results reporting: Since sweeping is the normal condition for arterial roadways in Seattle, sweeping was considered the Control and not sweeping was considered the Impact; meaning that the study design tested what is the impact to stormwater quality after stopping sweeping. For readability, results in the body of the report are presented as reductions *attributed to sweeping. In Appendix E, results are also presented as increases attributed to not sweeping.*

Samples were collected at the point roadway runoff entered the storm drain system via a grated inlet. A total of 24 manual grab and flow-weighted automatic composite stormwater sample sets were collected at each site over the two-year study. This resulted in a total sample number of n=68 under swept conditions and of n=28 under unswept conditions for all chemical parameters. Samples were always collected from all the four sites during each of the events sampled to maintain symmetry and comparability.

Since there is a known disparity between the particle size found in street sweepings (Seattle term for the total mass of street solids picked up by the street sweeper) and the particle sizes that can be captured by an automatic water quality sampler (autosampler) and analyzed by a laboratory, especially for the coarser size fractions (numerous studies, summarized by Pacific Water Resources 2008); this study took extra efforts to reduce this disparity. These efforts included:

1. Purchasing and using vacuum-style autosamplers which have higher withdrawal velocities compared to the more commonly used peristaltic pump-style autosamplers to attempt to capture as much of the sediment transported by stormwater as possible
2. Employing churn splitters for subsampling the composite sample to attempt to keep the sediment particles suspended as analyte-specific bottles are filled in the laboratory
3. Using two laboratory methods to quantify the suspended solids concentration:
    a. Total suspended solids (TSS) which is the standard analytical method for solids in both wastewater and stormwater but has been known to bias low for larger particles due to sub-sampling that is part of this method
    b. Modified suspended sediment concentration (SSC) which utilizes the whole sample (i.e., no subsampling) and quantifies the suspended sediment concentration by size fractions.

Monitoring activities were implemented successfully, and the study met all the Quality Assurance Project Plan (QAPP) (SPU 2014) sampling objectives. The sites monitored had small, impervious drainage catchments where 95 percent or greater of the land surface was controlled by sweeping. The sweepers swept at the desired weekly frequency and successfully stopped sweeping the Impact sites during Year 2. No sampling or weather anomalies were experienced during this two-year study.

1.2 Data Analysis

The data analysis phase of this study took longer than anticipated due to the complexity of the analysis. A frequent problem with stormwater effectiveness studies is that the variability of stormwater concentrations between events and the variability between sites and from event to event can be so great, that the impact of an activity like street sweeping may not be detected above the noise of that variability. Statistical significance is dependent on the magnitude of the impact and the sample size, particularly when data sets are highly variable.

Given the variability of stormwater concentrations, the sample size for this study (n = 96) was not large enough to detect statistically-significant differences for many parameters using the original statistical method proposed for this study – the Analysis of Variation (ANOVA). In addition, the ANOVA method cannot quantify the magnitude of the difference of the impact. Because of the variability and the need to quantify the magnitude of the impact, the original ANOVA method was replaced with the Analysis of Covariation (ANCOVA) method following approval from Ecology on July 17, 2017. The ANCOVA method is considered to do a better job of controlling for variability between events. The ANCOVA can also quantify the magnitude (e.g., percent change) of the difference of the impact (stopping sweeping).

1.3 Study Results

This study detected statistically-significant change (p-value <= 0.1) attributed to sweeping for the following parameters:

Table 1. ANCOVA Results (p<=0.1)

Parameter	p value	Reduction in Concentration Attributable to Sweeping *
Copper, Particulate	0.09	17%
Sediment Concentration > 500 um	0.09	64%
Sediment Concentration 500 to 250 um	0.10	48%
Sediment Concentration < 3.9 um	0.002	-133%

* – Positive values suggest that concentrations were reduced because of sweeping

The changes measured for particulate copper (17 percent concentration reduction) and the two coarsest sediment size fractions (>500 microns (um) and 500 to 250 um; 64 and 48 percent concentration reductions, respectively) were positive, inferring that street sweeping reduces the concentrations of these parameters in stormwater runoff. The change measured for the finest sediment size fraction (<3.9 um, which is clay/colloidal range) was negative, inferring that street sweeping may increase the concentration of the finest particles in stormwater runoff.

The following parameters exhibited change but with lower confidence (p-value between 0.1 and 0.3[1]):

[1] When evaluating environmental data, a p-value of 0.1 is typically the highest cutoff for statistical significance. Due to the problems of variability and small sample size in this study, parameters with p-values between 0.1 and 0.3 are presented to suggest parameters that may be impacted by street sweeping if a larger data set was available.

Table 2. ANCOVA Results (p between 0.1-0.3)

Parameter	p value	Reduction in Concentration Attributable to Sweeping *
Copper, Total	0.13	14%
Total Sediment Concentration	0.22	29%
Total Suspended Solids	0.29	24%
Zinc, Particulate	0.17	18%
Zinc, Total	0.17	15%
Nitrate + Nitrite	0.21	-28%

* – Positive values suggest that concentrations were reduced because of sweeping

When increasing the p value to 0.3 to consider parameters that street sweeping may be effective at reducing if a larger sample size was available; total copper (14 percent concentration reduction), total sediment concentration (the summed total of all the sediment size fractions, 29 percent concentration reduction), total suspended solids (24 percent concentration reduction), and total and particulate zinc (15 and 18 percent concentration reduction, respectively) were reduced. The change measured for nitrate + nitrite was negative, inferring that street sweeping may increase the concentration of this parameter.

No significant differences (p value higher than 0.3) were inferred for the other monitored parameters which included dissolved metals (zinc and copper), other nutrients (total phosphorus and total Kjeldahl nitrogen (TKN)), chemical oxygen demand (COD), total organic carbon (TOC), and polycyclic aromatic hydrocarbons (PAHs). Due to extreme variability, fecal coliform bacteria data violated the assumptions of the ANCOVA test so were not evaluated.

Using the primary analysis method (ANCOVA), this study detected significant (p value <= 0.1) and lower confidence reductions (p-value between 0.1 and 0.3) attributed to street sweeping for approximately half of the parameters measured. The large variability in stormwater concentrations measured is considered to have masked the entire impact of sweeping on stormwater pollutant reductions.

1.4 Recommended Future Actions

This study indicates that street sweeping is an effective stormwater BMP in addition to providing multiple other city-wide benefits not evaluated as part of this study. No changes are recommended to SPU's current street sweeping program.

2 INTRODUCTION AND BACKGROUND

2.1 Introduction

This document serves as the City of Seattle's (City) calendar year 2017 monitoring report as required by Special Condition S8.C.3 of the 2013-2018 National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permit (Permit) and the final report and the City's selected effectiveness study. On August 1, 2012, the Washington State Department of Ecology (Ecology) issued an updated 2013-2018 Permit that became effective on August 1, 2013. The Permit was modified on January 16, 2015.

The Permit uses a collective funding approach to fund the three components of a Regional Stormwater Monitoring Program[2] (RSMP) created under the Permit: 1) status and trends monitoring, 2) stormwater management effectiveness studies, and 3) source identification and diagnostic monitoring. Components 1 and 2 have an option that allows Permittees to perform their own monitoring or studies in lieu of paying all or some of their allotted payment amount to the regional fund.

In a letter dated November 26, 2013, the City notified Ecology that the City had selected the Effectiveness Studies option that allows the City to both pay into a collective fund to implement RSMP effectiveness studies and independently conduct an effectiveness study that will not be undertaken as part of the RSMP. The effectiveness study that the City selected, which is the subject of this report, is to evaluate the effectiveness of street sweeping at reducing pollution in urban stormwater runoff.

Monitoring for this study began in October 2014 and was completed by September 2016. Results for the first partial calendar year (2014) were documented in an interim report titled *Effectiveness Study Interim Results and Status Report*, dated March 2, 2015 (SPU 2015). The results from the second calendar year (2015) were documented in the second interim report titled *Effectiveness Study Interim Results and Status Report*, dated March 8, 2016. The results from the third and final calendar year of monitoring, including all monitoring results, were documented in the third interim report titled *Effectiveness Study Interim Results and Status Report*, dated March 28, 2017. The purpose of these previous documents was to comply with Permit Condition S8.C.3.b.iv: "*Describe interim results and status of the study implementation in annual reports throughout the duration of the study*." As the study is now complete (both monitoring and

[2] Ecology has renamed the Regional Stormwater Monitoring Program (RSMP) to Stormwater Action Monitoring (SAM) but this report will use the former RSMP name for consistency with past annual reports.

analysis finished), this report serves as both the 2017 annual report as well as a standalone report that summarizes this entire effectiveness project.

2.2 Background

The Seattle Finance and Administrative Services (FAS) owns and Seattle Department of Transportation (SDOT) operates a fleet of mechanical broom and regenerative air street sweepers. Under the direction of SPU, five to seven regenerative air sweepers are used on roadways that drain to surface waters as a stormwater management/source control BMP.

The effect of modern street sweeping technology on stormwater quality has not been well studied recently and/or the limited recent studies have not had sufficient rigor. This study was designed to help add to the limited data available about modern street sweeping technology's effect on stormwater quality.

3 Street Sweeping Program and Monitoring Study Overview

3.1 SPU Street Sweeping Program Overview

The City has been using street sweeping as a good housekeeping practice since the early 1900s. Street sweeping technology has changed significantly over the last two decades and the newer model sweepers use regenerative air and vacuum technology that are reported to be capable of removing very fine particulates (less than 10 µm).

In 2006, SPU conducted a pilot study, which suggested that street sweeping was effective at reducing roadway pollutants. In 2009, SPU further evaluated the economics of street sweeping and found it to be a cost-effective method for reducing the stormwater pollutant load from City roadways. Results from these two studies are documented in a 2009 report prepared by SPU and Herrera Environmental Consultants (SPU 2009).

In February 2011, SPU launched the Street Sweeping for Water Quality (SS4WQ) program which is a partnership between SPU and SDOT. Under the direction and funding of SPU, five to seven regenerative air sweepers are used on roadways that drain to surface waters as a stormwater management/source control BMP.

SPU sets the program direction and provides water quality expertise and funding for the portion of routes that discharge directly to Seattle's receiving waters. Currently, 24 street sweeping routes covering 660 lane miles, of which 490 drain to surface waters, are swept using regenerative air sweepers. SDOT provides operational expertise, street sweeping services, and funding for the portion of the non-SS4WQ routes on roadways that drain to combined sewer basins and ultimately sewage treatment plants.

3.2 Study Overview

3.2.1 Study Goals

The goal of this study was to quantify the effect of street sweeping on stormwater quality by directly measuring runoff concentrations from roadways under swept and unswept conditions. Specifically, this study assessed the ability of the City's current fleet of regenerative air Schwarze A9 Monsoon street sweepers utilized on a weekly basis to reduce pollution in stormwater runoff.

3.2.2 Study Design Overview

A paired Before/After-Control/Impact (BACI) design was used to test if stormwater quality differences can be detected when street sweeping is discontinued. Since sweeping is the normal condition for arterial roadways in Seattle, sweeping is considered the “control” and not sweeping is considered the “impact;” meaning that this study tested if by not sweeping, there is a measurable impact to stormwater quality.

Stormwater monitoring was conducted at four sites located on the same arterial street with similar characteristics, where two sites served as Control sites (swept on a weekly basis) and two sites served as Impact sites (not swept during Year 2). The four sites were monitored over a two-year period where Year 1 (2014-2015) represented the Before condition and Year 2 (2015-2016) represented the After condition.

The two Control sites were monitored under typical, weekly street sweeping operations during both years. The two Impact sites were monitored under typical, weekly street sweeping operations in Year 1 and under unswept conditions in Year 2. Sampling was initiated in October to sample seasonal first flush conditions and continued through September of the following year to sample under both wet and dry season conditions. Under this schedule, Year 1 sampling occurred from October 2014 through July 2015 and Year 2 occurred from October 2015 through July 2016. Sweeping was discontinued at the Impact sites on July 22, 2015, which was the last time that the Impact sites (SS3 and SS4) were swept. This schedule provided approximately 3 months of street dirt accumulation and equilibration at the Impact sites between Before (Year 1) and After (Year 2) conditions.

The goal was to collect 12 composite and grab samples from each location per each year for a total of 24 samples sets at each site. Because of unusually dry conditions during Year 1, only 10 events were sampled during Year 1. Year 2 sampling was increased to compensate, and 14 events were sampled during Year 2, which met the original project goal of 24 sample sets at each site. Eight wet season and two dry season events were sampled in Year 1, and 12 wet season and two dry season events were sampled in Year 2.

3.2.3 Monitoring Site Selection

Finding suitable and representative monitoring locations for stormwater studies of this nature is critical to the success of the study but can be very challenging. For the most comparable sampling data, the following requirements were imposed on the stormwater monitoring site selection:

1. Each monitoring site was located on the same arterial where the drainage basin area of each site extended only the distance between two adjacent storm drain inlets (typically 200-300 lineal feet) and from the curb line to the roadway crown.

2. Sites would have no significant run-on from impervious and pervious areas adjacent to the travel lanes (e.g., driveways, sloped planting strips, lack of curb, etc.).
3. Sites with no nighttime parking were selected so sweepers could be the most effective and parking restrictions would not be needed.
4. Sites would be in arterial roadway sections of nearly identical land use, slope, size, road surface type and condition, vegetation coverage, and similar traffic counts and type of vehicle usage.
5. Sites would have no paving or construction activities planned for the next four years.
6. Sites would have parking strips and adjacent residences/businesses amendable to an above-ground sampling cabinet installation; and have inlets suitable for monitoring (large enough both vertically and horizontally, enough vertical drop to bottom or water surface, abut curb, be structurally sound, etc.).

Potential arterials to monitor were investigated using a Geographical Information System (GIS) review and field reconnaissance to locate roadways that contain a minimum of six locations meeting the above requirements. Based on the review and field reconnaissance, six locations on Martin Luther King (MLK) Jr. Way S in South Seattle were selected for initial, project development-phase grab sample monitoring. The goal of this grab sampling was to select four locations to monitor during the full phase study.

Between November 2013 and March 2014, a total of six rounds of roadway runoff grab samples were collected from the six initial sites (identified as SS1 through SS6) during this development phase of the project. The original plan was to identify the four locations with the most similar water quality conditions to sample under the full-phase study. Because of unresolved capacity/drainage issues observed at sites SS1 and SS6, those two sites were eliminated from future consideration. The final sites selection for the full-scale study, identified as SS2 through SS5, are shown on Figure 1 and location details are provided in Table 3. Maps of the stormwater drainage for each monitoring locations are presented in Figure 2 through Figure 5, and photos of the four site inlets are shown on Figure 6 through Figure 9.

Table 3. Monitoring station location information

Station ID	Address	Catchment Area Estimate (square feet)	FEA_KEY	EQNUM_ID	X_COORD	Y_COORD
SS2	4051 M. L. King Way Jr S	13,500	7329200	978552	1279074.49	210314.26
SS3	2961 S Dakota (on M. L. King Way Jr. S)	3,500	4061938	929412	1279202.99	209938.85
SS4	4118 M. L. King Way Jr S	6,300	7331900	978926	1279257.93	209787.44

Station ID	Address	Catchment Area Estimate (square feet)	FEA_KEY	EQNUM_ID	X_COORD	Y_COORD
SS5	No address, approx. 4925 M. L. Jr Way S, 130' south of S Ferdinand St	5,800	7349489	983834	1280405.63	206774.28

SS2 and SS5 serve as the Control sites during this study so they were swept on a weekly basis over both years of the study. SS3 and SS4 were the Impact sites so they were sampled under swept conditions during Year 1 and unswept conditions during Year 2.

3.2.4 Drainage Basins Descriptions

As discussed above, the goal was to select four arterial roadway monitoring sites with drainage areas of very similar land use, slope, size, road surface type and condition, vegetation coverage, and similar traffic counts and type of vehicle usage. The final four monitoring sites are located in a portion of MLK Jr. Way S that was completely reconstructed when the Sound Transit Light Rail was installed from approximately 2004 to 2008. The roadway surface, median containing the Light Rail tracks, and drainage inlets and catch basins were all replaced during the Light Rail construction. This resulted in the surface of all four drainage basins being 100 percent impervious area consisting almost entirely of the same age and type of concrete. The roadway slopes of all four catchments are relatively flat and are visibly estimated to range from 1 to 2 percent.

As displayed on Figure 2 through Figure 5, the area draining to each monitoring location is almost entirely the MLK Jr. Way S arterial roadway surface located between the outside arterial curb and the curb that separates the median containing the Light Rail (the Light Rail median area is the tan-colored area shown in the figures that separates the north-bound and south-bound arterial lanes). A minor portion (less than 10 percent) of area draining to SS2 and SS4 extends to the adjacent side streets. When the street sweepers cross an intersection, they curve slightly onto the side street, so a portion of this small side street area was still swept. Any drainage from the Light Rail median area is contained by curbs and conveyed by a separate drainage system.

The four drainage catchment areas estimated using visual field observations and GIS analysis range from approximately 3,500 to 13,500 square feet. The catchments were selected to minimize stormwater run-on from unswept areas. Because of the continuous curbs lining both sides of the two arterial lanes swept (i.e., no driveways or alleys drain to the catchment area), and the relatively new age and good condition of the drainage system; it is assumed that the catchments draining to the monitoring locations consist only of impervious roadway surface and any runoff from adjacent pervious surfaces such as planting strips is negligible. It is estimated that the sweepers swept (controlled) between 95 to 100 percent of the land surface of the drainage basins monitored. Details of the drainage basins are listed on Table 4.

Figure 1. Monitoring site location map.

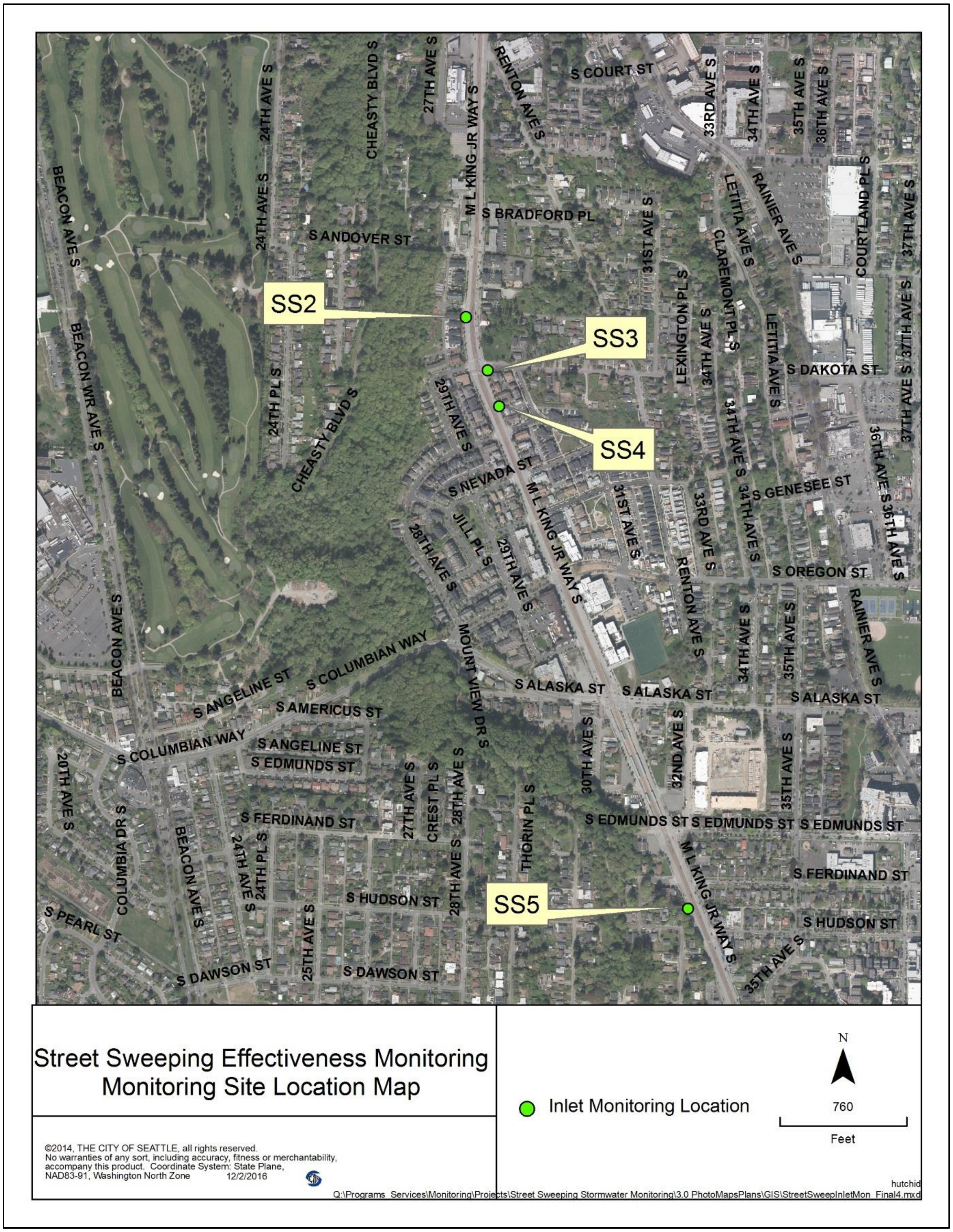


Figure 2. SS2 Drainage Catchment.

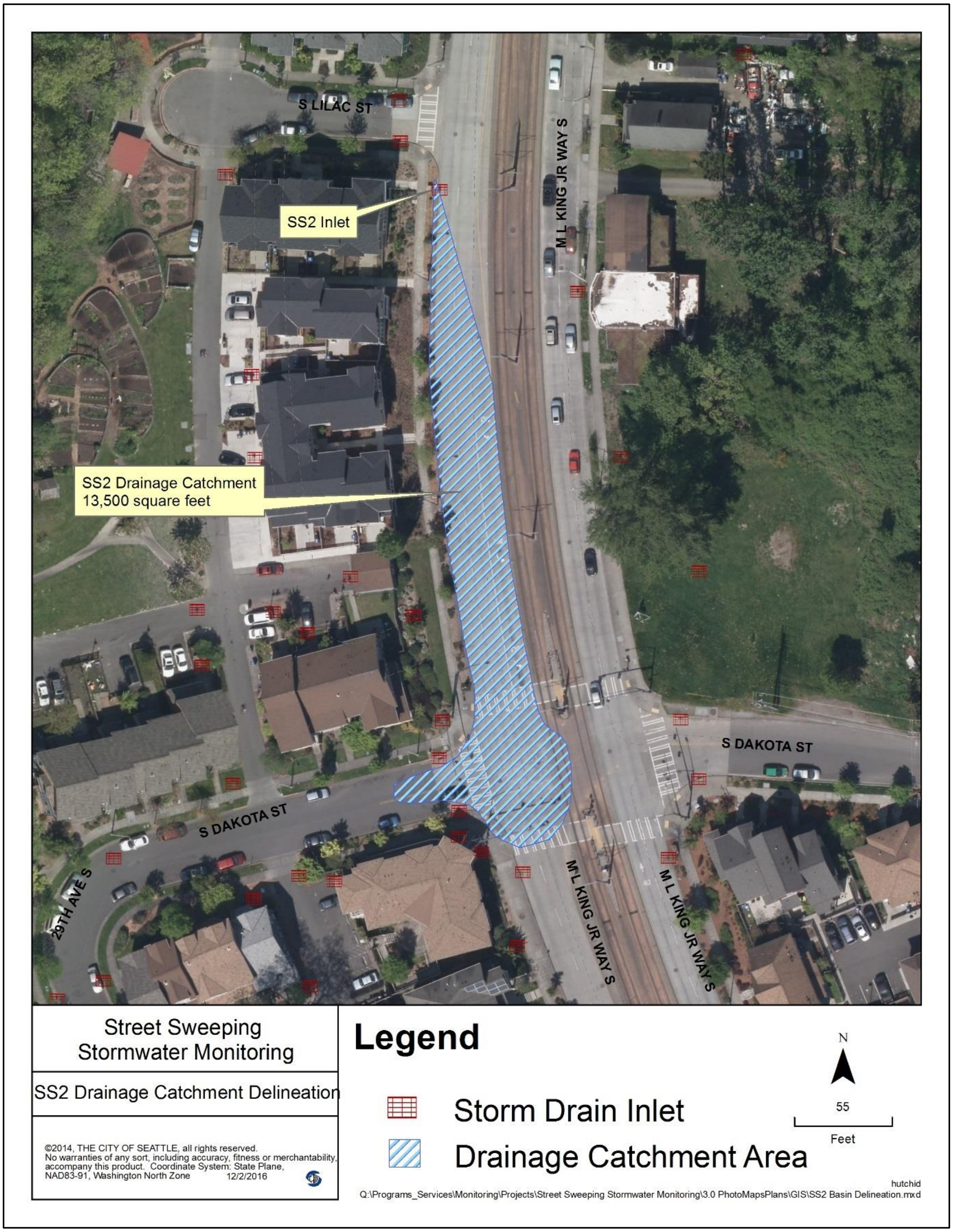


Figure 3. SS3 Drainage Catchment.

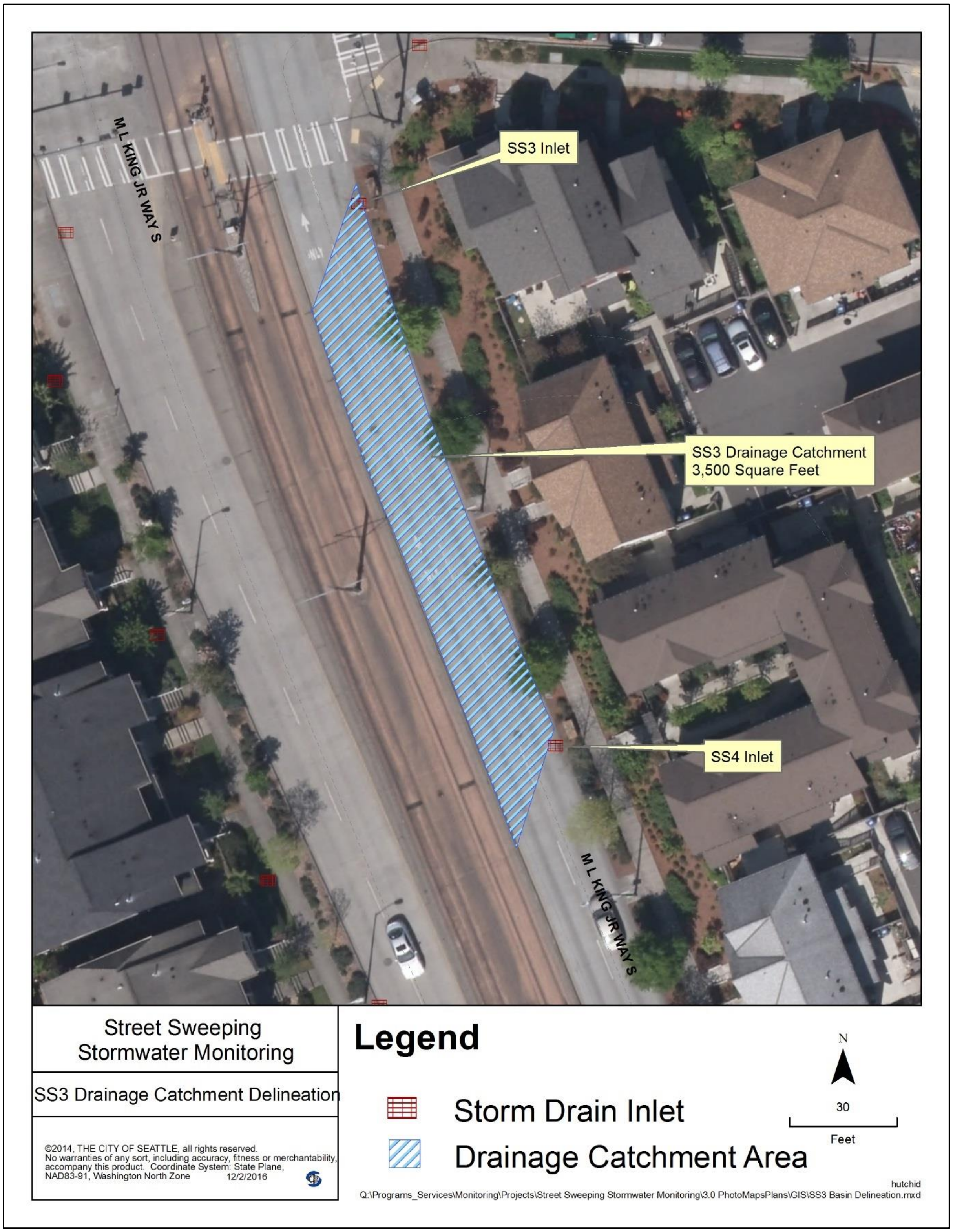


Figure 4. SS4 Drainage Catchment.

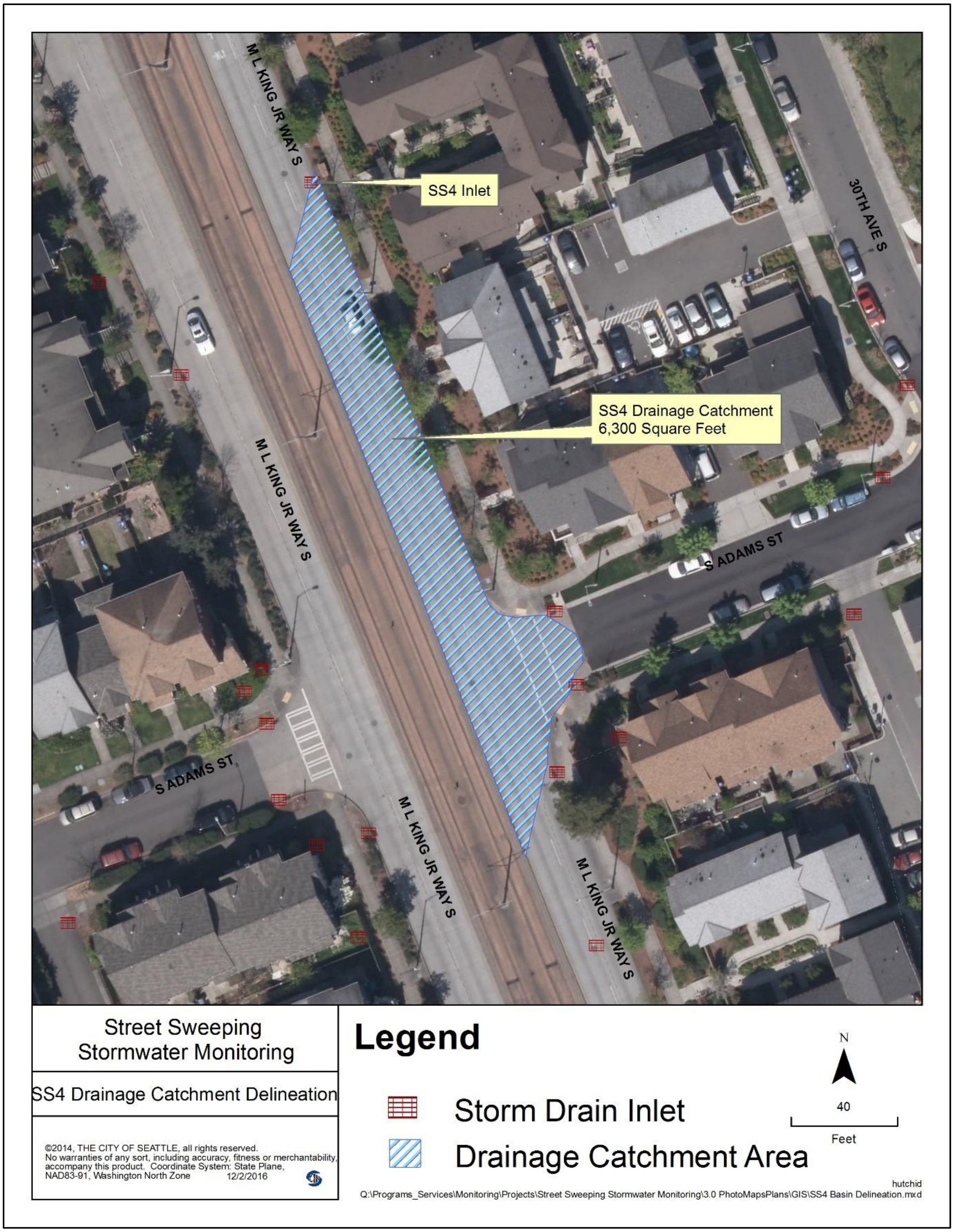


Figure 5. SS5 Drainage Catchment.

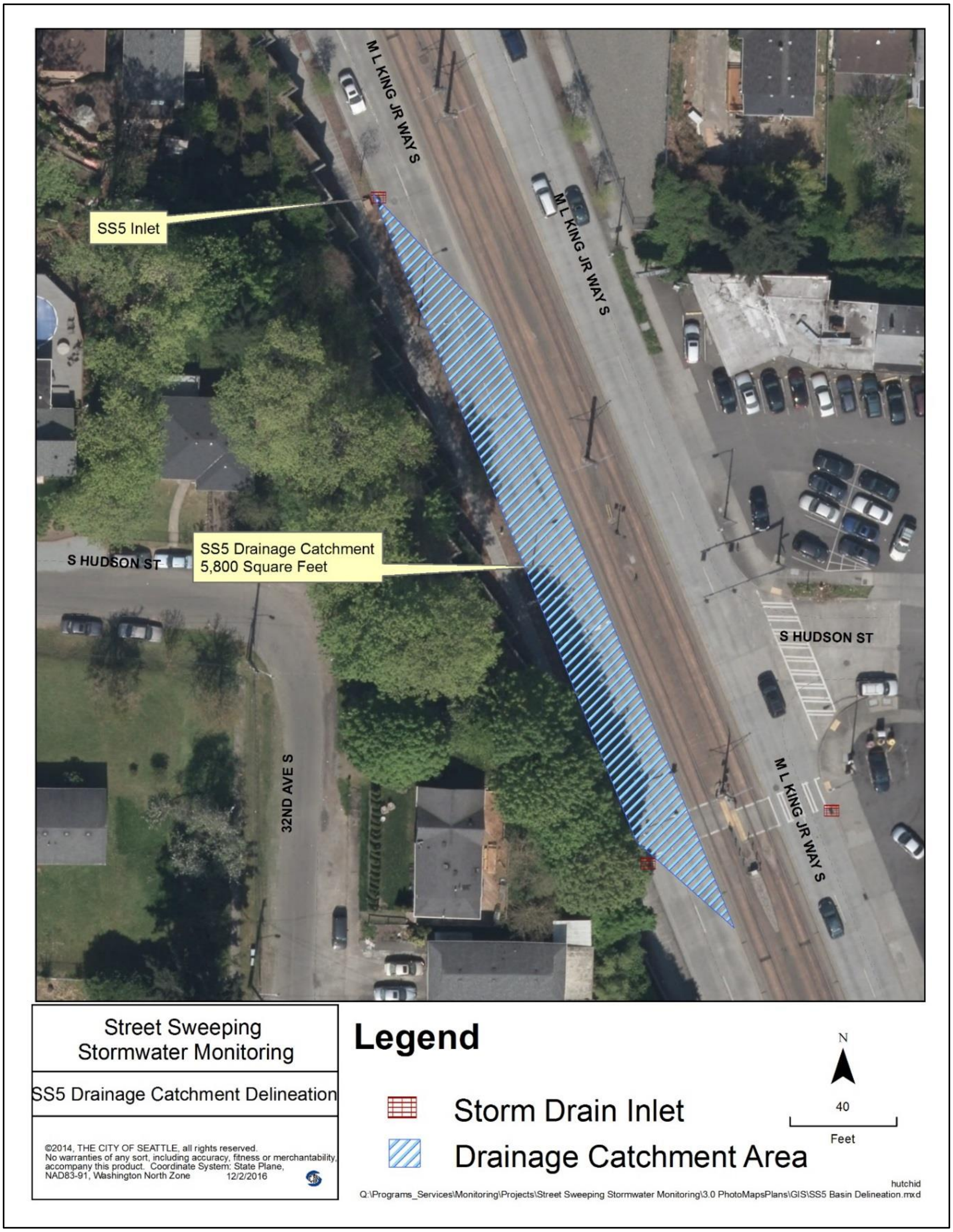


Table 4. Drainage basin characteristics

	Station ID			
	SS2	SS3	SS4	SS5
Total catchment area estimate, square feet	13,500	3,500	6,300	5,800
Catchment land use type estimate, square feet (percentage of total catchment): Arterial Road Surface	13,365 (90%)	3,500 (100%)	5,670 (90%)	5,800 (100%)
Side Street Road Surface	135 (10%)	0 (0%)	630 (10%)	0 (0%)
Catchment area swept estimate, percentage*	95%	100%	95%	100%
Roadway composition	Concrete	Concrete	Concrete	Concrete
Roadway condition	Excellent	Excellent	Excellent	Excellent

* - Since the sweepers curve onto side streets at intersections, the area controlled by sweeping is estimated to be greater than only the arterial roadway surface.

The area surrounding the monitoring locations consists primarily of newer multi-family housing units (built during and immediately following the Light Rail's construction) and some older single-family houses and commercial areas. The Annual Average Weekday Traffic (AAWDT) for the section of MLK Jr. Way S where the monitoring occurred is 21,900.

Figure 6 through Figure 9 present photographs of each of the four locations monitored.

Figure 6. Photograph of monitoring station SS2 (looking south)

Figure 7. Photograph of monitoring station SS3 (looking south)

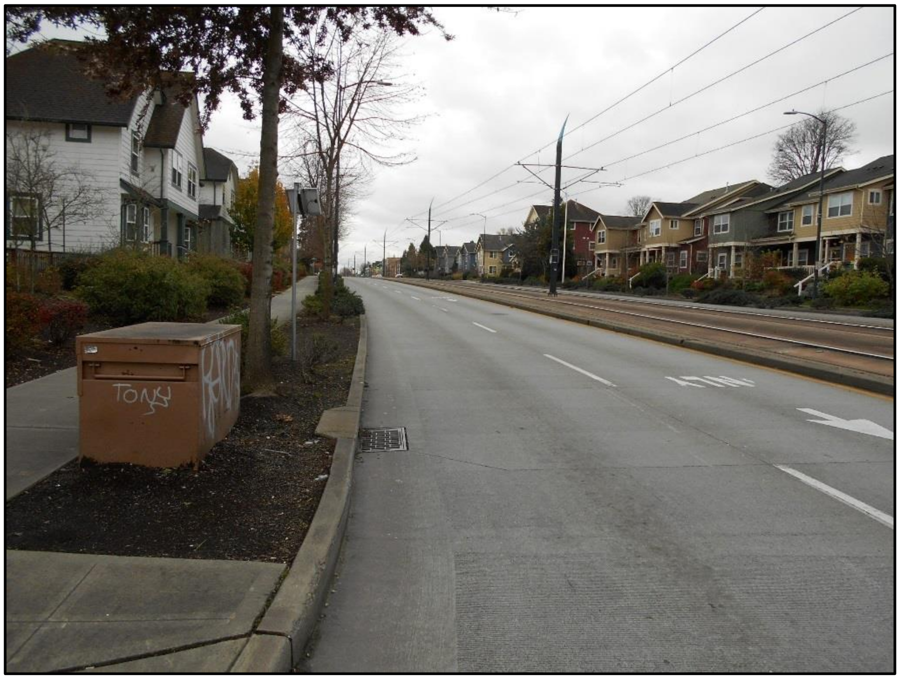


Figure 8. Photograph of monitoring station SS4 (looking south)

Figure 9. Photograph of monitoring station SS5 and project rain gage (looking south)

3.2.5 Street Sweeping Operations in Study Area

The sweepers used in the study area are Schwarze A9 Monsoon regenerative air sweepers. These sweepers are equipped with side gutter brooms on each side of the machine which loosen and direct material towards the sweeper’s pick-up head. The sweeper’s pick-up head is 90 inches wide and located under the center of the machine. The regenerative-air process blasts air down onto the pavement at the leading end of the pick-up head dislodging materials entrained on the pavement and material that was loosened/directed by the brooms and transports it upwards into the pick-up head. The trailing end of the pick-up head has a suction hose that vacuums out the materials within the head and discharges it into the 9.6 cubic yard built-in hopper. The air is recirculated within the sweeper, as a filtration system cleans the air before returning it to the blower to repeat the process. When the hopper is filled, the sweeper operator drives to a dump facility located on S. Charles Street and then returns and resumes sweeping. An image of the sweeper used in this study from the manufacturer’s website is presented below.

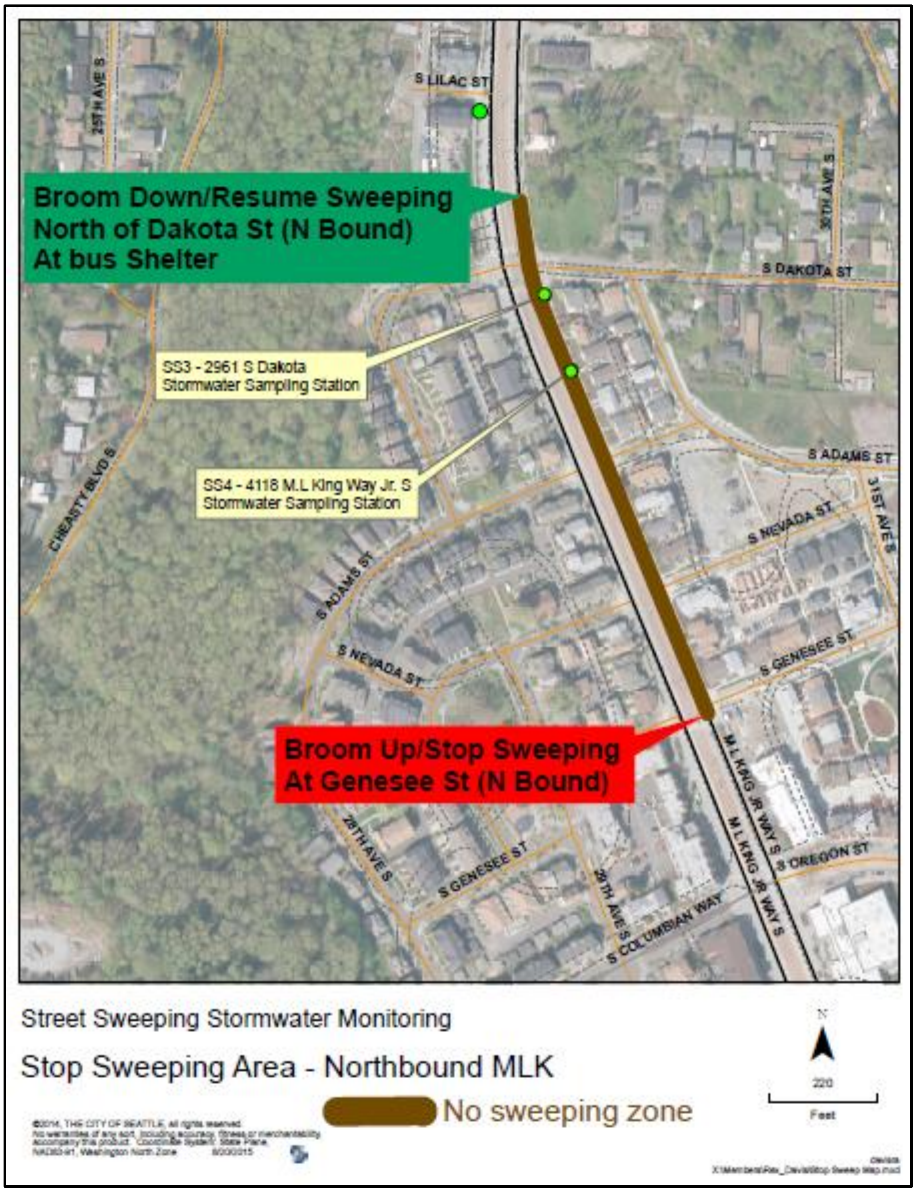
The street sweepers are operated by SDOT staff. During Year 1 (the *Before* year), the operators drove the sweepers down both the MLK Jr Way S. arterial lanes in each travel direction once per week, sweeping both northbound and southbound lanes. Sweeping was performed during an overnight shift, specifically between 8:00 pm and 6:30 am. Based on information collected from the Automated Vehicle Location (AVL) technology installed on each sweeper, the sweeper’s average speed on the route monitored was 6.2 miles per hour (mph).

Figure 10. Manufacturer's brochure image of A9 Monsoon sweeper

Image from: http://www.schwarze.com/Brochures/monsoon.pdf

During Year 2 (the *After* year), when sweeping the northbound lanes; the sweeper operators lifted the broom (which automatically turns off the regenerative air) at S. Genesee Street – which is two full blocks before (south) of the first (SS4) of the two adjacent Impact catchments (SS3 and SS4). Sweeping resumed one half block after (north) the downstream edge of the SS3 catchment, as shown on the following figure.

Figure 11. Stop sweeping area (Year 2 at impact sites)



Actual days swept were confirmed by reviewing AVL information. This information is presented on Table 9 displayed later in this report.

3.2.6 Parameters analyzed

Parameters were selected based upon their known presence in stormwater, their potential for adverse impacts, or their value in providing necessary supporting information. Parameters and corresponding sample collection methods are listed in Table 5.

Table 5. Parameters analyzed

Group Type	Parameter	Sample Collection Method
Conventional parameters in stormwater	Total Suspended Solids (TSS)	Auto sampler, composite
	Total Organic Carbon (TOC)	Auto sampler, composite
	Chemical Oxygen Demand (COD)	Auto sampler, composite
	Suspended Sediment Concentration (SSC)	Auto sampler, composite
	pH	Grab sample, field meter
	Hardness	Auto sampler, composite
Metals (total and dissolved) in stormwater	Copper	Auto sampler, composite
	Zinc	Auto sampler, composite
Nutrients in stormwater	Total Phosphorus	Auto sampler, composite
	Nitrate-Nitrite (N03-N02)	Auto sampler, composite
	Total Kjeldahl Nitrogen (TKN)	Auto sampler, composite
Organics in stormwater	Polycyclic Aromatic Hydrocarbons (PAHs)	Grab sample, direct in bottle
Bacteria in stormwater	Fecal coliform	Grab sample, direct in bottle
Stormwater flow data	Level/flow at each inlet	Level sensor and weir/data logger
Precipitation data	Local rainfall in project area	Tipping bucket rain gage/data logger

3.2.7 Monitoring Station Description

Each of the four monitoring stations were configured in a similar manner and consist of an aboveground metal equipment cabinet and solar panel installed in the parking strip with buried conduit connected to the adjacent storm drain inlet/catch basin structure. The one exception is a tipping bucket rain gage was installed at SS5 to measure rainfall for the localized project area. The elements of each monitoring station are shown on Figures 12 and 13 below.

3.2.7.1 Flow Monitoring Equipment

Stormwater running off the roadway and entering each of the four inlets/catch basins was continuously monitored to calculate flow rate and volume. Accurate flow monitoring within catch basins is challenging since they are compact and not designed for flow monitoring. To facilitate flow monitoring, custom-made weir boxes were fabricated and installed in each monitored catch basin. A sampling tray positioned above each weir box directed all the stormwater entering each catch basin into the influent chamber of the weir box. An internal baffle calmed the flow prior to it entering the outlet chamber where the flow exited the box through a Thel-Mar™ volumetric weir installed in the downstream wall of the outlet chamber. The weirs served as the primary measurement devices which constrict and shape the flow, creating a relationship between hydraulic head and flow.

Figure 12. Monitoring station schematic detail (plan view)

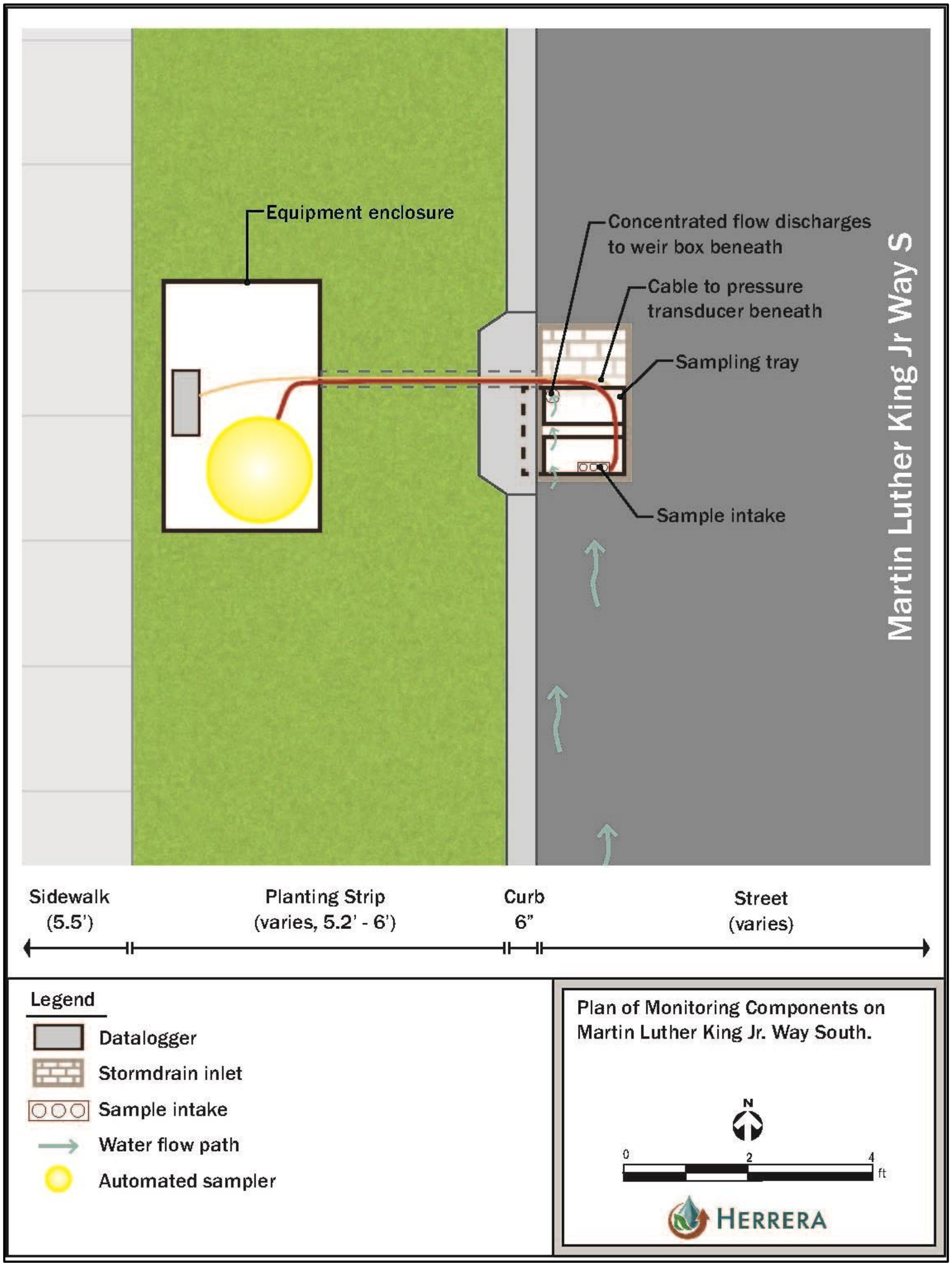


Figure 13. Monitoring station schematic detail (section view)

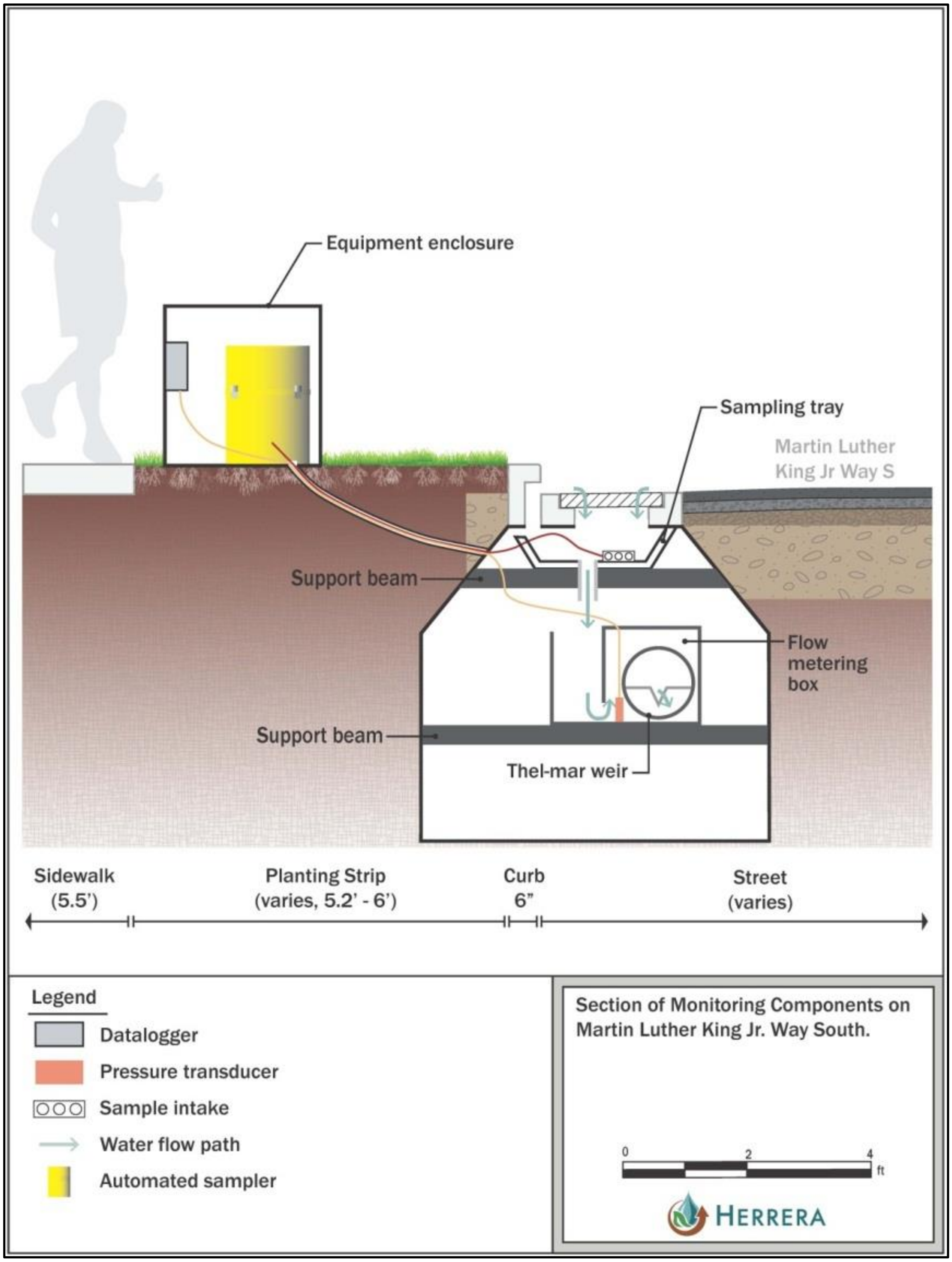


Figure 14. Sampling tray installed in inlet (inlet grate removed)

Figure 15. Weir box (prior to installation)

Pressure transducers (Campbell Scientific Inc. CS451-L) were installed in a stilling chamber to monitor water depth upstream of the weir in the outlet chamber.

The pressure transducers were connected to Campbell Scientific CR1000 data loggers which recorded water level measurements and controlled the automatic water sampling equipment. Loggers were programmed to record measurements every five (5) minutes. Level data were converted to flow rates and volumes based on an equation provided by the weir manufacturer. Each data logger was equipped with a digital cellular modem (Raven XTV) to provide remote access to flow data and adjust the pacing of the water quality sampler. Equipment was powered by rechargeable batteries augmented by solar panels. Aboveground monitoring equipment (data logger, modem, batteries and automatic samplers) was housed in Knaack Jobmaster Model 4830 storage cabinets.

3.2.7.2 Water Quality Sampling Equipment

The City purchased and used vacuum-type automatic samplers (Manning Environmental Inc., VST3 sampler) specifically for this project. Vacuum samplers were introduced to the market as an alternative to the more commonly used (for stormwater sampling) peristaltic-pump type samplers. Vacuum samplers use an external vacuum pump to draw water samples instead of the peristaltic pumps that induce flow by compressing flexible tubing. Advantages of the vacuum pumps are reported to include higher transport velocities (5.1 feet per second [fps] at 5 feet of head for the VST3 vs. ~3 fps for the standard peristaltic pump), greater vertical lift range, and less disruption of the water because tubing is not being squeezed. Because of these attributes, vacuum samplers are reputed to better represent solids concentration in stormwater, especially when larger particles are present such as in urban stormwater runoff. Since getting representative solids concentrations in urban stormwater is important when quantifying the effect of street sweeping, SPU invested in this new equipment to increase the representativeness of the water quality samples.

The sampler intake strainer (perforated stainless-steel sample head attached to the 3/8-inch internal diameter sample tubing) was installed in the custom-made sampling tray positioned below the inlet grate in each catch basin (see Figures 12 through 14) and pumped water to a 20-liter square (L) polyethylene (poly) composite bottle in the sampler base.

Figure 16. Cabinet containing sampler (yellow) and data logger enclosure (white)

3.2.7.3 Precipitation Monitoring Equipment

A project-specific tipping bucket rain gage (Hydrological Services model TB03) was installed at monitoring station SS5 (shown on Figure 9) and is identified as RG-SS5. This rain gage provided localized rain data for the four project monitoring sites and enabled controlling the water sampling equipment by ending sampling activities when rainfall has ceased for a six-hour period. This rain gage was maintained by Herrera Environmental Consultants (Herrera).

4 SAMPLING AND MONITORING PROCEDURES

Herrera, under contract with the City, performed all equipment fabrication and installation, weather tracking, flow and precipitation monitoring, and stormwater sampling activities for this project. Analytical Resources Inc. (ARI) of Tukwila, WA performed all the sampling processing and laboratory analysis for the duration of this study, except for modified suspended solids concentration (SSC) analyses, which were performed by ARI and then subcontracted to Materials Testing & Consulting, Inc. (MTC) of Tukwila, WA beginning with samples collected on March 14, 2015.

4.1 Qualifying Event Criteria

This study was designed to mimic the 2011 Technology Assessment Protocol - Ecology (TAPE) (Ecology 2011) procedures as much as possible with the understanding that TAPE was established to test/approve structural best management practices (BMPs) which have an inlet and outlet, have design flow rates, internal bypasses, etc.; not activities such as street sweeping.

The TAPE protocol defines "representative" storms that must be monitored when ascertaining performance of structural BMPs. Storm event criteria are established to: 1) provide that adequate flow will be discharged; 2) allow some build-up of pollutants during the dry weather intervals; and 3) sample a storm that will be "representative" (i.e., typical for the area in terms of intensity, depth, and duration).

Collection of samples during a storm event meeting these criteria provides that the resulting data will portray the most common conditions for each site. Ensuring a representative sample requires two considerations: 1) the storm event must be representative of typical regional rainfall, and 2) the sample collected must represent the runoff of that storm event.

Table 6 lists the qualifying storm event criteria:

Table 6. Qualifying storm event criteria

Criteria	Requirements
Minimum storm depth	A minimum of 0.15 inches of precipitation over a 24-hour period
Minimum storm duration	Target storms must have a duration of at least one hour
Antecedent dry period	A period of at least 6 hours preceding the event with less than 0.04 inches of precipitation.
Post-storm dry period	A continuous 6-hour period with less than 0.04 inches of precipitation.

Table 7 lists the qualifying composite sample criteria.

Table 7. Qualifying composite sample collection criteria

Storm event duration	<24 hours	>24 hours
Minimum storm volume sampled	75 percent of the storm event hydrograph	75 percent of the hydrograph of the first 24 hours of the storm
Minimum aliquot number	At least 10 flow-weighted sub-samples (aliquots) must be collected during the duration of the event. If fewer than 10, but 7 or more aliquots are collected, then the sample will be considered valid only if all other sampling criteria have been met.	
Maximum time period for sample collection (hours)	36	

Weather and rainfall data were continuously monitored using multiple forecasting, radar and satellite sources to target storms that meet the criteria for a qualifying event, listed above.

4.2 Flow Monitoring Procedures

Flow monitoring equipment type and configuration per each station are described in Section 3.2.7.1. Refer to Appendix A for a complete discussion of flow monitoring procedures.

4.3 Precipitation Monitoring Procedures

The project rain gage (RG-SS5) is described in Section 3.2.7.3. Refer to Appendix A for a complete discussion of precipitation monitoring procedures.

4.4 Stormwater Grab Sampling Procedures

Grab samples were collected by removing the inlet grate and filling bottles directly from stormwater runoff entering the catch basin structure (Figure 17). Ideally, all grab samples were collected between the first and last volume-proportional composite sample aliquot at each site. However, if the rain/runoff ended before the field crew could be present to collect the grab sample; a makeup round of grab samples was collected for the missed event during another event that met the storm criteria. Grab samples from each of the four locations were always collected during the same storm event so they would represent the same antecedent and loading conditions (i.e., to maintain symmetry and comparability).

4.5 Stormwater Composite Sampling Procedures

Volume-proportioned stormwater composite samples were collected using Manning Environmental VST3 automatic samplers. The samplers utilize a vacuum pump to draw stormwater from the strainer (a perforated stainless-steel sample head affixed to the end of the 3/8-inch internal diameter sampler tube) installed in the sampling tray and distribute it to a 20 L polyethylene (poly) composite bottle in the sampler base.

Figure 17. Collecting stormwater grab samples

The data loggers were programmed to trigger the samplers every time a specified volume (referred to as the "trigger volume") was measured passing through the weir box, creating a volume-weighted composite. The trigger volume was determined by past rainfall to runoff relationships and the predicted rainfall amount for each storm. Each trigger resulted in the collection of one stormwater aliquot (or subsample) collected by each sampler which deposited into the 20L composite bottle. Each aliquot was 200 mL so the composite bottle could receive 100 aliquots before becoming full.

Flows and sample collection times were monitored remotely using the telemetry systems associated with each data logger. Field crews were mobilized to each site during the event if it appeared that the composite bottle was at risk of filling, and bottles were removed and replaced as needed.

4.6 Sample Processing Procedures

Since stormwater samples, specifically stormwater solids concentrations and related contaminants, can be readily biased without proper processing procedures; all composite samples were composited and split in the project analytical laboratory (ARI) using 22-liter (L) polyethylene churn splitters for all events. The churn splitter keeps solids suspended and the sample mixed as the composite sample is split and deposited into analyte-specific containers.

Figure 18. Compositing/splitting samples with churn splitter

4.7 Decontamination Procedures

All water quality sampling equipment was initially decontaminated using the following procedure:

1. Wash in a solution of laboratory-grade, non-phosphate soap and tap (city) water.
2. Rinse in tap water.
3. Wash in a 10 percent nitric acid/deionized water solution.
4. Rinse in deionized water.
5. Final rinse in deionized water.

Sampling and sample processing equipment was decontaminated prior to every use with the exception of the sampler tubing. Following the initial wash, the sampler tubing and the sampling tray were rinsed with deionized water immediately prior to each sampling event. This is consistent with Ecology's *Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring – ECY002*, dated September 16, 2009.

4.8 Monitoring and Sampling Quality Assurance/Quality Control (QA/QC) Procedures

4.8.1 Flow Monitoring QA/QC Procedures

Refer to Appendix A for a complete discussion of flow monitoring QA/QC procedures and an evaluation of the quality of flow data collected for this project.

4.8.2 Precipitation Monitoring QA/QC Procedures

Refer to Appendix A for a complete discussion of precipitation monitoring QA/QC procedures and an evaluation of the quality of precipitation data collected for this project.

4.8.3 Field QC Sample Collection Procedures

Field QC samples were collected to evaluate the sampling operation and to quantify and document bias that can occur in the field due to sampling equipment contamination. QC samples provide the ability to assess the quality of the data produced by field sampling and a means for quantifying sampling bias.

The following table lists the types of QC samples collected, description of how the QC samples were collected, the purpose and information provided by each sample, and the number of QC samples collected over the duration of this two-year project.

Table 8. QC sample summary

QC Sample Type	Code	Description	Purpose/Info Provided	Number Collected Year 1 2014-2015	Number Collected Year 2 2015-2016	Collected on
Field Equipment Blank Sample	FEB	Blank water passed through decontaminated or new equipment	Tests cleaning procedures or cleanliness of sampling and processing equipment	6	8	Sampler tubing (at each station) and composite bottle/splitting equipment (churn splitters)
Field Split Samples	FSS	Primary Environmental Sample (PES) split in lab by field staff	Quantify variability from laboratory procedures	4	4	Stormwater composite samples

The field equipment blanks were made by field staff passing reagent grade deionized (DI) water over or through decontaminated sample equipment and capturing the blank water in analyte-specific bottles.

The sampler tubing was not fully decontaminated between events but rinsed with DI water (consistent with Ecology's *Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring – ECY002*, dated September 16, 2009) prior to sample or blank collection. However, after the first round of Year 2 blanks were collected in September 2015 which contained low concentrations of some parameters, all tubing was replaced and the samplers and new tubing was fully decontaminated with the solutions listed in Section 4.7. Immediately following these actions, a second round of Year 2 blanks were collected.

One combination churn splitter blank and composite bottle blank ("Churn_Bottle") was made by filling one 20L poly composite bottle with reagent grade DI water, letting it sit for 30 minutes and then pouring the DI water into the churn splitter. Analyte-specific bottles were filled while churning following the same process used for compositing/splitting stormwater samples.

The field split samples were generated in the laboratory by field staff by filling two identical analyte-specific containers simultaneously from the churn splitter. A total of eight split samples were collected over the duration of the project, a set of four per each year.

See Appendix B for a complete discussion of field QC sample results, corrective actions taken, and data flagging resulting from an evaluation of the field QC samples.

4.9 QA/QC Procedures and Analytical Methods and Reporting Limits

4.9.1 Analytical Data QA/QC Procedures

See Section B1 of Appendix B for a complete discussion of analytical data QA/QC procedures.

4.9.2 Analytical Methods and Reporting Limits

See Section B2 of Appendix B for a complete discussion of analytical data QA/QC procedures.

5 Sampling Events and Analytical Data

The following sections present a summary of the precipitation that occurred, storm events sampled, and the stormwater analytical data for this project.

5.1 Sampling Summary

5.1.1 Stormwater Sampling Events

Monitoring and sample collection for this project began in October 2014 with four storm events, identified as SE01 to SE04, sampled prior to the end of calendar year 2014. Year 1 sampling continued from SE05 on January 15, 2015 through SE10 on July 25, 2015. Sweeping was discontinued at the Impact sites (SS3 and SS4) after the last sweeping on July 22, 2015 and no sampling was attempted for approximately three months to allow for street dirt accumulation and equilibration at the Impact sites between Before (Year 1) and After (Year 2) conditions. Year 2 sampling began with SE11 on October 10, 2015 and ended with SE24 on September 2, 2016, which was the final event sampled for this project.

The project goal was to sample 12 events annually beginning in October and ending the following September for two years. Because Year 1 was unusually dry, only 10 events were sampled during the first year. Fourteen events were sampled in Year 2 to achieve the project goal of 24 events at each of the four sites. Precipitation, flow, and sample information for each event sampled are presented in a tabular form in Appendix C, Table C1.

Efforts were made to collect grab samples during the composite sample period, but if the rain ended before field crews could collect grabs, a makeup round of grab samples at the four sites were collected during another event that met all storm criteria. For this study, it was not essential that grabs and composite samples were collected within the same events, but it is considered critical that all composites for each event were collected within the same storm to maintain symmetry and comparability. All grabs for each event were also collected within the same storm event even if the storm events when the grabs and composites were on different dates. The storm event identification (e.g., SExx) applies to the dates and times that the composite sample was collected. Grab samples that were collected outside the composite sample period for events: SE03, SE05, SE07, SE10, SE11, SE14, SE19, and SE22. The following lists the actual dates the grabs samples were collected for these events:

SE03 - composites collected on 12/6/2014, grabs collected on 10/22/2014
SE05 - composites collected on 1/15/2015, grabs collected on 2/5/2015

SE07 - composites collected on 2/9/2015, grabs collected on 3/14/2015
SE10 - composites collected on 7/26/2014, grabs collected on 4/13/2015
SE11 - composites collected on 10/10/2015, grabs collected on 12/3/2015
SE14 - composites collected on 11/8/2015, grabs collected on 12/7/2015
SE19 - composites collected on 1/16/2016, grabs collected on 12/8/2015
SE22 - composites collected on 3/23/2016, grabs collected on 1/27/2016
SE24 – composites collected on 9/2/2016, grabs collected on 3/9/2016

Appendix D presents an Individual Storm Report (ISR) for each event sampled. The ISRs contain a hydrograph for each composite sample event which presents flow, rain, and aliquot information graphically in addition to repeating the tabular information presented above.

5.1.2 Sampling Event Timing Relative to Sweeping

With limited exceptions, the roadway in the project area was swept on a weekly basis, between the times of 8:00 PM and 6:30 AM. Storm events were sampled randomly when an event meeting qualifying event was forecasted. The following table presents the days since each sweeping event based on data tracked by the AVL system installed on each vehicle.

Table 9. Days since sweeping per event sampled.

	Days Since Sweeping	
Sampling Date	Swept sites	Unswept sites
10/25/2014	4	NA
11/21/2014	2	NA
12/6/2014	3	NA
12/9/2014	6	NA
1/15/2015	1	NA
2/5/2015	8	NA
2/8/2015	11	NA
3/13/2015	2	NA
5/13/2015	0	NA
7/26/2015	4	NA
10/10/2015	3	80
10/25/2015	4	95
10/30/2015	2	100
11/7/2015	3	108

	Days Since Sweeping	
Sampling Date	Swept sites	Unswept sites
11/12/2015	8	113
11/16/2015	3	117
12/1/2015	6	132
12/17/2015	1	148
1/16/2016	0	178
1/20/2016	0	182
2/29/2016	5	222
3/23/2016	0	245
7/8/2016	0	352
9/1/2016	2	407

NA – not applicable. All sites were swept during first year of study. Sweeping stopped at unswept sites on July 22, 2015.

Of the 24 events sampled, three occurred more than seven days after sweeping with 11 days being the largest period between sweeping and sampling for sites under swept conditions. For perspective, the first storm sampled at the unswept sites (SS3, SS4 during Year 2) was 80 days following the last time swept and the last event was sampled 407 days after the last time swept.

5.1.3 Field QC Sample Events

The QC samples collected during the study are summarized in Table 8. See Section B4 of Appendix B for a discussion of Field QC results.

5.1.4 Stormwater Analytical Data Summary

All stormwater sample analytical results including qualifiers collected are presented in Tables C2 to C5 in Appendix C.

6 Data Analysis Methods and Results

The following sections summarize the methods used to evaluate study data and the results of the analysis. The statistical analysis described in this report was performed by Geosyntec Consultants (Geosyntec). Appendix E contains the memorandum prepared by Geosyntec which describes the complete statistical methods and analysis results. The sections below summarize information detailed in that memo.

6.1 Statistical Analysis

6.1.1 Statistical Analysis Methods Discussion

In the approved QAPP (SPU 2014), the statistical method proposed for this study was the Analysis of Variation (ANOVA). During the preliminary data analysis phase, it was determined that the ANOVA method: 1) was not the best method for controlling for the variability of the stormwater analytical data; 2) does not have a way to quantify the magnitude of the impact (stopping sweeping).

SPU hired Geosyntec to review the study design, implementation, data collected, and propose an alternative method to analyze and interpret the results. Geosyntec determined that both the study design and implementation meet the goal of the study. After some data exploration and preliminary analysis, Geosyntec proposed using the Analysis of Covariation (ANCOVA) method. The ANCOVA method is considered to do a better job of controlling for stormwater concentration variability between events and can also quantify the magnitude (e.g., percent change) of the impact of stopping sweeping. Appendix E contains a discussion of the ANOVA versus ANCOVA methods. SPU requested permission to switch to the ANCOVA method and Ecology approved this request via email on July 18, 2017.

6.1.2 Data Preparation and Processing

Prior to the data analysis, Geosyntec prepared and processed the data. The following is a list of the water quality parameters evaluated:

- Chemical Oxygen Demand
- Dissolved Copper
- Total Copper
- Particulate Copper
- Fecal Coliform
- Nitrate + Nitrite
- Total Kjeldahl Nitrogen
- Sediment Conc. 62.5 to 3.9 um
- Sediment Conc. 250 to 62.5 um
- Sediment Conc. 500 to 250 um
- Sediment Conc. > 500
- Sediment Conc. Total
- Total Suspended Solids
- Total Organic Carbon

- Total Phosphorus
- Fluoranthene
- Pyrene
- Sediment Conc. < 3.9 um
- Dissolved Zinc
- Total Zinc
- Particulate Zinc

The following parameters were not evaluated because these parameters are not typically stormwater pollutants of concern, would not likely be affected by street sweeping, and/or have a high percentage of non-detect results (i.e, most PAHs).

- Calcium
- Hardness
- Magnesium
- pH
- Remaining PAHs (other than fluoranthene and pyrene)

Data preparation included removing certain sediment concentration data points that were believed to be of inadequate quality. Removed data values were only for sediment concentration fractions < 3.9 um and 3.9 to 62.5 um for all sites for event SE-07, and values for the 3.9 to 62.5 um size fraction were removed for events SE-01, -02, -03, and -04. These values were reported as mostly below detection limits but are believed to have been biased by the laboratory measurement methods. The decision to keep or exclude data applied to all sites for a given storm event to maintain symmetry and comparability. Removed data were entirely within the 2014/2015 monitoring season (Year 1).

Data processing included combining hydrologic and water quality datasets into a combined data structure, grouping data by sampling events, grouping data by control and impact sites, calculating particulate metals concentration (difference between total and dissolved concentrations), calculating normalized event loads, and other steps.

Next, data were inspected to determine and remove likely outliers. A data point was considered a likely outlier if it was more than two standard deviations away from the average of the overall dataset, based on an assumed log-normal distribution. Several data points were identified as potential outliers, but only a single point was considered a likely outlier. The point in question occurred during Event SE-10 on April 13, 2015 at site SS4. The fecal coliform count in this sample (580,000 cfu/100ml) exceeded two standard deviations of the dataset and was more than an order of magnitude greater than the next highest value (20,000 cfu/100ml) so was removed from the data set.

The Wilcoxon Signed Rank Test was then used to evaluate similarity between sites within years. The Wilcoxon Signed Rank Test is a non-parametric version of the paired t-test that is used to

test the null hypothesis that two related paired samples come from the same distribution. Data collected at different sites during the same storm event are considered “paired” for this test. An alpha significance value of 0.1 was used to interpret p-values resulting from this test.
Within each year, there are six comparisons between sites that are meaningful (SS2:SS3, SS2:SS4, SS2:SS5, SS3:SS4, SS3:SS5, SS4:SS5). These comparisons were used to inform whether the control and impact sites pooled (combined via an arithmetic average for a given storm) or individual sites data should be discarded for some parameters.

The overall purpose of this step was to determine whether it is appropriate to pool the data from control and impact sites for analysis, or whether it would be appropriate to discard one of the control or impact sites due to lack of similarity. The results of this step were that the two control sites (SS2 and SS5) were pooled for all parameters. Data from these sites are overwhelmingly similar. For the impact sites (SS3 and SS4), the comparison between sites differs by parameter. The before-after/control-impact study design is intended to help control for natural variability between sites. Therefore, pooling is generally considered appropriate even if sites are different. In cases where SS4 showed lack of similarity to the impact sites during Year 1 and lack of similarity to SS3 during Year 1 and Year 2, then it was also appropriate to evaluate SS3 as an individual impact site rather than pooling. See Appendix E for the results of Wilcoxon Signed Rank Tests and decisions about which impact dataset(s) were used.

Following the procedures discussed above, an ANCOVA analysis was conducted following procedures and assumptions similar to Selbig (2016) and as described by Helsel and Hirsch (2002). The analysis was based on pooled control vs. pooled impact for all parameters. This analysis was also conducted for pooled control vs. SS3 for certain parameters, as identified in Table 4 in Appendix E.

A summary of the ANCOVA results are presented in the next section. The graphical representation of the ANCOVA results (scatter plots with linear regression lines) are presented in Attachment 3 of Appendix E.

6.2 Analysis Results

Note on results reporting: The study tested what is the impact to stormwater quality after stopping sweeping. For readability, results in the body of the report are presented as reductions attributed to <u>*to*</u> *sweeping. In Appendix E, results are also presented as increases attributed to* <u>*not*</u> *sweeping.*

The primary analysis method (ANCOVA) detected statistically-significant change (at a p-value of 0.1) in runoff concentrations from swept versus unswept streets for the following parameters:

Table 10. ANCOVA Results (p<=0.1)

Parameter	p value	Reduction in Concentration Attributable to Sweeping *
Copper, Particulate	0.09	17%
Sediment Concentration > 500 um	0.09	64%
Sediment Concentration 500 to 250 um	0.10	48%
Sediment Concentration < 3.9 um	0.002	-133%

* – Positive values suggest that concentrations were reduced because of sweeping

The changes detected for particulate copper (17 percent concentration reduction) and the two coarsest sediment size fractions (>500 microns (um) and 500 to 250 um; 64 and 48 percent concentration reductions, respectively) were positive, inferring that street sweeping reduces the concentrations of these parameters in stormwater runoff. The change detected for the finest sediment size fraction (<3.9 um, clay/colloidal range) was negative, inferring that street sweeping may increase the concentration of the finest particles in stormwater runoff, with the assumption that sweepers may mobilize the finest size fractions. However, it is important to note that this smallest sediment size fraction amounts to only 2-5 percent of the total sediment mass measured in stormwater.

The following parameters exhibited change but with lower confidence (p-value between 0.1 and 0.3[3]):

Table 11. ANCOVA Results (p between 0.1-0.3)

Parameter	p value	Reduction in Concentration Attributable to Sweeping *
Copper, Total	0.13	14%
Total Sediment Concentration	0.22	29%
Total Suspended Solids	0.29	24%
Zinc, Particulate	0.17	18%
Zinc, Total	0.17	15%
Nitrate + Nitrite	0.21	-28%

* – Positive values suggest that concentrations were reduced because of sweeping

When increasing the p value to 0.3, street sweeping may likely to be effective at reducing total copper concentration (14 percent concentration reduction), total sediment concentration (the summed total of all the sediment size fractions, 29 percent concentration reduction), total suspended solids (24 percent concentration reduction), and total and particulate zinc (15 and 18

[3] When evaluating environmental data, a p-value of 0.1 is typically the highest cutoff for statistical significance. Due to the problems of variability and small sample size in this study, parameters with p-values between 0.1 and 0.3 are presented to suggest parameters that may be impacted by street sweeping if a larger data set was available.

percent concentration reduction, respectively). The change measured for nitrate + nitrite was negative, inferring that street sweeping may increase the concentration of this parameter.

No significant differences were detected for all other monitored parameters which included dissolved metals (zinc and copper), nutrients (total phosphorus and TKN), fecal coliform bacteria, COD, TOC, and PAHs.

It is assumed that this study did not accurately quantify the nutrient load removed by sweeping in the form of leaf mass during the fall and early winter season since the autosamplers utilized are unable to sample leaves or other coarse organic material due to the limited diameter of the autosampler tubing.

7 CONCLUSIONS

Beginning with the 1983 Nationwide Urban Runoff Program (NURP) study report (EPA 1983) that concluded that street sweeping does not significantly reduce stormwater pollutant concentrations, the role of street sweeping as a stormwater BMP has been questioned. The limited studies that have been performed since then have been inconsistent relative to scale, sweeper technology studied, scientific rigor, and the control the study designs have used in trying to reduce confounding factors.

There are no established study designs for evaluating the effectiveness of street sweeping on stormwater runoff and quantifying pollutant reductions from street sweeping is a challenging monitoring exercise. Also, street sweeping is an activity with no standards regarding frequency, equipment speed, and the technology utilized varies and is being continuously improved. For these reasons, results from street sweeping studies are not as transferrable as studies of other stormwater BMPs.

SPU created a two-year study to attempt to limit confounding factors such as run-on from unswept streets and mitigate sampling bias to the extent possible with commercially available monitoring equipment. This study represented real-world conditions on a Seattle arterial using a modern fleet of regenerative air street sweepers operated in the same manner Seattle sweeps all its arterials. This study was implemented successfully with no sampling, weather, or sweeper operation anomalies experienced during this two-year study.

This study detected statistically-significant change (at a p-value of 0.1) and reduction in runoff concentrations from swept versus unswept streets for particulate copper, suspended sediment greater than 500 microns, and suspended sediment in the 250 to 500 micron range. A significant change was also detected for suspended sediment less than 3.9 microns, but that change was negative.

When considering p-values up to 0.3 as an indication of other parameters that may be significantly impacted by sweeping if a larger data set was available: total copper, total suspended sediment, total suspended solids, particulate zinc, and total zinc concentrations were reduced, and nitrate + nitrite concentrations were increased.

No significant differences were detected for the other monitored parameters which included dissolved metals (zinc and copper), nutrients (total phosphorus and TKN), COD, TOC, and PAHs. Due to extreme variability, fecal coliform bacteria data could not be tested.

Using the primary analysis method (ANCOVA), this study detected significant (p value <= 0.1) and lower confidence reductions (p-value between 0.1 and 0.3) attributed to street sweeping for approximately half of the parameters measured. The large variability in stormwater concentrations measured is considered to have masked the entire impact of sweeping on stormwater pollutant reductions.

This study indicates that street sweeping is an effective stormwater BMP in addition to providing multiple other city-wide benefits not evaluated as part of this study. No changes are recommended to SPU’s current street sweeping program.

8 ACKNOWLEDGEMENTS

Stormwater sampling is very challenging environmental field work due to, among other factors: the difficulties of forecasting weather and targeting storms; operating and maintaining automatic sampling equipment continuously within elements of a drainage system; working in traffic and confined spaces at irregular hours in inclement weather, etc. Data in reports such as this are presented in a matter-of-fact style which typically does not acknowledge that sampling and laboratory personnel are constantly required to rearrange their work and personal schedules to prioritize capturing and analyzing stormwater samples. The data analysis phase of this project also presented challenges.

Over the duration of this project, the project team continued with the successfully implementation of this study. Many dedicated scientists collaborated effectively to implement and complete this study. The City acknowledges the dedication of the following staff:

Herrera Environmental Consultants – field sampling and monitoring staff, statistical analysis
Dylan Ahearn - field project manager, flow and precipitation data steward and validator, Hydrologic Data QA/QC report author
Dylan Ahearn, Kristen Matsumura, John Lenth – preliminary statistical analysis
Dan Bennett, Jeremy Bunn, Alex Svendsen, George Iftner - field sampling staff

Geosyntec Consultants – study peer review and statistical analysis
Aaron Poresky, Lucas Nguyen, Marc Leisenring – data analysis and intrepretation

Analytical Resources, Inc. – primary project analytical laboratory
Mark Harris – laboratory project manager
ARI chemists – chemical analysis

Seattle Public Utilities
Doug Hutchinson - principal investigator, study manager, report author
Rex Davis - SDOT sweeper oversight, assistant study manager
Shelly Basketfield – SS4WQ Program Manager, study and report reviewer
Jennifer Arthur - chemistry data steward and validator

Seattle Department of Transportation
Seang Ngy – primary street sweeper operator for MLK Jr. Way S route

9 REFERENCES

EPA (1983). *Results of the Nationwide Urban Runoff Program.* Water Planning Division, U.S. Environmental Protection Agency, Washington, D.C., dated December 1983

Helsel, D.R. and Hirsch, R.M. (2002). *Statistical Methods in Water Resources*. U.S. Geological Survey, Techniques of Water-Resources Investigations Book 4, Chapter A3. Water Resources Division, USGS. Reston, VA

Pacific Water Resources, Inc. (2008). *Recent Street Sweeping Pilot Studies are Flawed*. Roger C. Sutherland, dated October 15, 2008.

Selbig, WR. (2016). *Evaluation of leaf removal as a means to reduce nutrient concentrations and loads in urban stormwater*. U.S. Geological Survey – Wisconsin Water Science Center, 8505 Research Way, Middleton, WI 53562, USA. July 2016.

SPU (2009). *Seattle Street Sweeping Pilot Study Monitoring Report.* SPU and Herrera. April 22, 2009.

SPU (2014). *Street Sweeping Water Quality Effectiveness Quality Assurance Project Plan.* Dated September 22, 2014.

SPU (2015). *Effectiveness Study Interim Results and Status Report*, dated March 2, 2015

SPU (2016). *Effectiveness Study Interim Results and Status Report*, dated March 8, 2016

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Appendix A Hydrologic Monitoring Quality Assurance/Quality Control Report

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This Hydrologic Monitoring Quality Assurance/Quality Control (QA/QC) report documents results of the QA/QC review of time series level, flow, and precipitation data generated for the Street Sweeping Water Quality Effectiveness study. The following discussion includes QA/QC practices and an assessment of data quality. This QA/QC report discusses data collected from October 2014 through September 2016.

A1. Monitoring Locations

Detailed descriptions and figures of the monitoring equipment and monitored locations for this project are included in the body of the report. The four monitoring locations for this project are listed in Table A1 and are described briefly below. Refer to Section 3.2.7 of the main report for a complete description of the monitoring equipment.

Herrera Environmental Consultants (Herrera) installed and maintained all the monitoring equipment for this project.

Table A1. Monitoring Location Summary.

Site	Location	Hydrologic Parameters Monitored
SS2	4051 M.L. King Way Jr St	Level, Flow
SS3	2961 S Dakota (on M.L. King Way Jr St)	Level, Flow
SS4	4118 M.L. King Way Jr St	Level, Flow
SS5	4925 M.L. King Way Jr St (approximate)	Level, Flow, Precipitation

The level and flow monitoring locations for this project consisted of four storm drain inlets which drain into an underlying catch basin. Custom baffled weir boxes were constructed with an integrated 8-inch-diameter Thel-Mar weir to measure the discharge rate of the stormwater flowing into each catch basin (Figure A1). A submersible pressure transducer (Campbell Scientific CS450-L, 0 to 2.9 psi) level sensor was installed in a stilling well upstream of each weir to measure water levels above the weir crest. Flow was routed into the weir boxes via a custom-built sampling tray which fit under the inlet grate and captured all flow entering each inlet (Figure A2). Level measurements were converted to flow values based on a weir equation provided by the weir manufacturer.

A project rain gauge (Isco 674 with an 8-inch catch) was installed inlet in the planting strip adjacent to the monitoring station SS5 and is identified as RG-SS5.

The following sections present a quality assurance review of data collected from these monitoring locations. These data were assessed for the following data quality indicators: bias, completeness, representativeness, and comparability. Where applicable, the data are compared to specific Measurement Quality Objectives (MQOs) for each data quality indicator that was identified in the project Quality Assurance Project Plan (QAPP) (SPU 2014).

Figure A1. Flow Metering Weir Box (without sampling tray).

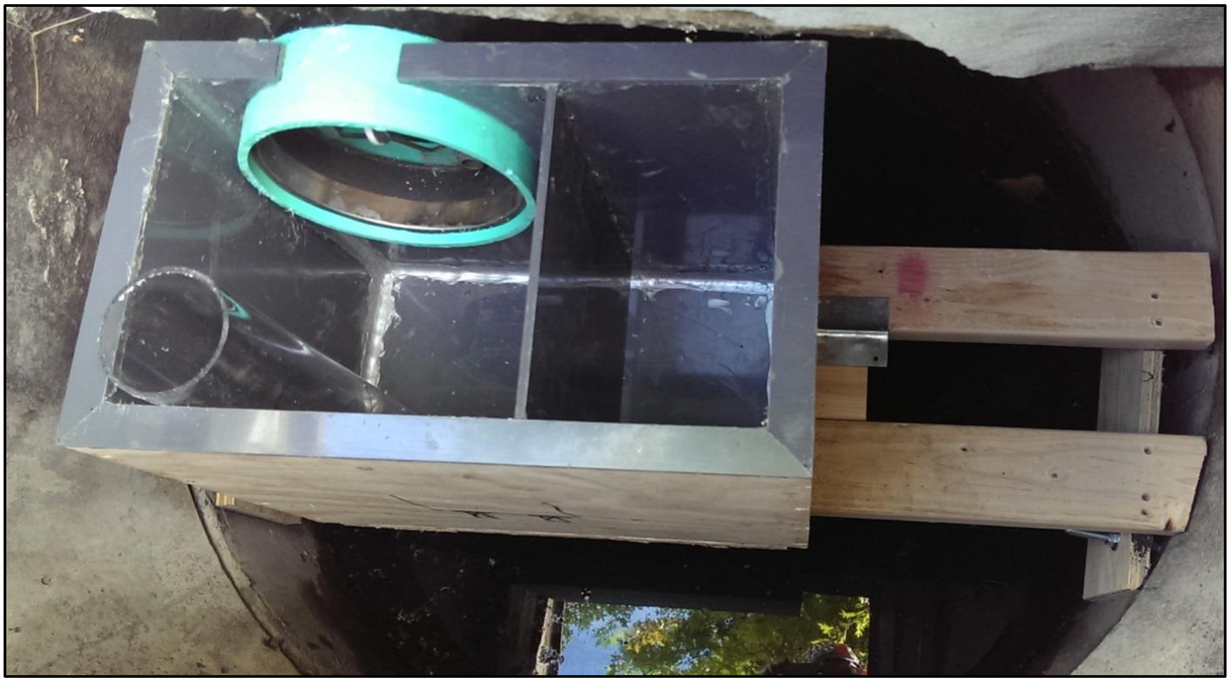

Figure A2. Sampling Tray Installed in Inlet (inlet grate removed).

A2. Flow Monitoring Procedures

Level and flow data were automatically downloaded on a 5-minute basis via wireless telemetry. On a weekly basis, Herrera inspected the data for any significant trends in reliability and/or accuracy (i.e., substantial level jump/drop, upward or downward drift, spikes, flat-line data, or data gaps). If anomalies were observed, a field crew was deployed to troubleshoot and calibrate the sensors.

Routine flow monitoring maintenance visits were performed at a minimum of once per month, prior to every storm event, or as needed based on remote real-time monitor checks or data reviews. During these visits, sensors were adjusted to exact level by topping off the Thel-Mar weirs by adding water and zeroing the transducers for the sensors. As part of the calibration procedure, level values before and after each calibration were recorded. If the before and after values differed by more than 0.02 feet (0.02 feet is less than 1 percent of the full 2.31-foot sensor range), the data were corrected for the level drift during post-processing data editing. The difference between these values was also tracked over time to assess long-term drift. Long-term drift was used to indicate when to replace the level sensors.

Raw level data and rain data were transferred into Herrera's AQUARIUS® time-series database for review and editing. Based on the before and after values recorded during each maintenance visit and rain data, level data were edited using proportional, fixed offset, or constant value correction tools. Finalized level data were converted to flow rates using custom level-to-flow equations generated for each weir based on rating tables provided by the weir manufacturer. Only edited/finalized data are used for calculations and presented in this report.

A3. Flow Data Quality Discussion

The following sections present a quality assurance review of the hydrologic data. These data were assessed for the following data quality indicators: bias, completeness, representativeness, and comparability. Where applicable, these data were compared to specific Measurement Quality Objectives (MQOs) for each data quality indicator that were in identified in the QAPP for the project (SPU 2014).

A3.1 Bias

Bias can be introduced into level, flow, and precipitation data by:

- Sensor drift and displacement (or a non-level tipping bucket)
- Sensor non-linearity
- Inaccurate rating equations (or a miscalibrated tipping bucket)
- Debris clogging the primary device (or rain gauge funnel)
- Flows exceeding the measurement range of the primary device

These sources of bias are assessed below.

A3.1.1 Sensor Drift and Displacement

Before each targeted event, the level sensors were calibrated. This resulted in more than 30 calibrations per sensor over the course of the 2-year study. During each calibration, pre- and post-calibration level measurements were recorded. Figures A3a through A3d present the control charts used to track the difference between actual versus recorded level during the calibration visits.

Each control chart contains a warning limit (one standard deviation from the mean) and a control limit (two standard deviations from the mean). The amount the actual level varies from the level recorded by the level sensor is called the drift. Sensor level drift was generally within the warning limit, with before and after calibration values averaging around +/-0.02 feet (which is less than 1 percent of the full span sensor range of 2.31 feet). Leaf clogs in the weirs and in the stilling wells were a perennial issue during the study (this is discussed in more detail below). The calibrations that fell outside the control and warning limits were likely not due to sensor internal drift as much as burial in leaf debris.

During the course of the study, the rain gauge level was checked on five occasions. On each occasion it was found to be level.

Figure A3a. Control Chart for SS2 Level Calibrations.

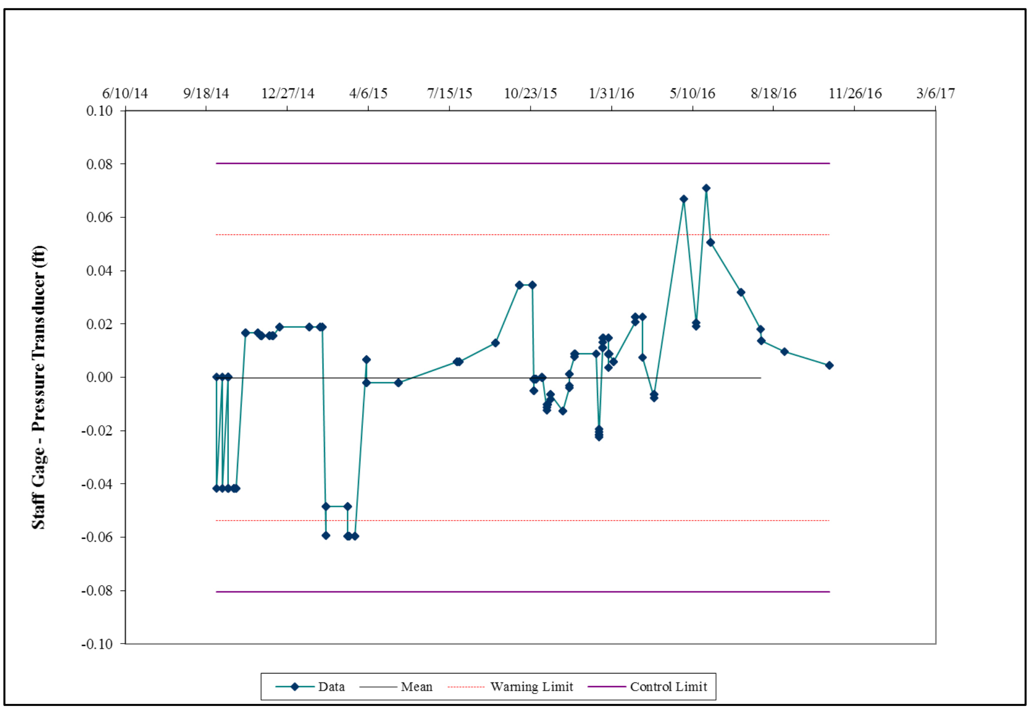

Figure A3b. Control Chart for SS3 Level Calibrations.

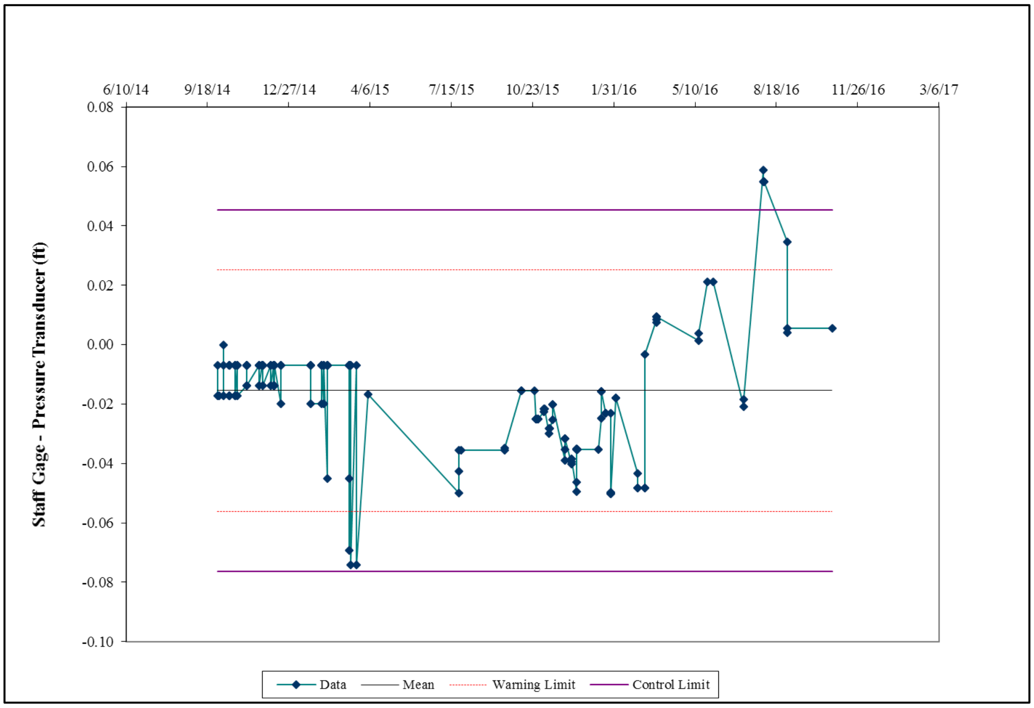

Figure A3b. Control Chart for SS4 Level Calibrations.

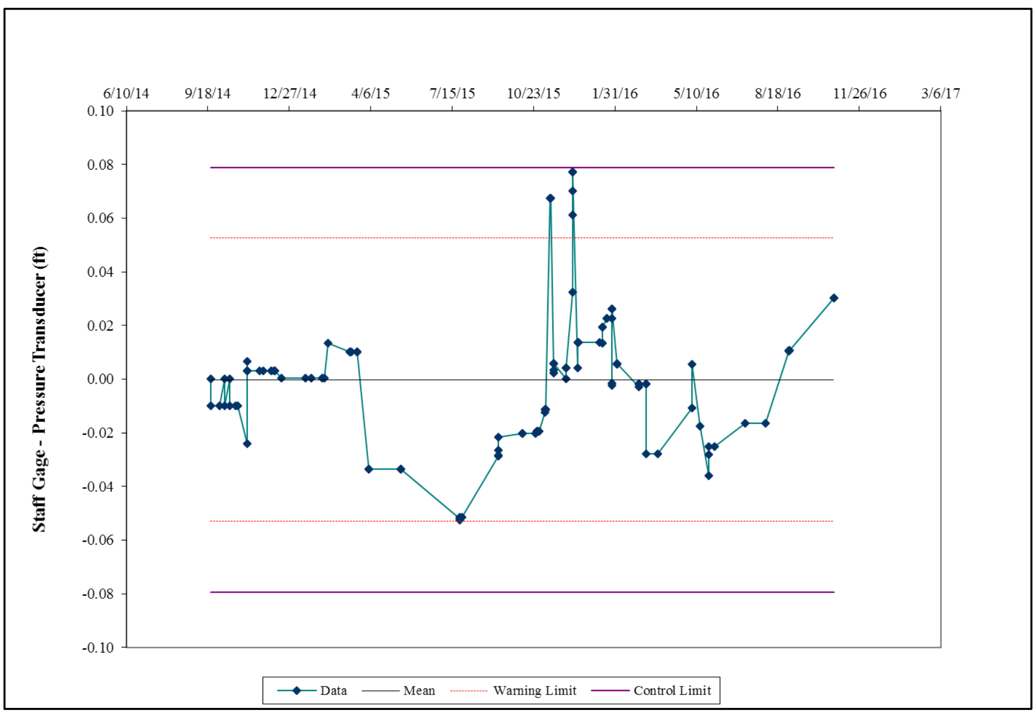

Figure A3d. Control Chart for SS5 Level Calibrations.

A3.2 Sensor Non-Linearity Bias

Linearity in a level sensor is defined by the relationship between increased water level and the corresponding increase in the measured reading. This relationship should be consistent and linear such that when the water level is raised by 0.1 foot the sensor reading increases by 0.1 foot. Ideally, this relationship is consistent through the measurement range (i.e., lowest to highest recorded depths) observed during the study period.

In September 2014 before the level sensors were installed, the linearity was checked by submersing the sensors in a graduated cylinder and then raising the water level by one inch and recording the resultant rise in water level reported by the sensor. This was repeated four times in a depth of water equivalent to what was encountered in the field (~8 to 12 inches). In April 2016, it became apparent that the SS2 sensor was drifting between events. The sensor was replaced with a new sensor on one occasion in April and an additional time in July. The results from the bias testing of all of these sensors is presented in Table A2. The percentage of error was all below 1 percent and met the goal defined in the QAPP. After replacing the sensors, it became apparent that the error was not due to the sensor itself but rather from the transducer head becoming buried is debris between events. This is discussed in more detail below.

Table A2. Sensor Level Linearity Bias.

Date	Location	Percent Error
9/2/14	SS2	-0.20
9/2/14	SS3	-0.04
9/2/14	SS4	-0.02
9/2/14	SS5	0.04
4/26/16	SS2 replacement 1	-0.80
7/7/16	SS2 replacement 2	-0.50

Bias in precipitation measurement can come from the tipping bucket being miscalibrated. Each tip is, in theory, equivalent to 0.01 inches of rain. To assess this, on October 1, 2015, a measured quantity of water (between 200 and 300 mL) was metered into the tipping bucket with a burette. The number of tips was recorded and the theoretical volume (assuming 0.01 inches per tip) was compared with the actual measured volume. This process was repeated three times with an overall average error of -0.5 percent, below 1 percent and meeting the goal defined in the QAPP.

A3.3 Level Sensor Precision

In addition to sensor bias, pressure transducers are also susceptible to drift over time. In order to assess sensor drift the sensors were placed in a graduated cylinder, and the top of the cylinder was covered to prevent evaporation. The sensors were then left for approximately 24 hours at room temperature. The data were then downloaded and analyzed to quantify how much drift in the level data occurred over that time period. The results from this analysis are presented in Table A3. The percent error was all below 1 percent and met the goal defined in the QAPP.

Table A3. Sensor Level Drift Bias.

Date	Location	Percent Error
9/2/14	SS2	0.02
9/2/14	SS3	0.08
9/2/14	SS4	0.07
9/2/14	SS5	0.02
4/26/16	SS2 replacement 1	0.04
7/7/16	SS2 replacement 2	0.07

A3.4 Anomalous Data, Data Spikes, or Small Data Gaps

Anomalous data spikes, drops, and small data gaps in the level data at each of the four monitoring stations were corrected using AQUARIUS® (ver. 2.5) software. All raw data were saved alongside corrected data in the project files. Small data gaps (fewer than 60 minutes) were filed using linear interpolation. Data gaps that were too large to fill through linear interpolation were quantified relative to the total flow record to assess the MQO for Completeness (see next section). A record of all edits made to project level data is provided in Attachment A1.

During the study, it became apparent that leaf and debris clogs on the weir crest frequently caused a damming effect which resulted in anomalously high level and related flow measurements, especially during the fall season. In addition, leaves and debris often buried the pressure sensors in the stilling well, which resulted in spurious level data. This source of error was so persistent that it was infeasible to correct all level/flow data to correct for this error. Instead, the weir boxes and weirs were cleaned and the level sensors were calibrated before each targeted event. This resulted in high quality data during the targeted event. However, many of the non-targeted/non-sampled events were affected by the debris accumulation because field crews were not present to clear the debris. Consequently, only the level/flow data for the targeted events are considered accurate. This is considered acceptable and the project goals where not compromised since the main purpose of the flow monitoring equipment was to pace the automatic samplers to generate a flow-proportioned sample.

A4. Completeness

Completeness was assessed based on the occurrence of gaps in the data record for all continuous level and flow data. The MQO for completeness requires that no less than 10 percent of the total data record is missing due to equipment malfunction or other operational problems. There were 5 days of missing data from the SS5 rain gauge, but this data gap was filled with rain data from the nearest City of Seattle rain gauge - RG18. After this correction, the completeness goal was achieved at all the monitoring locations.

A5. Representativeness

Representativeness is the degree to which data accurately and precisely represent the environmental condition of a site. It is difficult to establish quantitative representative criteria for hydrologic data, and there was no MQO listed in the QAPP for this data quality indicator. By using both a project specific raingage installed within the project area, and a flow monitor at each monitoring location, the collected hydrological data represented actual conditions during the two years monitored.

A6. Comparability

Comparability is the confidence with which one data set can be compared to another. Comparability can be related to accuracy and precision, as these quantities are measures of data reliability. Although there is no numeric MQO for this data quality indicator, standard monitoring procedures, units of measurement, and reporting conventions were used in this study to meet the quality indicator of data comparability.

Determining the comparability of recorded or logged flow to "actual" flow rates is difficult and rarely done, especially since flow is a calculated value (for this project, flow is calculated from level data) and typically the accuracy of the primary measurements (level only, for this project) are compared to actual measured values. The project team has flow tested the Thel-Mar weirs used for this project during previous stormwater monitoring projects and have found them to be accurate within +/- 5 percent.

A7. Summary

All hydrologic MQOs identified in the project QAPP were met for the hydrologic data collected for this project. However, due to leaves regularly clogging the weirs and pressure transducers being buried in debris in the weir boxes, much of the flow data collected between sampled events (i.e., data collected several days after an event-specific cleaning and calibration was performed) may have been compromised by debris damming and/or clogging. Therefore, it is recommended that only the flow data for the sampled events should be considered valid; and even then it is not recommended that these flow values be used for pollutant loading calculations. The flow data are deemed of a high enough quality for sampler pacing, but beyond that the overall quality of the flow data is unknown due to the leave clogging and burial issue.

Attachment A1 – Level Data Editing Log

Station	Editing Type	Editing Details	Editing Start	Editing Stop	Editing Applied
SS2	Delete Region	Delete Region	10/22/2014 16:45	10/24/2014 15:30	1/28/2015 12:24
SS2	Offset Correction	Offset Correction with value of 0.03107ft	10/24/2014 15:35	11/5/2014 14:25	1/28/2015 12:48
SS2	Offset Correction	Offset Correction with value of 0.05900ft	10/14/2014 16:05	10/22/2014 16:35	1/28/2015 12:48
SS2	Delete Region	Delete drop/spike	11/5/2014 14:25	11/5/2014 14:40	1/28/2015 12:50
SS2	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	11/5/2014 14:20	11/5/2014 14:45	1/28/2015 12:50
SS2	Copy and Paste	Copy and Paste from Stage.Stage_ft_Avg	1/5/2015 14:55	1/15/2015 10:05	1/28/2015 13:58
SS2	Copy and Paste	Copy and Paste from Stage.Stage_ft_Avg	10/22/2014 16:30	10/24/2014 16:30	1/28/2015 14:00
SS2	Amplification	Amplification Correction -- Simple with start factor of 1.80000 and end factor of 1.80000	1/8/2015 6:40	1/13/2015 15:35	1/28/2015 14:03
SS2	Offset Correction	Offset Correction with value of 0.00800ft	1/8/2015 6:40	1/13/2015 15:35	1/28/2015 14:06
SS2	Amplification	Amplification Correction -- Simple with start factor of 1.40000 and end factor of 1.40000	10/22/2014 16:37	10/24/2014 19:00	1/28/2015 14:08
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2014-10-27 22:30:00 0.00765ft) (2014-11-01 00:00:00 0.01695ft)	10/27/2014 22:30	11/1/2014 0:00	1/28/2015 15:00
SS2	Delete Region	Delete Region	2/7/2015 10:35	2/7/2015 10:50	1/14/2016 12:37
SS2	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	2/7/2015 10:30	2/7/2015 10:55	1/14/2016 12:38
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-01-29 08:10:00 0.00000ft) (2015-02-12 12:15:00 -0.06136ft)	1/29/2015 8:10	2/12/2015 12:15	1/14/2016 12:39
SS2	Offset Correction	Offset Correction with value of 0.07000ft	3/14/2015 10:05	4/3/2015 10:25	1/14/2016 12:42
SS2	Offset Correction	Offset Correction with value of 0.03100ft	5/5/2015 7:05	5/11/2015 11:20	1/14/2016 12:43
SS2	Delete Region	Delete Region - noisy data. no rain during noise	5/28/2015 9:40	7/10/2015 13:30	1/14/2016 12:46
SS2	Fill Data Gaps	Fill Data Gaps (Linear) noisy data	5/28/2015 9:40	7/10/2015 13:30	1/14/2016 12:50
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-10-09 15:55:00 0.00000ft) (2015-10-27 11:40:00 -0.05784ft)	10/9/2015 15:55	10/27/2015 11:40	1/14/2016 13:46
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-12-02 10:05:00 0.00707ft) (2015-12-16 00:10:00 0.01090ft)	12/2/2015 10:05	12/16/2015 0:10	1/14/2016 13:48
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-12-18 23:35:00 0.00000ft) (2016-01-02 08:05:00 -0.01005ft)	12/18/2015 23:35	1/2/2016 8:05	1/14/2016 13:49
SS2	Delete Region	Delete Region - flow test	12/16/2015 7:45	12/16/2015 14:50	1/14/2016 13:50
SS2	Fill Data Gaps	Fill Data Gaps (Linear) - flow test	12/16/2015 7:45	12/16/2015 14:50	1/14/2016 13:50
SS2	Delete Region	Delete Region - offset error	1/15/2016 11:45	1/15/2016 12:05	10/27/2016 11:11
SS2	Fill Data Gaps	Delete Region - calibration error	1/15/2016 11:40	1/15/2016 12:10	10/27/2016 11:11
SS2	Offset Correction	Offset Correction with value of 0.02000ft	1/15/2016 20:55	1/17/2016 6:40	10/27/2016 11:13
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction - Stilling well clogging	1/22/2016 10:55	1/22/2016 21:40	10/27/2016 11:17

Station	Editing Type	Editing Details	Editing Start	Editing Stop	Editing Applied
SS2	Multi-Point Drift Correction	Multi-Point Drift Correction - Stilling well clogging	2/27/2016 6:35	2/28/2016 5:05	10/27/2016 11:19
SS2	Clock Drift Correction	Clock Drift Correction with start offset of 0.000 and end offset of -60.000	6/4/2016 8:55	8/2/2016 4:45	10/27/2016 14:39
SS2	Clock Drift Correction	Clock Drift Correction with start offset of 0.000 and end offset of -60.000	6/2/2016 17:53	7/11/2016 11:15	10/27/2016 14:43
SS2	Clock Drift Correction	Clock Drift Correction with start offset of 0.000 and end offset of 60.000	7/6/2016 23:13	7/9/2016 16:01	10/28/2016 10:24
SS2	Clock Drift Correction	Clock Drift Correction with start offset of 0.000 and end offset of -30.000	7/8/2016 18:58	7/9/2016 6:07	10/28/2016 10:25
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	10/31/2014 12:35	11/2/2014 13:35	1/28/2015 12:56
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	11/2/2014 19:00	11/3/2014 8:35	1/28/2015 12:57
SS3	Recession Curve	Recession curve with recession constant k = 24.99970, offset constant c = 0.00000	11/4/2014 7:50	11/5/2014 13:20	1/28/2015 12:57
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	12/8/2014 5:20	12/8/2014 15:05	1/28/2015 13:02
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	12/9/2014 12:45	12/9/2014 21:10	1/28/2015 13:02
SS3	Recession Curve	Recession curve with recession constant k = 12.00000, offset constant c = 0.00000	12/10/2014 4:00	12/10/2014 7:30	1/28/2015 13:04
SS3	Recession Curve	Recession curve with recession constant k = 15.00000, offset constant c = 0.00000	12/10/2014 8:35	12/10/2014 12:10	1/28/2015 13:08
SS3	Recession Curve	Recession curve with recession constant k = 20.00000, offset constant c = 0.00000	12/10/2014 21:30	12/11/2014 8:15	1/28/2015 13:09
SS3	Recession Curve	Recession curve with recession constant k = 8.00000, offset constant c = 0.00000	12/11/2014 17:25	12/11/2014 21:15	1/28/2015 13:10
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	12/12/2014 1:00	12/16/2014 15:05	1/28/2015 13:11
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	12/16/2014 16:40	12/17/2014 4:05	1/28/2015 13:12
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	12/17/2014 9:35	12/17/2014 19:45	1/28/2015 13:12
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	12/17/2014 6:00	12/17/2014 7:45	1/28/2015 13:13
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	10/25/2014 20:25	10/26/2014 10:25	1/28/2015 13:37
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	10/29/2014 8:15	10/30/2014 7:20	1/28/2015 13:38
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	1/12/2015 1:40	1/15/2015 9:50	1/28/2015 13:51
SS3	Recession Curve	Recession curve with recession constant k = 24.99980, offset constant c = 0.00000	1/16/2015 0:00	1/17/2015 9:00	1/28/2015 13:52
SS3	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	1/5/2015 11:05	1/9/2015 23:10	1/28/2015 13:53
SS3	Recession Curve	Recession curve with recession constant k = 29.97860, offset constant c = 0.00000	1/2/2015 20:05	1/4/2015 0:00	1/28/2015 13:54
SS3	Recession Curve	Recession curve with recession constant k = 30.00000, offset constant c = 0.00000	1/4/2015 3:05	1/4/2015 7:45	1/28/2015 13:55
SS3	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-10-03 00:35:00 -0.00638ft) (2015-10-07 00:50:00 -0.00424ft)	10/3/2015 0:35	10/7/2015 0:50	1/14/2016 14:16
SS3	Delete Region	Delete drop/spike	10/27/2015 13:10	10/27/2015 13:30	1/14/2016 14:17
SS3	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	10/27/2015 13:10	10/27/2015 13:30	1/14/2016 14:18

Station	Editing Type	Editing Details	Editing Start	Editing Stop	Editing Applied
SS3	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-10-17 17:00:00 -0.01068ft) (2015-10-27 14:55:00 -0.00586ft)	10/17/2015 17:00	10/27/2015 14:55	1/14/2016 14:19
SS3	Delete Region	Delete Region	11/16/2015 10:45	11/16/2015 10:50	1/14/2016 14:21
SS3	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	11/16/2015 10:45	11/16/2015 10:50	1/14/2016 14:22
SS3	Delete Region	Delete Region	12/16/2015 14:15	12/16/2015 14:40	1/14/2016 14:23
SS3	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	12/16/2015 14:15	12/16/2015 14:40	1/14/2016 14:23
SS3	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-12-18 18:00:00 -0.00258ft) (2016-01-03 14:25:00 -0.00660ft)	12/18/2015 18:00	1/3/2016 14:25	1/14/2016 14:25
SS3	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-01-27 01:30:00 -0.01346ft) (2015-03-07 20:40:00 -0.01619ft)	1/27/2015 1:30	3/7/2015 20:40	1/14/2016 14:27
SS3	Delete Region	Delete Region	9/9/2015 11:00	9/9/2015 11:05	1/14/2016 14:30
SS3	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	9/9/2015 11:00	9/9/2015 11:05	1/14/2016 14:30
SS4	Offset Correction	Offset Correction with value of 0.01200ft	10/20/2014 5:05	11/5/2014 12:55	1/28/2015 13:22
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-02-06 16:25:00 0.00000ft) (2015-02-07 02:35:00 -0.30000ft)	2/6/2015 16:25	2/7/2015 2:35	1/14/2016 15:23
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-02-08 00:45:00 0.00000ft) (2015-02-08 19:00:00 -0.30000ft)	2/8/2015 0:45	2/8/2015 19:00	1/14/2016 15:23
SS4	Delete Region	Delete Region	2/22/2015 1:00	2/22/2015 1:10	1/14/2016 15:24
SS4	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	2/22/2015 1:00	2/22/2015 1:10	1/14/2016 15:24
SS4	Delete Region	Delete Region	3/11/2015 10:50	3/11/2015 11:25	1/14/2016 15:25
SS4	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	3/11/2015 10:50	3/11/2015 11:25	1/14/2016 15:25
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-03-10 22:45:00 -0.00610ft) (2015-04-03 09:15:00 -0.03873ft)	3/10/2015 22:45	4/3/2015 9:15	1/14/2016 15:26
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-04-11 00:30:00 0.01118ft) (2015-05-12 20:00:00 0.00242ft)	4/11/2015 0:30	5/12/2015 20:00	1/14/2016 15:27
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-06-20 15:20:00 -0.02543ft) (2015-06-30 21:40:00 0.00000ft)	6/20/2015 15:20	6/30/2015 21:40	1/14/2016 15:27
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-06-20 15:20:00 0.00000ft) (2015-06-30 21:40:00 0.00000ft)	6/20/2015 15:20	6/30/2015 21:40	1/14/2016 15:28
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-07-20 18:40:00 -0.10000ft) (2015-07-24 12:30:00 -0.06383ft)	7/20/2015 18:40	7/24/2015 12:30	1/14/2016 15:28
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-08-12 05:25:00 0.02140ft) (2015-09-09 08:50:00 0.04060ft)	8/12/2015 5:25	9/9/2015 8:50	1/14/2016 15:29
SS4	Delete Region	Delete Region	10/27/2015 12:45	10/27/2015 12:50	1/14/2016 15:29
SS4	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	10/27/2015 12:45	10/27/2015 12:50	1/14/2016 15:29
SS4	Delete Region	Delete Region	11/12/2015 11:05	11/12/2015 12:05	1/14/2016 15:30
SS4	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	11/12/2015 11:05	11/12/2015 12:05	1/14/2016 15:31
SS4	Delete Region	Delete Region	11/16/2015 10:10	11/16/2015 10:50	1/14/2016 15:31

Station	Editing Type	Editing Details	Editing Start	Editing Stop	Editing Applied
SS4	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	11/16/2015 10:10	11/16/2015 10:50	1/14/2016 15:31
SS4	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-12-18 17:10:00 -0.00531ft) (2015-12-26 22:25:00 -0.00487ft)	12/18/2015 17:10	12/26/2015 22:25	1/14/2016 15:32
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2014-10-20 05:00:00 -0.02519ft) (2014-11-18 15:45:00 -0.01456ft)	10/20/2014 5:00	11/18/2014 15:45	1/28/2015 13:27
SS5	Recession Curve	Recession curve with recession constant k = 0.06000, offset constant c = 0.00000	1/3/2015 10:20	1/4/2015 12:45	1/28/2015 13:29
SS5	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	1/18/2015 20:40	1/19/2015 21:35	1/28/2015 13:30
SS5	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	1/20/2015 0:00	1/22/2015 4:05	1/28/2015 13:31
SS5	Recession Curve	Recession curve with recession constant k = 25.00000, offset constant c = 0.00000	1/22/2015 5:40	1/23/2015 0:45	1/28/2015 13:33
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-03-09 12:05:00 -0.01473ft) (2015-03-13 09:25:00 -0.03108ft)	3/9/2015 12:05	3/13/2015 9:25	1/14/2016 14:47
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-03-23 01:50:00 0.00000ft) (2015-03-26 08:45:00 -0.00554ft)	3/23/2015 1:50	3/26/2015 8:45	1/14/2016 14:47
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-03-30 20:05:00 0.00000ft) (2015-04-03 08:50:00 -0.01398ft)	3/30/2015 20:05	4/3/2015 8:50	1/14/2016 14:48
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-04-03 15:30:00 0.00000ft) (2015-04-13 10:20:00 -0.02633ft)	4/3/2015 15:30	4/13/2015 10:20	1/14/2016 14:48
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-04-14 08:05:00 0.00000ft) (2015-04-17 21:40:00 -0.00409ft)	4/14/2015 8:05	4/17/2015 21:40	1/14/2016 14:51
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-04-29 03:05:00 0.00000ft) (2015-05-02 17:10:00 -0.00516ft)	4/29/2015 3:05	5/2/2015 17:10	1/14/2016 14:52
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-05-05 02:35:00 0.00000ft) (2015-05-09 11:10:00 -0.01769ft)	5/5/2015 2:35	5/9/2015 11:10	1/14/2016 14:53
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-06-19 05:20:00 -0.01518ft) (2015-07-01 02:15:00 0.00000ft)	6/19/2015 5:20	7/1/2015 2:15	1/14/2016 14:53
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-07-21 06:45:00 -0.04777ft) (2015-07-24 14:40:00 -0.05050ft)	7/21/2015 6:45	7/24/2015 14:40	1/14/2016 14:54
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-08-31 15:55:00 -0.03244ft) (2015-09-09 13:05:00 -0.05709ft)	8/31/2015 15:55	9/9/2015 13:05	1/14/2016 14:55
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-10-02 06:35:00 -0.01335ft) (2015-10-09 12:05:00 -0.01239ft)	10/2/2015 6:35	10/9/2015 12:05	1/14/2016 14:56
SS5	Delete Region	Delete Region	10/27/2015 11:00	10/27/2015 11:10	1/14/2016 14:56
SS5	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	10/27/2015 11:00	10/27/2015 11:10	1/14/2016 14:56
SS5	Delete Region	Delete Region	10/27/2015 10:30	10/27/2015 15:45	1/14/2016 14:57
SS5	Fill Data Gaps	Fill Data Gaps (Linear) with gap resample rate of 5.00 min	10/27/2015 10:30	10/27/2015 15:45	1/14/2016 14:57
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-11-09 14:40:00 0.00000ft) (2015-11-10 22:35:00 -0.34900ft)	11/9/2015 14:40	11/10/2015 22:35	1/14/2016 15:01
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-11-19 09:35:00 0.00000ft) (2015-11-23 06:30:00 -0.30000ft)	11/19/2015 9:35	11/23/2015 6:30	1/14/2016 15:14
SS5	Multi-Point Drift Correction	Multi-Point Drift Correction of (Date/Time, Diff) (2015-11-24 11:14:56 0.00000ft) (2015-11-27 01:49:01 -0.30000ft)	11/24/2015 11:14	11/27/2015 1:49	1/14/2016 15:16
SS5	Recession Curve	Recession curve with recession constant k = 20.14950, offset constant c = 0.00000	10/26/2016 23:25	10/27/2016 8:00	10/27/2016 11:53

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APPENDIX B. ANALYTICAL DATA QUALITY ASSURANCE/QUALITY CONTROL REPORT

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This analytical data Quality Assurance/Quality Control (QA/QC) report addresses all analytical laboratory and field sample data generated for the Street Sweeping Effectiveness project. The following discussion includes QA/QC practices and results for analytical laboratory and field sample data for all samples collected over the course of this study. Samples were collected from October 22, 2014 through September 2, 2016. QA/QC evaluation documented in previously submitted Annual Reports (SPU 2015 and SPU 2016) is considered preliminary. Since the sampling for the study is now complete, all data were re-evaluated within the complete context of data generated and QA/QC results and flagging contained in this report are considered final.

B1. Analytical Data QA/QC Procedures

All laboratory data packages, by sample delivery group (SDG), were received with chain-of-custody (COC) and laboratory data package including a hardcopy report and an electronic data deliverable (EDD) in a format compatible for loading into SPU's EQuIS™ database.

For each SDG, laboratory case narratives from the hardcopy report were reviewed for quality control issues and corrective action(s) taken. Data were verified and validated at an EPA Tier 1 data review level and reviewed for required methods, sample preservation and holding times, blank contamination, precision, accuracy, and completeness.

Deviations from the project measurement quality objectives (MQOs) were identified and data qualifiers were applied to sample chemistry data based on the results of validation. Four data validation qualifiers were used; U, J, UJ and R; and are defined in Table B1 below. All data qualifications were documented in a data qualification summary table by SDG and MQO.

Table B1. Data Qualifier Definitions

Qualifier	Definition
U	Analyte was analyzed for, but not detected above reported result.
J	Reported result is an estimated quantity.
UJ	The analyte was not detected above the sample reporting limit. However, the reporting limit is approximate and may or may not represent the actual limit of quantitation necessary to measure the analyte accurately and precisely in the sample.
R	Result value was rejected. Analyte may or may not be present; result should not be used in report analyses.

In each EDD, validation qualifiers were added to sample chemistry data with the validation qualifier remark fields populated to identify the MQO and reason for qualification. After the EDDs were loaded to EQuIS, the EQuIS data validation field was populated as complete (validated_YN = "Y"), completing the data review process.

B2. Analytical Methods and Reporting Limits (Sensitivity)

Analytical Resources Inc. (ARI) performed the sample analyses for the duration of this study, with the exception of modified suspended solids concentration (SSC) analyses, which were performed by ARI and then subcontracted to Materials Testing & Consulting, Inc. (MTC) beginning with samples collected on March 14, 2015.

Table B2 presents the laboratory methods and target reporting limit (RL) values for the analyses performed for this project. A reporting limit (RL) represents the minimum concentration of an analyte in a specific matrix that can be identified and quantified above the method detection limit and within specified limits of precision and bias during routine analytical operating conditions.

RLs reported by the laboratory with individual sample analytical results in some cases varied from the target reporting limits listed in Table B2, for example in cases where dilutions, reanalyses, or dilutions affected the minimum detectable value. In cases where the laboratory performed dilutions or re-analyses that resulted in multiple reportable values, only the result with the lowest RL was reported. In cases where the RL was elevated due to laboratory deficiencies in analytical parameter quantification, these results and validator qualifications, if any, are discussed in Section B3.5 (Target Analyte Identification) below.

Table B2. Analytes, Methods, and Target Reporting Limits.

Group Type	Parameter	Target Reporting Limit	Units	Laboratory Method
Conventional parameters	Total Suspended Solids (TSS)	1.0	mg/L	SM2540D
	Total Organic Carbon (TOC)	1.5	mg/L	EPA 415.1
	Chemical Oxygen Demand (COD)	10.0	mg/L	EPA 410.4
	Modified Suspended Solids Concentration (SSC)	1.0	mg/L	ASTM D3977-97
	pH	0.2	standard units	EPA 150.2
	Hardness as CaCO3	1	mg/L CaCO3	SM2340B
Metals (total/dissolved)	Copper	0.5/0.5	µg/L	EPA 200.8
	Zinc	4.0/4.0	µg/L	EPA 200.8
Nutrients	Total Phosphorus	0.008	mg/L	SM4500-PE
	Nitrate-Nitrite (N03-N02)	0.01	mg-N/L	EPA 353.2
	Total Kjeldahl Nitrogen (TKN)	0.5	mg-N/L	EPA 351.2
Bacteria	Fecal Coliform	1	cfu/100mL	SM9222D
Organics	Polycyclic Aromatic Hydrocarbons (PAHs)	0.1	µg/L	8270D-SIM

B3. Laboratory Data QA/QC Evaluation Results

B3.1. Sample Preservation and Holding Time

All sample results were assessed for sample preservation and holding time compliance in accordance with 40 CFR Part 136. For composite samples collected with an automated sampler, the sample time used to calculate holding time was "at the time of the end of collection of the composite sample" (40 CFR 136, Table II, note 4). For dissolved copper and zinc analyses, best efforts were made to perform pre-filtration as close to the specified holding time as possible and no data were qualified on this basis.

Analytical results obtained for samples analyzed outside of holding time or preserved improperly were qualified as estimated (J). Sample preservation and holding time criteria were met for all field sample results except as listed in Table B3.1. Fifty-two (52) of 3927 of total field sample results were J-qualified based on holding time exceedances

Samples from several sample events were analyzed outside of holding time for fecal coliform, primarily due to the short, eight-hour (8h) holding time for this analysis and availability of laboratory resources within this timeframe. Samples from one sample event were analyzed slightly outside of holding time for modified suspended solids concentration (SCC). No corrective action was taken based on these results.

Table B3.1. Sample Preservation and Holding Time Qualifications.

Chemical Name	Sample Name	Sample Date	Validation Qualifier	Reason
Fecal Coliform	SS4-102514-G	10/25/2014	J	Exceeded holding time[1] by 39 h
Fecal Coliform	SS3-102514-G	10/25/2014	J	Exceeded holding time by 38 h
Fecal Coliform	SS2-102514-G	10/25/2014	J	Exceeded holding time by 38 h
Fecal Coliform	SS5-102514-G	10/25/2014	J	Exceeded holding time by 38 h
Fecal Coliform	SS2-03152015-G	3/15/2015	J	Exceeded holding time by 15 h
Fecal Coliform	SS5-03152015-G	3/15/2015	J	Exceeded holding time by 15 h
Fecal Coliform	SS4-03152015-G	3/15/2015	J	Exceeded holding time by 14 h
Fecal Coliform	SS3-03152015-G	3/15/2015	J	Exceeded holding time by 14 h
Fecal Coliform	SS5-102515-G	10/25/2015	J	Exceeded holding time by 17 h
Fecal Coliform	SS4-102515-G	10/25/2015	J	Exceeded holding time by 16 h
Fecal Coliform	SS3-102515-G	10/25/2015	J	Exceeded holding time by 16 h
Fecal Coliform	SS2-102515-G	10/25/2015	J	Exceeded holding time by 16 h
Fecal Coliform	SS2-103115-G	10/31/2015	J	Exceeded holding time by 46 h
Fecal Coliform	SS5-103115-G	10/31/2015	J	Exceeded holding time by 46 h
Fecal Coliform	SS4-103115-G	10/31/2015	J	Exceeded holding time by 45 h
Fecal Coliform	SS3-103115-G	10/31/2015	J	Exceeded holding time by 45 h
Fecal Coliform	SS2-120115-G	12/1/2015	J	Exceeded holding time by 6 h

Chemical Name	Sample Name	Sample Date	Validation Qualifier	Reason
Fecal Coliform	SS3-120115-G	12/1/2015	J	Exceeded holding time by 6 h
Fecal Coliform	SS4-120115-G	12/1/2015	J	Exceeded holding time by 6 h
Fecal Coliform	SS5-120115-G	12/1/2015	J	Exceeded holding time by 5 h
Fecal Coliform	SS5-012716-G	1/27/2016	J	Exceeded holding time by 8 h
Fecal Coliform	SS4-012716-G	1/27/2016	J	Exceeded holding time by 8 h
Fecal Coliform	SS3-012716-G	1/27/2016	J	Exceeded holding time by 7 h
Fecal Coliform	SS2-012716-G	1/27/2016	J	Exceeded holding time by 7 h
Fecal Coliform	SS5-07082016-G	7/8/2016	J	Exceeded holding time by 20 h
Fecal Coliform	SS4-07082016-G	7/8/2016	J	Exceeded holding time by 20 h
Fecal Coliform	SS3-07082016-G	7/8/2016	J	Exceeded holding time by 20 h
Fecal Coliform	SS2-07082016-G	7/8/2016	J	Exceeded holding time by 19 h
Sediment Conc. < 3.9 um	SS3-120215-C	12/2/2015	J	Exceeded holding time[2] by 1 d
Sediment Conc. < 3.9 um	SS2-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. < 3.9 um	SS4-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. < 3.9 um	SS5-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. > 500 um	SS3-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. > 500 um	SS2-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. > 500 um	SS4-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. > 500 um	SS5-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 250 to 62.5 um	SS3-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 250 to 62.5 um	SS2-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 250 to 62.5 um	SS4-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 250 to 62.5 um	SS5-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 500 to 250 um	SS3-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 500 to 250 um	SS2-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 500 to 250 um	SS4-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 500 to 250 um	SS5-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 62.5 to 3.9 um	SS3-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 62.5 to 3.9 um	SS2-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 62.5 to 3.9 um	SS4-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. 62.5 to 3.9 um	SS5-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. Total	SS3-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. Total	SS2-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. Total	SS4-120215-C	12/2/2015	J	Exceeded holding time by 1 d
Sediment Conc. Total	SS5-120215-C	12/2/2015	J	Exceeded holding time by 1 d

1. Fecal coliform method SM9222A holding time eight (8) hours
2. Modified suspended solids concentration method ASTM D3977-97 holding time seven (7) days

B3.2 Blanks (Representativeness)

As part of the evaluation of the representativeness of the data collected for this study, QC results for both laboratory and field equipment blanks were reviewed to ensure that the data generated are characteristic of the sample population. The application of qualifiers to sample results based on the blank QC sample type is shown below in Table B3.2a. Validation criteria and qualification actions based on laboratory method blank results are shown below in Table B3.2b. Laboratory method and filter blank results will be discussed in this section; field equipment blanks will be discussed separately, in Section B4.1 below.

Table B3.2a. Association of Blank QC to Sample Results.

Blank Sample Type	Associated Results
Laboratory Method Blank	All results in prep batch
Laboratory Filter Blank	All results from same sample delivery group
Field Equipment (Tubing) Blank	Composite results from project water year[1] and same site
Field Equipment (Churn Bottle) Blank	Composite results from project water year[1]

1. Qualified results were not necessarily all results from the associated project water year; samples were qualified based on best judgment as to the effect the contamination may have had on the associated sample results and for what duration.

Table B3.2b. Blank Validation Criteria.

Blank	Sample	Action
Blank > RL	Sample < RL	Qualify sample result as non-detect (U) at the RL
	RL < Sample < Blank	Qualify sample result as non-detect (U) at the reported concentration.
	Blank < Sample < 10x Blank	Qualify sample result as estimated (J).
	10x Blank < Sample	No qualification needed.
Blank < (-RL)	Sample < RL	Qualify sample result as estimated non-detect (UJ) at the RL
	RL < Sample < 10x Blank	Qualify sample result as estimated (J).
	10x Blank < Sample	No qualification needed.
(-RL) < Blank < RL	Sample < RL	Qualify sample result as non-detect (U) at the RL
	RL < Sample	No qualification needed.

RL – reporting limit

Laboratory method and filter blanks were generated and analyzed by the laboratories as required by the analytical methods and per project specifications. All laboratory blank results were non-detect (below the laboratory RL), except for those listed in Table B3.2c below. Of 722 total laboratory blank results for target analytes for all analytical methods, five results were detected above the laboratory RL. No corrective action was taken based on these results.

Table B3.2c. Laboratory Blank Exceedances.

Chemical Name	Analysis Date	Result	Reporting Limit	Unit
Total Phosphorus	11/21/2015	0.013	0.008	mg/L
Total Phosphorus	11/21/2015	0.013	0.008	mg/L
Total Phosphorus	3/25/2016	0.012	0.008	mg/L
Nitrate + Nitrite	7/18/2016	0.01	0.01	mg/L
Total Organic Carbon	9/8/2016	0.72	0.5	mg/L

Sample results were qualified based on the laboratory blank exceedances shown in Table B3.2c**.** Sample results associated with the laboratory method blanks were not qualified if the sample result exceeded the concentration in the method blank by ten times (10x). As a result, only one of 3927 total field sample results was qualified as estimated (“J”-qualified) based on laboratory blank exceedances, as shown in Table B3.2d.

Table B3.2d. Laboratory Blanks Field Sample Qualifications.

Chemical Name	Sample Name	Sample Date	Validation Qualifier	Reason
Total Phosphorus	SS4-111515-C	11/15/2015	J	Laboratory Blank Contamination

B3.3 Precision

Precision is the degree of observed reproducibility of measurement results. Both laboratory and field precision QC sample results were reviewed to evaluate laboratory analysis and field sampling procedures. Results were reviewed for laboratory sample duplicates (DUP), laboratory control sample duplicates (LCSD), matrix spike duplicates (MSD), and field split samples (FSS). The application of qualifiers to sample results based on the precision QC sample types is shown below in Table B3.4a. Validation criteria and qualification actions based on the precision analysis are shown below in Table B3.4b. Laboratory precision QC results will be discussed in this section; FSS results will be discussed separately, in Section B4.2 below.

Table B3.3a. Association of Precision QC to Sample Results.

QC Sample Type	Associated Results
Laboratory Duplicate (DUP)	Parent sample results only
Laboratory Control Sample Duplicate (LCSD)	All results in prep batch
Matrix Spike Duplicate (MSD)	Results for associated analyte in parent sample only
Field Split Sample (FSS)	Results for associated analyte in parent sample only

Table B3.3b. Precision Validation Criteria.

Matrix	Original and Duplicate		Associated Sample	Action
	Criterion 1	Criterion 2		
Water	Both Original and DUP Results < 5x RL	|original - duplicate| > RL	Result < RL	Qualify sample results as estimated non-detect (UJ).
			Result > RL	Qualify sample results as estimated (J).
		|original - duplicate| ≤ RL	All	No qualification needed.
	Either Original or DUP Results > 5x RL	RPD† > 20*%	Result < RL	Qualify sample results as estimated non-detect (UJ).
			Result > RL	Qualify sample results as estimated (J).
		RPD ≤ 20*%	All	No qualification needed.

DUP—laboratory duplicate, RL – Reporting Limit
† RPD – Relative Percent Difference between the original and the duplicate, calculated as follows:

$$RPD = 100 \times \left| \frac{(original - duplicate)}{Mean\ (original, duplicate)} \right|$$

* An RPD control limit of 25% was used when assessing field duplicate water samples.

Laboratory sample duplicates (DUP), laboratory control sample duplicates (LCSD), and matrix spike duplicates (MSD) were generated and analyzed by the laboratory as required by the analytical methods and per project specifications. All precision laboratory QC results were within laboratory control limits (CLs) except for those listed in Table B3.4c below. Associated sample results were qualified as shown in Table B3.4d. Sixteen (16) of 3727 total field sample results were qualified based on precision QC exceedances. No corrective action was taken based on these results.

Table B3.3c. Laboratory Precision Exceedances.

Chemical Name	QC Sample	Analysis Date	Result	Units	RPD (|∆|)	Validation Action
Fecal Coliform	SS5-051315-GDUP	5/13/2015	2800	cfu/100ml	22	Associated results qualified J/UJ
Magnesium	SS5-012216-CDDUP	2/1/2016	1200	ug/l	57	Associated results qualified J/UJ
Nitrogen, Total Kjeldahl	SS5-121815-CDUP	12/30/2015	12	mg/l	24	Associated results qualified J/UJ
Sediment Conc. > 500 um	SS5-030216-CDUP	3/4/2016	68.2	mg/l	69.8	Associated results qualified J/UJ
Sediment Conc. > 500 um	SS5-012216-CDUP	1/26/2016	91	mg/l	75	Associated results qualified J/UJ
Sediment Conc. > 500 um	SS5-101015-CDUP	10/14/2015	0.4	mg/l	54.5	Associated results qualified J/UJ
Sediment Conc. > 500 um	SS5-090216-CDUP	9/9/2016	7.1	mg/l	70.3	Associated results qualified J/UJ
Sediment Conc. 500 to 250 um	SS5-012216-CDUP	1/26/2016	30.7	mg/l	43.0	Associated results qualified J/UJ
Sediment Conc. 500 to 250 um	SS5-101015-CDUP	10/14/2015	0.8	mg/l	46.2	Associated results qualified J/UJ
Sediment Conc. 62.5 to 3.9 um	SS5-090216-CDUP	9/9/2016	71.5	mg/l	140	Associated results qualified J/UJ
Sediment Conc. Total	SS5-030216-CDUP	3/4/2016	172.1	mg/l	23.0	Associated results qualified J/UJ
Sediment Conc. Total	SS5-012216-CDUP	1/26/2016	233.5	mg/l	41.4	Associated results qualified J/UJ
Solids, Total Suspended	SS5-110715-CDUP	11/10/2015	152	mg/l	20.0	Associated results qualified J/UJ
Solids, Total Suspended	SS2-03142015-CDUP	3/19/2015	60.5	mg/l	29.8	Associated results qualified J/UJ
Zinc	SS5-020915-CDUP	2/11/2015	102	ug/l	44	Associated results qualified J/UJ
Zinc	SS2-112114-CDUP	11/28/2014	82	ug/l	138	Associated results qualified J/UJ

RPD – Relative percent difference
|∆| -- Absolute value of the difference between sample and duplicate

Table B3.3d. Precision Field Sample Qualifications/

Chemical Name	Sample Name	Sample Date	Analysis Method	Validation Qualifier	Reason
Fecal Coliform	SS5-051315-G	5/13/2015	SM9222D	J	Laboratory Duplicates (High RPD)
Magnesium	SS5-012216-CD	1/22/2016	SW6010C	J	Laboratory Duplicates (High RPD)
Nitrogen, Total Kjeldahl	SS5-121815-C	12/18/2015	EPA351.2	J	Laboratory Duplicates (High RPD)
Sediment Conc. > 500 um	SS5-101015-C	10/10/2015	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. > 500 um	SS5-012216-C	1/22/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. > 500 um	SS5-030216-C	3/2/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. > 500 um	SS5-090216-C	9/2/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. 500 to 250 um	SS5-101015-C	10/10/2015	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. 500 to 250 um	SS5-012216-C	1/22/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. 62.5 to 3.9 um	SS5-090216-C	9/2/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. Total	SS5-012216-C	1/22/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Sediment Conc. Total	SS5-030216-C	3/2/2016	ASTMD3977C	J	Laboratory Duplicates (High RPD)
Solids, Total Suspended	SS2-03142015-C	3/14/2015	SM2540D	J	Laboratory Duplicates (High RPD)
Solids, Total Suspended	SS5-110715-C	11/7/2015	SM2540D	J	Laboratory Duplicates (High RPD)
Zinc	SS2-112114-C	11/21/2014	EPA200.8	J	Laboratory Duplicates (High RPD)
Zinc	SS5-020915-C	2/9/2015	EPA200.8	J	Laboratory Duplicates (High RPD)

RPD—relative percent difference

B3.4 Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference value. Laboratory QC sample results were reviewed to evaluate laboratory analysis procedures. Results were reviewed for matrix spike/matrix spike duplicate (MS/MSD), laboratory control sample (LCS), certified reference material (CRM), surrogate compound (SUR), and calibration verification standard QC sample types. The application of qualifiers to sample results based on the MS/MSD QC sample types is shown below in Table B3.3a. Validation criteria and qualification actions based on the precision analysis are shown below in Table B3.3b. Laboratory control limits (CLs) for QC samples were used to evaluate the associated sample results.

Table B3.4a. Association of Accuracy QC to Sample Results.

QC Sample Type	Associated Results
Laboratory Control Sample/Laboratory Control Sample Duplicate/Certified Reference Material (LCS/LCSD/CRM)	All results in prep batch
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	Results for associated analyte in parent sample only
Surrogate	Results for associated analyte in parent sample only
Continuing Calibration Verification	All results in prep batch

Table B3.4b. Accuracy Validation Criteria.

Percent Recovery (%R)*	Sample	Action
%R < Lower Control Limit	Sample ≤ RL	Qualify sample result as estimated non-detect (UJ).
	RL < Sample	Qualify sample result as estimated (J).
	Parent† > 4x spike added	No qualification needed.
Upper Control Limit < %R/%D**	Sample ≤ RL	No qualification needed.
	RL < Sample	Qualify sample result as estimated (J).
	Parent > 4x spike added	No qualification needed.

RL – reporting limit
† Parent - The sample from which an aliquot is used to make the spiked QC sample.
* The percent recovery (%R) of the spiked compound and is calculated as:

$$\%R = \frac{(Spiked\ QC\ Sample\ Result - Parent\ Sample\ Result)}{Spike\ amount}$$

**The percent difference (%D) is calculated as the difference between consecutive continuing calibration verification standards; associated sample results are qualified as estimated (UJ/J) for non-detect, detect results, respectively.

MS/MSD, LCS, CRM, surrogate, and calibration verification standard QC samples were generated and analyzed by the laboratory as required by the analytical methods and per project specifications. Accuracy QC results were within the laboratory CLs, except for those listed in Table B3.3c below. Associated sample results were qualified as shown in Table B3.3d below. Thirty-two (32) of 3927 total primary environmental samples were qualified based on accuracy QC exceedances. Note that not all QC sample exceedances resulted in qualifications, for example in the case of high surrogate recovery for non-detect sample results. No corrective action was taken based on these results.

Table B3.4c. Laboratory Accuracy Exceedances.

Chemical Name	QC Sample Type	Analysis Date	Reason	Validation Action
Benzo(a)Anthracene	Surrogate	4/23/2015	%R Low	Associated Results Qualified J/UJ
Benzo(a)anthracene	MS/MSD	12/16/2015	%R Low	Associated Results Qualified J/UJ
Benzo(a)Anthracene	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Benzo(g,h,i)Perylene	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Benzo(g,h,i)Perylene	CCV	11/7/2014	%D High	Associated Results Qualified J/UJ
Benzofluoranthenes, Total	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Chemical Oxygen Demand	MS	11/3/2015	%R Low	Associated Results Qualified J/UJ
Chemical Oxygen Demand	MS	11/17/2015	%R Low	Associated Results Qualified J/UJ
Chemical Oxygen Demand	MS/MSD	2/1/2016	%R Low	Associated Results Qualified J/UJ
Chemical Oxygen Demand	MS/MSD	3/9/2016	%R Low	Associated Results Qualified J/UJ
Chemical Oxygen Demand	MS/MSD	3/29/2016	%R Low	Associated Results Qualified J/UJ
Chemical Oxygen Demand	MS/MSD	2/13/2015	%R Low	Associated Results Qualified J/UJ
Chrysene	Surrogate	4/23/2015	%R Low	Associated Results Qualified J/UJ
Chrysene	MS/MSD	12/16/2015	%R Low	Associated Results Qualified J/UJ
Chrysene	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Fluoranthene	Surrogate	4/23/2015	%R Low	Associated Results Qualified J/UJ
Fluoranthene	MS/MSD	12/16/2015	%R Low	Associated Results Qualified J/UJ
Fluoranthene	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Indeno(1,2,3-cd)pyrene	MS/MSD	12/16/2015	%R Low	Associated Results Qualified J/UJ
Indeno(1,2,3-cd)pyrene	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Indeno(1,2,3-cd)pyrene	CCV	11/7/2014	%D High	Associated Results Qualified J/UJ
Pyrene	Surrogate	4/23/2015	%R Low	Associated Results Qualified J/UJ
Pyrene	MS/MSD	12/16/2015	%R Low	Associated Results Qualified J/UJ
Pyrene	MS/MSD	12/28/2015	%R Low	Associated Results Qualified J/UJ
Total Organic Carbon	MS/MSD	1/22/2016	%R Low	Associated Results Qualified J/UJ
Zinc	MS/MSD	2/11/2015	%R Low	Associated Results Qualified J/UJ

CCV – Continuing Calibration Verification standard; %R – percent recovery; %D percent difference

Table B3.4d. Accuracy Field Sample Qualifications.

Chemical Name	Sample Name	Sample Date	Analysis Method	Validation Qualifier	Reason
Benzo(a)Anthracene	SS4-04132015-G	4/13/2015	SW8270DSIM	UJ	Surrogates
Benzo(a)Anthracene	SS5-120315-G	12/3/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Benzo(a)Anthracene	SS5-121715-G	12/17/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Benzo(g,h,i)Perylene	SS2-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Benzo(g,h,i)Perylene	SS3-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Benzo(g,h,i)Perylene	SS4-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Benzo(g,h,i)Perylene	SS5-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Benzo(g,h,i)Perylene	SS5-121715-G	12/17/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Benzofluoranthenes, Total	SS5-121715-G	12/17/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chemical Oxygen Demand	SS2-020615-C	2/6/2015	EPA410.4	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chemical Oxygen Demand	SS5-102515-C	10/25/2015	EPA410.4	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chemical Oxygen Demand	SS5-110715-C	11/7/2015	EPA410.4	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chemical Oxygen Demand	SS5-011616-C	1/16/2016	EPA410.4	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chemical Oxygen Demand	SS5-030216-C	3/2/2016	EPA410.4	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chemical Oxygen Demand	SS4-032316-C	3/23/2016	EPA410.4	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chrysene	SS4-04132015-G	4/13/2015	SW8270DSIM	UJ	Surrogates
Chrysene	SS5-120315-G	12/3/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Chrysene	SS5-121715-G	12/17/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Fluoranthene	SS4-04132015-G	4/13/2015	SW8270DSIM	UJ	Surrogates
Fluoranthene	SS5-120315-G	12/3/2015	SW8270DSIM	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Fluoranthene	SS5-121715-G	12/17/2015	SW8270DSIM	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Indeno(1,2,3-cd)pyrene	SS2-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Indeno(1,2,3-cd)pyrene	SS3-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Indeno(1,2,3-cd)pyrene	SS4-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Indeno(1,2,3-cd)pyrene	SS5-102514-G	10/25/2014	SW8270DSIM	UJ	Continuing Calibration Verification
Indeno(1,2,3-cd)pyrene	SS5-120315-G	12/3/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Indeno(1,2,3-cd)pyrene	SS5-121715-G	12/17/2015	SW8270DSIM	UJ	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Pyrene	SS4-04132015-G	4/13/2015	SW8270DSIM	UJ	Surrogates
Pyrene	SS5-120315-G	12/3/2015	SW8270DSIM	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Pyrene	SS5-121715-G	12/17/2015	SW8270DSIM	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Total Organic Carbon	SS5-011616-C	1/16/2016	SM5310B	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)
Zinc	SS2-020615-C	2/6/2015	EPA200.8	J	Matrix Spikes/Matrix Spike Duplicates (Low %R)

%R—Percent Recovery

B3.5 Target Analyte Identification (Precision and Accuracy)

In addition to laboratory and field precision and accuracy QC sample results, laboratory data were also reviewed for target analyte identification, which affects both accuracy and precision of results. The data quality indicators used to evaluate target analyte identification are based on laboratory criteria, on a per method basis, and are discussed in detail below. Forty (40) of 3927 total field sample results were qualified as estimated (“J”-qualified) based on reported deficiencies in the laboratory's ability to identify target analytes for the analyses SW8270DSIM, ASTMD3977C, and SM9222D. The qualifications are discussed, by method, below and shown in Table B3.5.

- For analytical method SW8270DSIM, the analytes Anthracene and Acenaphthene were "J"-qualified due to a low spectral match between target and reference compounds for the laboratory analysis of sample SS3-121715-G. Because these analytes were identified within laboratory CLs for the LCS for the associated analytical batch, no corrective action was taken.

- For analytical method ASTMD3977C, the suspended sediment concentration size fractions Sediment Conc. < 3.9 um and Sediment Conc. 62.5 to 3.9 um were "J"-qualified due to agglomeration of particles observed during the laser analysis of these two smallest size fractions for samples SS2-011616-C, SS3-011616-C, SS4-011616-C, SS5-011616-C, SS2-012216-C, SS3-012216-C, SS4-012216-C, SS5-012216-C, SS2-030216-C, SS3-030216-C, SS5-030216-C, SS2-032316-C, SS3-032316-C, SS2-07092016-C, SS3-07092016-C, SS2-090216-C, SS3-090216-C, SS4-090216-C, and SS5-090216-C. The laboratory reported the results for any material larger than 62.5 um as added to the 62.5 to 3.9 um fraction, and no corrective action was taken.

- For analytical method SM9222D, the analyte Fecal Coliform was "R"-qualified (rejected) for samples SS2-04132015-G and SS4-03142015-G due to elevated reporting limits and indeterminate quantification reported by the laboratory. For sample SS2-04132015-G, the reported result was >2,670 cfu/100mL, the minimum RL at the dilution factor run for this sample, because confluent growth prevented an accurate bacteria count. For sample SS4-03142015-G, the reported result was >20,000, greater than the maximum RL for this method, because the colonies were too numerous to count. Both samples were qualified as rejected, "R"-qualified because the laboratory was unable to quantify the target analyte. No corrective action was taken due to the short holding time for this analysis and inherent nature of the samples.

Table B3.5. Target Analyte Identification Field Sample Qualifications .

Chemical Name	Sample Name	Sample Date	Analysis Method	Validation Qualifier	Reason
Anthracene	SS3-121715-G	12/17/2015	SW8270DSIM	J	Spectral Match Low
Acenaphthene	SS3-121715-G	12/17/2015	SW8270DSIM	J	Spectral Match Low
Fecal Coliform	SS2-04132015-G	4/13/2015	SM9222D	R	Elevated RL
Fecal Coliform	SS4-03142015-G	3/14/2015	SM9222D	R	Elevated RL
Sediment Conc. < 3.9 um	SS2-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS3-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS4-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS5-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS2-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS3-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS4-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS5-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS2-030216-C	3/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS3-030216-C	3/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS5-030216-C	3/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS2-032316-C	3/23/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS3-032316-C	3/23/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS2-07092016-C	7/9/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS3-07092016-C	7/9/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS2-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS3-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS4-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. < 3.9 um	SS5-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS2-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS3-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS4-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS5-011616-C	1/16/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS2-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS3-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS4-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS5-012216-C	1/22/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS2-030216-C	3/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS3-030216-C	3/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS5-030216-C	3/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS2-032316-C	3/23/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS3-032316-C	3/23/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS2-07092016-C	7/9/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS3-07092016-C	7/9/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS2-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS3-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS4-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate
Sediment Conc. 62.5 to 3.9 um	SS5-090216-C	9/2/2016	ASTMD3977C	J	Laser Analysis Indeterminate

RL – Reporting Limit

B3.6 Completeness and Comparability

Completeness

Completeness is defined as the percentage of acceptable samples collected/sample results compared to the total number of samples collected/sample results planned for a project. Completeness is evaluated to determine if an acceptable amount of usable data were collected so that the results of the project study are considered valid. Completeness for this project was evaluated using two measures: sampling completeness and analytical completeness, which are defined below. The project MQO for completeness for both measures is 90 percent.

- *Sampling completeness* was calculated by dividing the number of samples collected by the number of samples planned (including primary environmental sample (PES), field blank (FEB), and field split (FSS) samples). All 212 planned field samples were collected, for a sampling completeness of 100 percent.

- *Analytical completeness* was calculated by dividing the number of usable (not qualified as rejected, "R") analytical results generated by the laboratory by the number of analytical results planned. A total of 3940 results were planned for PES, FEB and FSS samples. A total of 3927 analytical results were generated by the laboratory. Analytical results were not generated for method ASTMD3977C (suspended sediment concentration) for two sample locations from sampling event SE23, and for method EPA410.4 (chemical oxygen demand) for one location from sampling event SE24, due to insufficient sample volume. Of the 3927 analytical results generated by the laboratory, two results were "R"-qualified and 3925 results were considered usable, for an overall project completeness of 99.62 percent.

The results of the completeness calculations are shown below in TableB3.6. All completeness results met the project completeness target of 90 percent.

Table B3.6. Project Completeness.

Completeness	Planned (count)	Collected/Generated (count)	Usable* (count)	Completeness (Percent)**
Sampling completeness $\left(\frac{\#\text{samples collected}}{\#\text{samples planned}} \times \mathbf{100}\right)$	212	212	212	100
Analytical completeness $\left(\frac{\#\text{usable results generated}}{\#\text{results planned}} \times \mathbf{100}\right)$	3940	3927	3925	99.62

*Usable = samples not qualified as rejected ("R")
**Completeness evaluated against the project completeness target of 90%

Comparability

Comparability is a qualitative measure of whether data can be compared to other data sets. Because this study was conducted associated with the City of Seattle's NPDES Municipal Stormwater Permit, these data will be reported to Washington State Department of Ecology and potentially used in conjunction with other water quality data sets. The field sample analyses were performed using standard analytical methods for water approved under 40 CFR (Code of Federal Regulations) Part 136, Section 136.3. Following these standard procedures, the data are expected to be comparable with other data sets for a similar matrix; in this case, stormwater runoff under similar treatments (i.e., swept versus unswept street conditions). The overall confidence in data comparability will be evaluated as part of the final data quality assessment considering all project MQOs, in Section B5 below.

B4. Field Sample QC Results

The following section discusses the results of QC samples generated in the field or laboratory by field staff. The project goal was to collect one round of field QC blanks during Year 1 and one round during Year 2.

B4.1 Field Equipment Blanks

Field Equipment Blanks Year 1

The first round of field equipment blanks samples were collected during Year 1. A tubing blank was collected on each of the four automatic sampler tubing on November 5, 2014. A sampling processing blank was taken on the combination of composite bottle and churn splitter on November 17, 2014. Based the results of this bottle/churn sample, corrective actions were initiated by the laboratory and a second sample processing blank was taken on December 17, 2014. Year 1 field blank results are presented in the following table.

Table B4.1a. Analytical Summary – Field blank samples (Year 1).

	Sample ID	SS2_Tubing Blank	SS3_Tubing Blank	SS4_Tubing Blank	SS5_Tubing Blank	Churn_Bottle Blank	Churn_Bottle Blank
	Date	05 Nov 2014	05 Nov 2014	05 Nov 2014	05 Nov 2014	17 Dec 2014	17 Dec 2014
Analyte	Units						
Metals							
Copper, Total	ug/l	0.6	0.8	0.8	0.5	0.5 U	NA
Zinc, Total	ug/l	4 U	4 U	4 U	4 U	4 U	NA
Nutrients							
Nitrate + Nitrite	mg/l	0.01 U	0.01 U	0.01 U	0.01 U	0.04	0.01 U
Phosphorus, Total	mg/l	0.008 U	0.008 U	0.008 U	0.008 U	0.008 U	NA

NA – not analyzed

Tubing blanks were non-detect for all analytes except for minor detections of total copper ranging from 0.5 to 0.8 micrograms per liter (µg/L). The detected range of the total copper in the associated stormwater samples was greater than ten (10) times the amount detected in the highest blank so no corrective action or sample qualification were needed.

The first combination composite bottle/churn splitter blank collected on November 17, 2014 was non-detect for all analytes except for 0.04 milligrams nitrogen per liter (mg-N/L) of nitrate-nitrite. Although this result was just above the reporting limit of 0.01 mg-N/L, it was within ten (10) times some of the initial stormwater sample results so correction action was required. SPU observed the nitrate-nitrite contamination during early data screening and requested that the field and laboratory staff investigate. After extensive testing, the source of contamination was determined to be a sodium hydroxide (NaOH) solution used by the lab to preserve samples immediately prior to analysis. Corrective action was taken by the lab and another composite bottle/churn splitter blank was taken on December 17, 2014 which was non-detect for nitrate-nitrite and the lab has since observed no recurrence of the contamination.

The corrective actions were put in place by December 15, 2014. Sample results within 10 times the blank concentrations and collected prior to December 15, 2014 have been qualified as discussed in the following section.

Nitrate-nitrite results for stormwater samples collected using the same field collection and laboratory preservation procedures as the composite bottle/churn splitter ("Churn_Bottle") blank collected on November 17, 2014 and before corrective action was taken on December 15, 2014 were qualified based on the following criteria:

- No additional qualification was made to sample results reported as non-detect ("U-" qualified) at the method reporting limit (RL).
- Sample results reported as detected above the RL but less than the concentration of the churn bottle blank were qualified as non-detect at the reported concentration of the sample.
- Sample results reported as detected at or above the churn bottle blank concentration but less than ten (10) times the churn bottle blank concentration were qualified as estimated ("J-" qualified).
- No qualification was made to sample results reported as detected at or above ten (10) times the concentration of the churn bottle blank.

Field Equipment Blanks – Year 2

An additional round of tubing blanks was collected during Year 2 (2015-2016). A tubing blank was collected on each of the four automatic sampler tubes, and one sampling processing blank was taken on the combination of composite bottle and churn splitter the composite bottle and churn splitter on September 9 and 18, 2015, respectively. These blank results are presented in the following table.

Table B4.1b. Analytical Summary – Field blank samples (Year 2 - Round 1).

	Sample ID	SS2_Tubing Blank	SS3_Tubing Blank	SS4_Tubing Blank	SS5_Tubing Blank	Churn_Bottle Blank
	Date	09 Sep 2015	18 Sep 2015	09 Sep 2015	09 Sep 2015	09 Sep 2015
Analyte	Units					
Metals						
Copper, Total	ug/l	3.5	0.7	1.7	0.5 U	1.1
Zinc, Total	ug/l	8	4 U	4 U	4 U	4 U
Nutrients						
Nitrate + Nitrite	mg/l	0.017	0.014	0.01 U	0.011	0.01 U
Phosphorus, Total	mg/l	0.013	0.014	0.012	0.008 U	0.008 U

Several parameters were detected at low concentrations in the September 2015 tubing blanks as discussed below, which resulted in corrective field action (discussed later in this section) and flagging the associated primary samples results, where applicable. Since these September 2015 blanks were the first round of blanks collected since the previous (Year 1) blanks in November 2014, a decision was required as to which primary samples from which dates were potentially impacted by contaminants measured in the September 2015 tubing blanks. Since the November 2014 (Year 1) blanks tested "clean" indicating there was no residual contamination on the tubing at that time, the working assumption is that the three additional events sampled in calendar year 2014 (events SE02 to SE04) were also collected under conditions when the tubing, bottle and churn were still clean enough to not impact the primary sample results. Therefore, no retrospective flagging will be done on 2014 samples.

With the assumption that tubing contamination accumulates in a linear manner over sampling events, primary samples beginning in calendar 2015 may have been potentially impacted by levels of residual contamination at concentrations high enough to warrant considering the primary data as estimates. Therefore, a conservative approach to flagging primary sample data was taken: all primary sample data collected from January 2015 and ending prior to blanks collected in September 2015 were evaluated for flagging. The associated primary sample concentrations that were within ten (10) times the blank result collected on tubing at the corresponding location where the blank was collected were flagged as estimated (J). Primary sample results that were greater than ten (10) times the associated blanks result were not flagged. A total of 13 primary sample results were qualified based on tubing blank contamination.

Total copper tubing blank sample concentrations from September 2015 ranged from non-detect to 3.5 micrograms per liter (µg/L). Corresponding total copper concentrations in all January to September 2015 primary samples ranged from 19.8 to 133 µg/L. The blank hits resulted in two SS2 primary samples, SS2-020915-C and SS2-03142015-C, flagged as estimated (J).

Total zinc was detected in the tubing blank sample from SS2 only from September 2015 at a concentration of 8 µg/L. Corresponding total zinc concentrations in all January to September 2015 SS2 primary samples ranged from 68 to 390 µg/L. The blank hit resulted in two SS2 primary samples, SS2-020915-C and SS2-03142015-C, flagged as estimated (J).

Nitrate-nitrite tubing blank sample concentrations from September 2015 ranged from non-detect to 0.07 milligrams per Liter (mg/L). Corresponding nitrate-nitrite concentrations in all January to September 2015 primary samples ranged from 0.046 to 0.679 µg/L. The blank hits resulted in three SS2 samples, SS2-020615-C, SS2-020615-CD, and SS2-011515-C; three SS3 samples, SS3-020615-C, SS3-020615-CD, and SS3-011515-C; and two SS5 samples, SS5-020615-C and SS5-020615-CD, flagged as estimated (J).

Total phosphorus tubing blank concentrations from September 2015 ranged from non-detect to 0.014 mg/L. Corresponding total phosphorus concentrations in all January to September 2015 primary samples ranged from 0.126 to 1.3 mg/L. The blank hits resulted in one SS3 sample, SS3-020915-C, flagged as estimated (J).

The only parameter detected in the churn/bottle blank sample was total copper at a concentration of 1.1 µg/L. The detected range of the total copper in the associated stormwater samples was greater than ten (10) times this blank concentration so no corrective action or sample qualification were needed related to the churn/bottle blank.

Based on the September 2015 tubing blank results, corrective action was considered necessary. However, it is important to note that passing DI water through sample tubing provides "worst-case scenario" assessment of residual contamination since DI water, because it is free of ions, salts, metals, trace elements, and micro-particles; acts like to a solvent to scavenge any trace concentrations from the sampling equipment. All sample tubing was replaced with new Teflon-lined tubing and the tubing and internal parts of the automatic sampler that contacts stormwater were decontaminated using the solutions listed in the body of the report (soapy, 10 percent nitric, and DI rinses). Following this corrective action, another round of tubing blanks was collected on October 9, 2015 and the results are presented in the table below.

Table B4.1c. Analytical Summary – Field QC samples (Year 2 - Round 2).

	Sample ID	SS2_Tubing Blank	SS3_Tubing Blank	SS4_Tubing Blank	SS5_Tubing Blank
	Date	09 Oct 2015	09 Oct 2015	09 Oct 2015	09 Oct 2015
Analyte	Units				
Metals					
Copper, Total	ug/l	0.7	0.7	0.5 U	0.5 U
Zinc, Total	ug/l	4 U	4 U	4 U	4 U
Nutrients					
Nitrate + Nitrite	mg/l	0.05 U	0.016	0.01 U	0.01 U
Phosphorus, Total	mg/l	0.01 U	0.01 U	0.01 U	0.01 U

The second round of tubing blanks was non-detect for most analytes except for minor detections of total copper and nitrate+nitrite. The total copper concentrations ranged from non-detect up to 0.7 µg/L and nitrate+nitrite was detected in the blank from SS3 at a concentration of 0.016. The detected amount of the total copper and nitrate + nitrite in the associated stormwater samples was greater than ten (10) times the amount detected in the highest blank so no addition corrective action or sample qualification were needed.

B4.2 Field Duplicate Samples

Field Duplicates Year 1

Year 1 field duplicate (field split samples or FSS) samples were generated in the laboratory for samples collected at four locations (SS2-5) on February 6, 2015. Relative percent difference (RPD) or absolute difference (|Δ|) values between the primary (parent) (SSx-020615-C) and field split (SSx-020615-CD) samples were calculated for each sampling location for each analytical parameter to help evaluate laboratory analysis precision. In the cases where RPD values exceeded the project control limit (CL) (25 percent), parent and field split samples at that specific location were qualified, as applicable. If both parent and field split samples were less than five times (< 5x) the laboratory reporting limit (RL), the absolute difference (|Δ|) between parent and field split samples, rather than the RPD criterion, was used to evaluate precision; in this case, if |Δ| exceeded the RL, parent and field split samples at that specific location were qualified, as applicable. A detailed description of sample qualification by analytical parameter is provided below.

- *Chemical Oxygen Demand (COD)*. RPD values between parent and field split sample results were greater the project CL at locations SS2 and SS4. Parent samples from two of the four locations, COD results for samples SS2-020615-C, SS2-020615-CD, SS4-020615-C, and SS4-020615-CD were qualified as estimated (J) on this basis.

- *Total Copper*. The RPD value between parent and field split sample results was greater the project CL at location SS2. A parent sample from one of the four locations, total copper results for samples SS2-020615-C and SS2-020615-CD were qualified as estimated (J) on this basis.

- *Total Kjeldahl Nitrogen (TKN)*. TKN results for parent and field split sample were both < 5x the RL and the |Δ| value was greater than the RL at location SS4. A parent sample from one of the four locations, TKN results for samples SS4-020615-C and SS4-020615-CD were qualified as estimated (J) on this basis.

- *Total Phosphorus*. The RPD value between parent and field split sample results was greater the project CL at location SS2. A parent sample from one of the four locations, total phosphorus results for samples SS2-020615-C and SS2-020615-CD were qualified as estimated (J) on this basis.

- *Suspended Sediment Concentration ("Sediment Concentration")*. Samples from each location were analyzed for five Sediment Concentration (Conc.) size fractions; in addition, a total value was calculated from the five size fractions. Twelve (12) of the 24 total parent sample results from all locations were qualified as estimated (J). The RPD or |Δ| values between parent and field split sample results were greater the project CLs for the following specific analytes and locations:

    - Sediment Conc. < 3.9 um; locations SS3, SS4, SS5. Parent samples from three of the four locations, Sediment Conc. < 3.9 um results for samples SS3-020615-C, SS3-020615-CD, SS4-020615-C, SS4-020615-CD, SS5-020615-C, and SS5-020615-CD were qualified as estimated (J) on this basis.

    - Sediment Conc. 62.5 to 3.9 um; location SS3. A parent sample from one of the four locations, Sediment Conc. 62.5 to 3.9 um results for samples SS3-020615-C and SS3-020615-CD were qualified as estimated (J) on this basis.

    - Sediment Conc. 500 to 250 um; locations SS2, SS3, SS4. Parent samples from three of the four locations, Sediment Conc. 500 to 250 um results for samples SS2-020615-C, SS2-020615-CD, SS3-020615-C, SS3-020615-CD, SS4-020615-C, and SS4-020615-CD were qualified as estimated (J) on this basis.

- Sediment Conc. > 500 um; locations SS2, SS3, SS4. Parent samples from three of the four locations, Sediment Conc. > 500 um results for samples SS2-020615-C, SS2-020615-CD, SS3-020615-C, SS3-020615-CD, SS4-020615-C, and SS4-020615-CD were qualified as estimated (J) on this basis.

- Sediment Conc. Total; locations SS2, SS3. Parent samples from two of the four locations, Sediment Conc. Total results for samples SS2-020615-C, SS2-020615-CD, SS3-020615-C, and SS3-020615-CD were qualified as estimated (J) on this basis.

- *Total Suspended Solids (TSS)*. The RPD value between parent and field split sample results was greater the project CL at location SS2. A parent sample from one of the four locations, TSS results for samples SS2-020615-C and SS2-020615-CD were qualified as estimated (J) on this basis.

- *Total Organic Carbon (TOC)*. The RPD value between parent and field split sample results was greater the project CL at location SS5. A parent sample from one of the four locations, TOC results for samples SS5-020615-C and SS5-020615-CD were qualified as estimated (J) on this basis.

- *Dissolved Zinc*. Dissolved zinc results for parent and field split sample were both < 5x the RL and the |Δ| value was greater than the RL at location SS3. A parent sample from one of the four locations, dissolved zinc results for samples SS3-020615-C and SS3-020615-CD were qualified as estimated (J) on this basis.

Field Duplicates Year 2

Year 2 field duplicate (split) samples were generated in the laboratory for samples collected at four locations (SS2-5) on January 22, 2016. Relative percent difference (RPD) or absolute difference (|Δ|) values between the parent (SSx-012216-C) and field split (SSx-012216-CD) samples were calculated for each sampling location for each analytical parameter to help evaluate laboratory analysis precision. In the cases where RPD values exceeded the project CL (25 percent), parent and field split samples at that specific location were qualified, as applicable. If both parent and field split samples were less than five times (< 5x) the RL, the absolute difference (|Δ|) between the parent and field split samples, rather than the RPD criterion, was used to evaluate precision; in this case, if |Δ| exceeded the RL, the parent and field split samples at that specific location were qualified, as applicable. A detailed description of sample qualification by analytical parameter is provided below.

- *Chemical Oxygen Demand (COD)*. The RPD value between parent and field split sample results was greater the project CL at location SS3. A parent sample from one of the four locations, COD results for samples SS3-012216-C and SS3-012216-CD were qualified as estimated (J) on this basis.

- *Dissolved Copper*. The RPD value between parent and field split sample results was greater the project CL at location SS3. A parent sample from one of the four locations, dissolved copper results for samples SS3-012216-C and SS3-012216-CD were qualified as estimated (J) on this basis.

- *Total Kjeldahl Nitrogen (TKN)*. The RPD value between parent and field split sample results was greater the project CL at location SS3. A parent sample from one of the four locations, TKN results for samples SS3-012216-C and SS3-012216-CD were qualified as estimated (J) on this basis.

- *Total Phosphorus*. The RPD values between parent and field split sample results were greater the project CL at locations SS3 and SS5. Parent samples from two of the four locations, total phosphorus results for samples SS3-012216-C, SS3-012216-CD, SS5-012216-C, and SS5-012216-CD were qualified as estimated (J) on this basis.

- *Suspended Sediment Concentration ("Sediment Concentration")*. Samples from each location were analyzed for five Sediment Concentration size fractions; in addition, a total value was calculated from the five size fractions. Fifteen (15) of the 24 total parent sample results from all locations were qualified as estimated (J). The RPD or |Δ| values between parent and field split sample results were greater the project CLs for the following analytes and specific locations:

    - Sediment Conc. < 3.9 um; locations SS2, SS3, SS5. Parent samples from three of the four locations, Sediment Conc. < 3.9 um results for samples SS2-012216-C, SS2-012216-CD, SS3-012216-C, SS3-012216-CD, SS5-012216-C, and SS5-012216-CD were qualified as estimated (J) on this basis.

    - Sediment Conc. 62.5 to 3.9 um; locations SS2, SS5. Parent samples from two of the four locations, Sediment Conc. 62.5 to 3.9 um results for samples SS2-012216-C, SS2-012216-CD, SS5-012216-C, and SS5-012216-CD were qualified as estimated (J) on this basis.

- Sediment Conc. 500 to 250 um; locations SS2, SS3. Parent samples from two of the four locations, Sediment Conc. 500 to 250 um results for samples SS2-012216-C, SS2-012216-CD, SS3-012216-C, and SS3-012216-CD were qualified as estimated (J) on this basis.

- Sediment Conc. > 500 um; locations SS2, SS3, SS4, SS5. Parent samples from four of four locations, Sediment Conc. > 500 um results for samples SS2-012216-C, SS2-012216-CD, SS3-012216-C, SS3-012216-CD, SS4-012216-C, SS4-012216-CD, SS5-012216-C, and SS5-012216-CD were qualified as estimated (J) on this basis.

- Sediment Conc. Total; locations SS2, SS3, SS4, SS5. Parent samples from four of four locations, Sediment Conc. Total results for samples SS2-012216-C, SS2-012216-CD, SS3-012216-C, SS3-012216-CD, SS4-012216-C, SS4-012216-CD, SS5-012216-C, and SS5-012216-CD were qualified as estimated (J) on this basis.

- *Total Suspended Solids (TSS).* RPD values between parent and field split sample results were greater the project CL at locations SS3 and SS4. Parent samples from two of the four locations, TSS results for samples SS3-012216-C, SS3-012216-CD, SS4-012216-C, and SS4-012216-CD were qualified as estimated (J) on this basis.
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Tables presenting field duplicate sample results are included at the end of this Appendix.

B5. Data Quality Assessment Summary

Data were reviewed with respect to the project measurement quality objectives (MQOs), and validation qualifiers were applied based on the data quality indicators (laboratory control limits and/or project criteria) for each MQO. The MQOs sample preservation and holding time, blanks (representativeness), precision, accuracy, target analyte identification, completeness, and comparability were reviewed individually; and these MQOs together were used to assess the overall comparability, completeness, and usability of the data for this study. The field sample analyses were performed using standard analytical methods, and, as such, the data are considered comparable, as qualified, with other data sets for stormwater runoff under similar treatments, i.e., swept versus unswept street conditions, per the objectives of this study.

Completeness measures met the project completeness criterion of 90 percent. All 212 planned field samples were collected, for a sampling completeness of 100 percent. Of the total 3940 analytical results planned, 3925 usable results were generated by the analytical laboratory, for an analytical completeness of 99.62 percent. Thirteen analytical results were not generated due to low sample volume, and two analytical results were “R”-qualified due to target analyte identification. Of these 3925 analytical results, all are considered usable, as qualified.

Table B4.2a. Field Duplicate Sample Results – Year 1.

	Location:	SS2					SS3					SS4					SS5				
	Sample ID:		SS2-020615-C	SS2-020615-CD				SS3-020615-C	SS3-020615-CD				SS4-020615-C	SS4-020615-CD				SS5-020615-C	SS5-020615-CD		
	Date Sampled:		2/6/15	2/6/15				2/6/15	2/6/15				2/6/15	2/6/15				2/6/15	2/6/15		
	Sample Type:		Parent	Split				Parent	Split				Parent	Split				Parent	Split		
Analyte	Units	RL[a]	Result	Result	RPD or |Δ|	Qualifier	RL[a]	Result	Result	RPD or |Δ|	Qualifier	RL[a]	Result	Result	RPD or |Δ|	Qualifier	RL[a]	Result	Result	RPD or |Δ|	Qualifier
Chemical Oxygen Demand	mg/l	10	66.2	45	**38.13%**	**J**	10	51.4	50.7	1.37%		10	69.4	44	**44.80%**	**J**	10	61.4	53.6	13.57%	
Copper, Dissolved	ug/l	0.5	3.9	3.4	13.70%		0.5	3.4	3.5	2.90%		0.5	2.8	2.8	0.00%		0.5	4	3.7	7.79%	
Copper, Total	ug/l	0.5	45.6	67	**38.01%**	**J**	0.5	41.3	46.6	12.06%		0.5	24.9	22.4	10.57%		0.5	34.5	33.9	1.75%	
Hardness	ug/l	331	37000	35000	5.56%		331	43000	42000	2.35%		331	36000	34000	5.71%		331	35000	35000	0.00%	
Nitrate + Nitrite	mg/l	0.01	0.048	0.049	0.001		0.01	0.046	0.052	12.24%		0.01	0.05	0.049	2.02%		0.01	0.047	0.049	0.002	
Nitrogen, Total Kjeldahl	mg/l	0.5	1.2	1.3	0.1		0.5	1.4	1.6	0.2		0.5	1	1.8	**0.8**	**J**	0.5	1.3	1.4	0.1	
Phosphorus, Total	mg/l	0.008	0.267	0.2	**28.69%**	**J**	0.008	0.252	0.309	20.32%		0.008	0.189	0.177	6.56%		0.008	0.183	0.186	1.63%	
SSC < 3.9 um	mg/l	0.01	11.18	12.44	10.67%		0.01	48.29	17.1	**95.40%**	**J**	0.01 (55.81)	10.8[b]	<55.81	9.51%		0.01 (63.58)	12.82[b]	<63.58	17.00%	
SSC > 500 um	mg/l	0.01	139.79	21.98	**145.7%**	**J**	0.01	244.58	31.79	**154.0%**	**J**	0.01	55.97	34.49	**47.49%**	**J**	0.01	9.02	10	10.30%	
SSC 250 to 62.5 um	mg/l	0.01	92.32	52.86	**54.36%**	**J**	0.01	106.9	81.81	**26.59%**	**J**	0.01	45.07	44.1	2.18%		0.01	19.3	19.9	3.06%	
SSC 500 to 250 um	mg/l	0.01	93.47	31.93	**98.15%**	**J**	0.01	72.56	48.15	**40.44%**	**J**	0.01	43.17	29.79	**36.68%**	**J**	0.01	3.36	3.58	6.34%	
SSC 62.5 to 3.9 um	mg/l	0.01	74.79	59.46	22.84%		0.01	142.57	99.24	**35.84%**	**J**	0.01 (55.81)	50.58[b]	<55.81	9.51%		0.01 (63.58)	62.57[b]	<63.58	17.00%	
SSC Total	mg/l	0.01	411.55	178.67	**78.91%**	**J**	0.01	614.9	278.09	**75.43%**	**J**	0.01	205.59	164.19	22.39%		0.01	107.07	97.05	9.82%	
Solids, Total Suspended	mg/l	3.3	125	75	**50.00%**	**J**	2.5 (2.8)	114	137	18.33%		3.6 (2.9)	78.6	69.4	12.43%		3.3 (2.9)	75	84	11.32%	
Total Organic Carbon	mg/l	1.5	11	12.4	11.97%		1.5	12.3	13.5	9.30%		1.5	9.02	9.07	0.55%		1.5	10.4	14.6	**33.60%**	**J**
Zinc, Dissolved	ug/l	4	13	11	2		4	9	15	**6**	**J**	4	9	9	0		4	9	8	1	
Zinc, Total	ug/l	4	105	107	1.89%		4	136	138	1.46%		4	71	68	4.32%		4	92	99	7.33%	

Notes:
Bold values = exceeds RPD Control Limits (per QAPP Table 7)
|Δ| = Absolute value of difference between parent, split results
RL = Reporting Limit
RPD = Relative percent difference
SSC = Suspended Sediment Concentration
[a] The listed RL is for the parent sample; in the cases where the RL differed between the parent and split samples, the split sample RL is given in parentheses.
[b] Because the RL was elevated for the field split sample for the analytes SSC 62.5 to 3.9 um and SSC < 3.9 um (two smallest particle size fractions), and the same RL was applied to both these fractions combined, the sum of the parent sample results for these two size fractions and the RL value were used to calculate the RPD for each size fraction.

Table B4.2b. Field Duplicate Sample Results – Year 2.

Location:		SS2					SS3					SS4					SS5				
Sample ID:			SS2-012216-C	SS2-012216-CD				SS3-012216-C	SS3-012216-CD				SS4-012216-C	SS4-012216-CD				SS5-012216-C	SS5-012216-CD		
Date Sampled:			1/22/16	1/22/16				1/22/16	1/22/16				1/22/16	1/22/16				1/22/16	1/22/16		
Sample Type:			Parent	Split				Parent	Split				Parent	Split				Parent	Split		
Analyte	Units	RL[a]	Result	Result	RPD or |Δ|	Qualifier	RL[a]	Result	Result	RPD or |Δ|	Qualifier	RL[a]	Result	Result	RPD or |Δ|	Qualifier	RL[a]	Result	Result	RPD or |Δ|	Qualifier
Chemical Oxygen Demand	mg/l	10	34.9	39.5	4.6		10	85.2	115	**29.77%**	**J**	10	46.1	50.4	8.91%		10	55.9	58.9	5.23%	
Copper, Dissolved	ug/l	0.5	2.7	2.8	3.64%		0.5	2.6	3.7	**34.92%**	**J**	0.5	2.4	2.5	4.08%		0.5	2.6	2.5	3.92%	
Copper, Total	ug/l	0.5	26.6	25.1	5.80%		0.5	32.5	31.4	3.44%		0.5	25.1	24.2	3.65%		0.5	31.4	30.2	3.90%	
Hardness	ug/l	331	28000	33000	16.39%		331	38000	41000	7.59%		331	41000	36000	12.99%		331	35000	33000	5.88%	
Nitrate + Nitrite	mg/l	0.01	0.086	0.096	10.99%		0.01	0.086	0.105	19.90%		0.01	0.083	0.081	2.44%		0.01	0.107	0.089	18.37%	
Nitrogen, Total Kjeldahl	mg/l	0.5	1.1	1.2	0.1		0.5 (1)	1.2	14	**12.8**	**J**	0.5	1.2	0.95	0.3		0.5	1.4	1.6	0.2	
Phosphorus, Total	mg/l	0.008	0.11	0.096	13.59%		0.008 (0.016)	0.161	1.19	**152.3%**	**J**	0.008	0.144	0.178	21.12%		0.008	0.245	0.163	**40.20%**	**J**
SSC < 3.9 um	mg/l	0.1	6.3	2.2	**96.47%**	**J**	0.1	7.8	4.6	**51.61%**	**J**	0.1	4.6	4.6	0.00%		0.1	7.5	5.2	**36.22%**	**J**
SSC > 500 um	mg/l	0.1	15.9	9	**55.42%**	**J**	0.1	446.9	224.9	**66.09%**	**J**	0.1	241.3	70.8	**109.3%**	**J**	0.1	200.1	119.8	**50.20%**	**J**
SSC 250 to 62.5 um	mg/l	0.1	34	28.8	16.56%		0.1	72.6	61.7	16.23%		0.1	41.2	44.3	7.25%		0.1	48.3	40.2	18.31%	
SSC 500 to 250 um	mg/l	0.1	8.7	6.5	**28.95%**	**J**	0.1	110	58.7	**60.82%**	**J**	0.1	50.9	58.7	14.23%		0.1	47.5	41.2	14.21%	
SSC 62.5 to 3.9 um	mg/l	0.1	35.7	15.6	**78.36%**	**J**	0.1	52.9	44.1	18.14%		0.1	31.4	30.3	3.57%		0.1	51.8	37.6	**31.77%**	**J**
SSC Total	mg/l	0.1	100.7	62.2	**47.27%**	**J**	0.1	690.1	394	**54.63%**	**J**	0.1	369.4	208.7	**55.60%**	**J**	0.1	355.3	244.1	**37.10%**	**J**
Solids, Total Suspended	mg/l	2	70.2	72.2	2.81%		2 (2.5)	141	185	**26.99%**	**J**	2.5 (2)	938	85.2	**166.7%**	**J**	2 (2.5)	110	111	0.90%	
Total Organic Carbon	mg/l	0.5	6.21	6.99	11.82%		0.5	11.6	12.5	7.47%		0.5	7.66	8.76	13.40%		0.5	9.22	9.59	3.93%	
Zinc, Dissolved	ug/l	4	11	11	0		4	10	12	2		4	9	11	2		4	10	10	0	
Zinc, Total	ug/l	4	80	81	1.24%		4	114	112	1.77%		4	87	79	9.64%		4	104	112	7.41%	

Notes:
Bold values = exceeds RPD Control Limits (per QAPP Table 7)
|Δ| = Absolute value of difference between parent, split results
RL = Reporting Limit
RPD = Relative percent difference
SSC = Suspended Sediment Concentration
[a] The listed RL is for the parent sample; in the cases where the RL differed between the parent and split samples, the split sample RL is given in parentheses.

APPENDIX C. HYDROLOGIC AND ANALYTICAL DATA SUMMARY TABLES

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Table C1. Event Hydrologic Data – All Sites, All Events.

Analyte Name	Goal	SE-01	SE-02	SE-03	SE-04	SE-05	SE-06	SE-07	SE-08	SE-09	SE-10	SE-11	SE-12	SE-13	SE-14	SE-15	SE-16	SE-17	SE-18	SE-19	SE-20	SE-21	SE-22	SE-23	SE-24
RG-SS5 Precipitation Summary																									
Precip Start	NA	10/25/2014 8:20	11/21/2014 3:35	12/6/2014 00:25	12/9/2014 21:10	01/15/2015 14:20	02/05/2015 12:55	02/08/2015 21:05	03/13/2015 23:10	05/13/2015 13:00	07/26/2015 16:50	10/10/2015 04:35	10/25/2015 16:10	10/30/2015 03:10	11/07/2015 08:45	11/12/2015 16:30	11/16/2015 23:45	12/01/2015 18:15	12/17/2015 07:55	1/16/2016 00:00	1/20/2016 10:40	2/29/2016 22:45	3/23/2016 18:00	7/8/2016 22:40	9/1/2016 22:30
Precip Stop	NA	10/25/2014 19:45	11/21/2014 19:10	12/6/2014 6:50	12/10/2014 7:50	01/15/2015 23:40	02/06/2015 14:45	02/09/2015 01:55	03/14/2015 09:00	05/14/2015 01:35	07/26/2015 18:10	10/10/2015 15:25	10/26/2015 12:20	11/01/2015 16:45	11/08/2015 11:10	11/15/2015 08:20	11/17/2015 20:00	12/02/2015 06:20	12/18/2015 06:25	1/16/2016 17:10	1/22/2016 8:50	3/2/2016 6:05	3/24/2016 00:05	7/9/2016 1:15	9/2/2016 10:20
Storm Event Duration (hrs)	NA	11.4	15.6	6.4	10.7	9.3	25.8	4.8	9.8	12.6	1.3	10.8	20.2	61.6	26.4	63.8	20.3	12.1	22.5	17.2	36.2	31.3	6.1	2.6	11.8
Event Rainfall (in)	≥ 0.15	0.38	0.66	0.22	0.41	0.40	1.20	0.13	0.70	0.22	0.10	0.68	0.40	1.68	0.58	3.47	0.58	0.36	1.09	0.39	1.54	0.74	0.12	0.10	0.27
Storm Event Rainfall Mean (in/hr)	NA	0.03	0.04	0.03	0.04	0.04	0.05	0.03	0.07	0.02	0.08	0.06	0.02	0.03	0.02	0.05	0.03	0.03	0.05	0.02	0.04	0.02	0.02	0.04	0.02
Event Rainfall Max (in/hr)	NA	4.32	2.88	2.88	2.88	0.12	0.36	0.24	0.48	0.12	0.24	0.48	0.24	0.48	0.24	0.72	0.48	0.12	0.36	0.24	0.24	0.24	0.12	0.12	0.36
Antecedent Dry Period (hrs)	>6	10	26	14	10	100	4	23	64	14	902	62	164	31	118	39	9	179	31	61	24	20	46	18	602
SS2 Flow and Sampling Summary																									
Event Total Flow Mean (gpm)	NA	1.4	3.3	2.3	3.8	2.7	4.2	2.7	4.1	1.3	2.7	5.5	1.6	3.6	4.2	8.9	4.4	2.6	4.6	1.7	5.5	2.4	0.7	1.8	3.1
Flow Duration (hrs)	>1	11.3	16.3	9.0	12.2	13.2	27.7	4.0	16.7	10.2	2.3	16.8	17.3	54.0	29.3	66.9	23.3	11.7	28.3	18.3	42.3	32.8	12.3	3.8	6.1
First Sample Time	NA	10/25/2014 15:07	11/21/2014 3:40	12/6/2014 00:25	12/9/2014 21:20	01/15/2015 14:25	02/05/2015 16:10	02/08/2015 21:05	03/13/2015 23:47	05/13/2015 13:05	07/26/2015 16:52	10/10/2015 04:50	10/25/2015 16:12	10/30/2015 02:40	11/07/2015 09:02	11/12/2015 18:25	11/17/2015 02:47	12/01/2015 18:25	12/17/2015 07:50	1/16/2016 00:10	1/20/2016 10:50	2/29/2016 23:00	3/23/2016 18:05	7/8/2016 22:52	9/1/2016 22:55
Last Sample Time	NA	10/25/2014 19:17	11/21/2014 17:32	12/6/2014 4:27	12/10/2014 3:37	01/15/2015 23:27	02/06/2015 14:52	02/09/2015 05:27	03/14/2015 07:12	05/13/2015 21:27	07/26/2015 17:57	10/10/2015 14:17	10/26/2015 10:27	11/01/2015 19:32	11/08/2015 05:57	11/15/2015 07:32	11/17/2015 20:12	12/02/2015 02:17	12/18/2015 06:27	1/16/2016 7:22	1/22/2016 7:07	3/2/2016 6:12	3/23/2016 23:47	7/9/2016 1:32	9/2/2016 10:32
Event Total Flow Max (gpm)	NA	21.8	20.4	23.5	22.9	15.4	30.6	23.3	57.5	34.6	12.5	64.6	14.7	47.0	26.0	56.2	41.3	10.7	32.6	15.5	30.5	20.1	6.2	9.4	30.4
No. Composite Sample Aliquots	≥ 10	10	100	12	24	18	98	29	41	24	14	100	84	43	92	57	62	34	71	12	47	25	17	21	73
Event Flow Volume Sampled (%)	≥ 75	84.3	97.5	98.5	98.4	93.9	97.2	99.9	96.4	96.7	84.1	85.9	87.8	100.0	73.7	98.6	98.2	97.7	99.4	78.7	98.2	99.7	95.2	96.5	99.1
Sample Duration (hrs)	<36	4.2	13.9	4.0	6.3	9.0	22.7	8.4	7.4	8.4	1.1	9.5	18.3	64.9	20.9	61.1	17.4	7.9	22.6	7.2	34.3	31.2	5.7	2.7	11.6
Flow Start	NA	10/25/2014 8:25	11/21/2014 3:40	12/6/2014 00:20	12/9/2014 21:10	01/15/2015 14:20	02/05/2015 12:50	02/08/2015 21:05	03/13/2015 23:10	05/13/2015 12:55	07/26/2015 16:50	10/10/2015 04:35	10/25/2015 16:05	10/30/2015 02:35	11/07/2015 08:40	11/12/2015 16:25	11/16/2015 23:45	12/01/2015 18:15	12/17/2015 07:50	1/15/2016 23:55	1/20/2016 20:35	2/29/2016 22:45	3/23/2016 17:55	7/8/2016 22:48	9/1/2016 22:25
Flow Stop	NA	10/25/2014 22:10	11/21/2014 20:55	12/6/2014 13:10	12/10/2014 12:40	01/16/2015 03:30	02/06/2015 16:25	02/09/2015 08:35	03/14/2015 17:00	05/13/2015 23:00	07/26/2015 19:00	10/10/2015 21:20	10/26/2015 14:25	11/01/2015 19:40	11/08/2015 13:50	11/15/2015 14:15	11/17/2015 23:10	12/02/2015 05:50	12/18/2015 12:20	1/16/2016 21:00	1/22/2016 14:45	3/2/2016 12:05	3/24/2016 6:05	7/9/2016 2:26	9/2/2016 11:25
Event Total Flow Volume (gal)	NA	949	3,233	1,224	2,793	2,163	7,002	646	4,126	803	371	5,511	1,700	11,509	7,446	35,784	6,198	1,849	7,762	1,880	14,061	4,804	502	420	1,144
SS3 Flow and Sampling Summary																									
Event Total Flow Mean (gpm)	NA	0.9	1.2	1.1	2.0	1.1	1.1	0.7	0.6	0.4	0.8	2.3	0.5	1.3	0.6	1.1	0.9	0.8	1.7	0.4	1.0	0.4	0.3	0.4	1.5
Flow Duration (hrs)	>1	18.2	17.5	14.6	15.6	17.5	32.0	5.8	15.1	10.3	2.0	8.8	16.6	28.8	29.3	60.9	18.8	10.1	22.8	23.3	42.3	33.2	6.5	4.2	2.6
First Sample Time	NA	10/25/2014 14:00	11/21/2014 3:47	12/6/2014 00:25	12/9/2014 21:20	01/15/2015 14:25	02/05/2015 16:05	02/08/2015 21:12	03/13/2015 23:10	05/13/2015 13:00	07/26/2015 16:52	10/10/2015 04:50	10/25/2015 16:17	10/30/2015 02:40	11/07/2015 08:42	11/12/2015 18:50	11/17/2015 02:37	12/01/2015 18:25	12/17/2015 08:00	1/16/2016 00:05	1/20/2016 20:50	3/1/2016 2:32	3/23/2016 18:05	7/8/2016 22:50	9/1/2016 23:00
Last Sample Time	NA	10/25/2014 21:57	11/21/2014 18:32	12/6/2014 11:27	12/10/2014 7:52	01/15/2015 23:52	02/06/2015 15:27	02/09/2015 00:32	03/14/2015 09:37	05/13/2015 21:17	07/26/2015 18:02	10/10/2015 15:12	10/26/2015 08:17	11/01/2015 15:12	11/08/2015 05:52	11/15/2015 05:07	11/17/2015 19:15	12/02/2015 00:52	12/18/2015 06:17	1/16/2016 10:17	1/22/2016 6:52	3/2/2016 1:17	3/23/2016 23:17	7/9/2016 1:17	9/2/2016 10:25
Event Total Flow Max (gpm)	NA	12.1	7.7	13.0	13.2	7.1	4.8	5.1	2.5	12.0	3.4	15.6	4.7	9.6	6.8	10.9	15.9	2.6	12.6	4.4	6.2	4.9	2.0	2.4	6.8
No. Composite Sample Aliquots	≥ 10	27	84	33	39	24	67	25	35	29	15	86	35	42	73	32	30	34	43	20	35	13	15	14	53
Event Flow Volume Sampled (%)	≥ 75	87.4	98.5	95.1	96.9	96.4	95.4	96.0	97.7	96.0	84.8	98.4	89.7	99.9	70.4	96.7	97.8	95.4	98.1	81.4	97.3	87.4	91.8	89.1	98.5
Sample Duration (hrs)	<36	8.0	14.8	11.0	10.5	9.5	23.4	3.3	10.5	8.3	1.2	10.4	16.0	60.5	21.2	58.3	16.6	6.5	22.3	10.2	34.0	22.8	5.2	2.5	11.4
Flow Start	NA	10/25/2014 8:25	11/21/2014 3:35	12/6/2014 00:20	12/9/2014 21:10	01/15/2015 14:15	02/05/2015 12:50	02/08/2015 21:10	03/13/2015 23:10	05/13/2015 12:55	07/26/2015 16:50	10/10/2015 04:45	10/25/2015 16:05	10/30/2015 02:35	11/07/2015 08:40	11/12/2015 16:25	11/16/2015 23:45	12/01/2015 18:20	12/17/2015 07:50	1/15/2016 23:55	1/20/2016 20:35	2/29/2016 22:55	3/23/2016 17:55	7/8/2016 22:45	9/1/2016 22:50
Flow Stop	NA	10/26/2014 3:40	11/21/2014 21:00	12/6/2014 14:50	12/10/2014 12:40	01/16/2015 07:40	02/06/2015 20:45	02/09/2015 02:55	03/14/2015 14:10	05/13/2015 23:10	07/26/2015 18:45	10/10/2015 15:50	10/26/2015 13:35	11/01/2015 17:15	11/08/2015 13:50	11/15/2015 08:40	11/17/2015 20:55	12/02/2015 04:25	12/18/2015 07:40	1/16/2016 23:10	1/22/2016 14:45	3/2/2016 12:00	3/24/2016 1:00	7/9/2016 7:00	9/2/2016 10:35
Event Total Flow Volume (gal)	NA	956	1,268	980	1,910	1,196	2,071	232	521	222	95	1,216	503	2,220	1,010	3,853	1,026	499	2,358	589	2,628	817	132	94	229
SS4 Flow and Sampling Summary																									
Event Total Flow Mean (gpm)	NA	1.7	0.9	0.8	1.3	1.0	2.5	0.8	1.6	0.4	0.7	2.1	0.8	1.4	0.8	1.7	2.4	1.5	3.4	0.7	2.0	0.9	0.5	0.4	1.5
Flow Duration (hrs)	>1	8.5	16.0	11.0	9.2	12.2	28.8	11.7	17.9	18.7	1.6	10.2	22.4	48.3	27.1	62.8	19.2	10.5	27.3	18.0	42.3	37.0	7.6	2.8	4.7
First Sample Time	NA	10/25/2014 14:27	11/21/2014 3:40	12/6/2014 00:25	12/9/2014 21:25	01/15/2015 14:25	02/05/2015 16:10	02/08/2015 21:10	03/13/2015 23:32	05/13/2015 13:00	07/26/2015 16:52	10/10/2015 04:50	10/25/2015 16:10	10/30/2015 04:07	11/07/2015 09:07	11/12/2015 18:50	11/17/2015 02:42	12/01/2015 18:22	12/17/2015 08:00	1/16/2016 00:05	1/20/2016 20:50	3/1/2016 1:02	3/23/2016 18:05	7/8/2016 22:55	9/1/2016 22:55
Last Sample Time	NA	10/25/2014 19:22	11/21/2014 17:17	12/6/2014 12:12	12/10/2014 7:42	01/15/2015 23:47	02/06/2015 16:57	02/09/2015 03:52	03/14/2015 10:17	05/14/2015 02:37	07/26/2015 17:52	10/10/2015 15:17	10/26/2015 08:02	11/01/2015 15:22	11/08/2015 06:40	11/15/2015 07:02	11/17/2015 20:47	12/02/2015 03:12	12/18/2015 02:12	1/16/2016 10:07	1/22/2016 8:22	3/2/2016 4:22	3/23/2016 23:57	7/9/2016 1:17	9/2/2016 10:42
Event Total Flow Max (gpm)	NA	13.7	3.4	7.8	5.8	4.6	8.8	7.8	13.3	14.8	2.1	14.2	6.0	15.8	6.6	12.6	15.3	5.0	9.8	4.8	9.1	7.0	2.5	1.6	10.5
No. Composite Sample Aliquots	≥ 10	36	100	36	24	30	79	33	81	49	9	81	51	76	98	52	79	61	100	24	66	38	20	7	70
Event Flow Volume Sampled (%)	≥ 75	87.3	95.3	98.8	99.0	97.1	93.2	94.4	98.8	97.2	80.6	98.7	88.3	98.4	75.4	97.8	98.7	97.7	90.1	82.9	98.7	96.4	96.7	86.2	99.5
Sample Duration (hrs)	<36	4.9	13.6	11.8	10.3	9.4	24.8	6.7	10.8	13.6	1.0	10.5	15.9	59.3	21.5	60.2	18.1	8.8	18.2	10.0	35.5	27.3	5.9	2.4	11.8
Flow Start	NA	10/25/2014 8:25	11/21/2014 3:40	12/6/2014 00:20	12/9/2014 21:15	01/15/2015 14:20	02/05/2015 12:50	02/08/2015 21:00	03/13/2015 23:10	05/13/2015 12:55	07/26/2015 16:50	10/10/2015 04:45	10/25/2015 16:05	10/30/2015 02:35	11/07/2015 08:40	11/12/2015 16:25	11/17/2015 02:10	12/01/2015 18:15	12/17/2015 07:50	1/15/2016 23:55	1/20/2016 20:40	2/29/2016 22:40	3/23/2016 17:55	7/8/2016 22:50	9/1/2016 22:50
Flow Stop	NA	10/25/2014 21:40	11/21/2014 20:30	12/6/2014 14:30	12/10/2014 12:40	01/16/2015 02:25	02/06/2015 17:35	02/09/2015 08:35	03/14/2015 17:00	05/14/2015 07:30	07/26/2015 18:20	10/10/2015 16:20	10/26/2015 14:25	11/01/2015 18:25	11/08/2015 13:50	11/15/2015 09:05	11/17/2015 23:00	12/02/2015 04:40	12/18/2015 11:00	1/16/2016 20:35	1/22/2016 14:50	3/2/2016 12:00	3/24/2016 1:25	7/9/2016 1:50	9/2/2016 11:15
Event Total Flow Volume (gal)	NA	874	832	497	693	738	4,247	568	1,686	483	64	1,266	1,077	4,193	1,302	6,294	2,765	927	5,516	706	4971.3	1920.7	211.3	63.8	411.0492
SS5 Flow and Sampling Summary																									
Event Total Flow Mean (gpm)	NA	1.8	1.1	0.9	1.5	0.4	1.7	1.0	2.2	0.4	1.6	3.2	1.0	1.3	1.0	2.0	1.4	1.0	2.2	1.1	2.1	1.4	0.4	0.2	1.2
Flow Duration (hrs)	>1	10.5	13.3	6.1	15.5	10.3	33.9	11.7	13.0	11.5	2.5	12.8	18.0	54.3	29.3	59.3	25.9	17.2	26.6	23.3	38.7	37.4	6.3	4.6	7.3
First Sample Time	NA	10/25/2014 8:27	11/21/2014 8:05	12/6/2014 00:30	12/9/2014 21:25	01/15/2015 14:30	02/05/2015 13:12	02/08/2015 21:22	03/13/2015 23:27	05/13/2015 13:05	07/26/2015 16:57	10/10/2015 04:47	10/25/2015 16:10	10/30/2015 02:45	11/07/2015 09:12	11/12/2015 18:45	11/17/2015 02:32	12/01/2015 18:25	12/17/2015 08:05	1/16/2016 00:00	1/20/2016 20:55	2/29/2016 23:05	3/23/2016 18:10	7/8/2016 22:55	9/1/2016 22:50
Last Sample Time	NA	10/25/2014 19:47	11/21/2014 17:32	12/6/2014 3:22	12/10/2014 8:27	01/15/2015 22:52	02/06/2015 14:12	02/09/2015 08:22	03/14/2015 08:22	05/13/2015 21:27	07/26/2015 18:07	10/10/2015 11:17	10/26/2015 11:17	11/01/2015 17:27	11/07/2015 23:22	11/15/2015 04:02	11/17/2015 21:52	12/02/2015 03:57	12/18/2015 06:22	1/16/2016 10:22	1/22/2016 7:07	3/2/2016 6:02	3/23/2016 23:42	7/9/2016 1:32	9/2/2016 10:42
Event Total Flow Max (gpm)	NA	16.7	7.4	5.5	9.7	1.1	6.8	6.7	24.2	7.2	8.1	28.2	11.8	19.6	9.3	15.2	14.1	6.0	18.4	9.2	12.8	12.1	2.4	0.9	16.6
No. Composite Sample Aliquots	≥ 10	25	22	23	46	9	82	84	17	16	16	100	34	54	20	16	64	69	69	51	64	63	10	7	52
Event Flow Volume Sampled (%)	≥ 75	98.0	95.2	96.6	95.8	87.8	91.6	97.8	95.4	95.0	87.0	70.4	95.4	99.0	69.1	94.0	99.0	98.5	98.1	83.2	98.2	99.6	97.8	90.3	98.8
Sample Duration (hrs)	<36	11.3	9.5	2.9	11.0	8.4	25.0	11.0	8.9	8.4	1.2	6.5	19.1	62.7	14.2	57.3	19.3	9.5	22.3	10.4	34.2	31.0	5.5	2.6	11.9
Flow Start	NA	10/25/2014 8:25	11/21/2014 3:45	12/6/2014 00:25	12/9/2014 21:10	01/15/2015 14:20	02/05/2015 12:50	02/08/2015 21:00	03/13/2015 23:10	05/13/2015 12:55	07/26/2015 16:50	10/10/2015 04:30	10/25/2015 16:05	10/30/2015 02:40	11/07/2015 08:40	11/12/2015 16:35	11/16/2015 23:45	12/01/2015 18:10	12/17/2015 07:55	1/15/2016 23:55	1/20/2016 20:45	2/29/2016 22:45	3/23/2016 18:05	7/8/2016 22:50	9/1/2016 22:25
Flow Stop	NA	10/25/2014 21:30	11/21/2014 19:25	12/6/2014 12:30	12/10/2014 12:40	01/16/2015 01:25	02/06/2015 22:40	02/09/2015 08:35	03/14/2015 12:20	05/14/2015 00:20	07/26/2015 19:15	10/10/2015 17:50	10/26/2015 14:25	11/01/2015 20:55	11/08/2015 13:50	11/15/2015 08:45	11/18/2015 01:45	12/02/2015 12:10	12/18/2015 10:25	1/16/2016 23:10	1/22/2016 11:20	3/2/2016 12:05	3/24/2016 00:50	7/9/2016 3:20	9/2/2016 11:45
Event Total Flow Volume (gal)	NA	1,133	880	317	1,401	221	3,519	671	1,743	305	246	2,484	1,103	4,274	1,678	7,086	2,238	1,042	3,482	1,510	4,822	3,122	136	68	507

Table C2. Analytical Results – SS2.

Event ID		SE01	SE02	SE03*	SE04	SE05*	SE06	SE07*	SE08	SE09	SE10*	SE11*	SE12	SE13	SE14*	SE15	SE16	SE17	SE18	SE19*	SE20	SE21	SE22*	SE23	SE24*
Event Date		10/25/14	11/21/14	12/6/14	12/10/14	1/15/15	2/6/15	2/9/15	3/14/15	5/13/15	7/26/15	10/10/15	10/25/15	11/1/15	11/8/15	11/15/15	11/17/15	12/2/15	12/18/15	1/16/16	1/22/16	3/2/16	3/23/16	7/9/16	9/2/16
Analyte	Units																								
Conventionals																									
Solids, Total Suspended	mg/l	273	54.3	91	64.7	121	125 J	74.2	81.7 J	234	114	89.9	79.7	58.1	97.4	43.1	99.7	77.7	69.8	305	70.2	103	186	46	63.5
Total Organic Carbon	mg/l	13.3	13.5	18.8	15.1	19.2	11	13.8	9.81	38.1	47.9	10.8	18.7	6.95	8.83	8.19	13.8	15.9	8.89	38.4	6.21	14.4	52.4	20.9	29.8
Chemical Oxygen Demand	mg/l	55.8	65.6	13	47.7	87.8	66.2 J	57.8	50.7	261	210	52.3	88.6	44.4	101	32.4	75.3	65.7	37.4	172	34.9	61.4	103	79.2	109
pH	pH	6.6	6	6.8	7.6	8.6	6.4	8	7.8	8	8	7.3	7.5	7.3	7.7	7.5	7.9	7.5	8.1	7.7	7.7	7.7	7.8	7.8	7.5
Hardness	ug/l	37000	35000	37000	33000	35000	37000	39000	33000	69000	54000	37000	44000	31000	48000	26000	41000	33000	32000	56000	28000	45000	78000	48000	43200
Metals																									
Copper, Dissolved	ug/l	6.3	6.8	4.3	2.8	5	3.9	4.7	7.9	16	38	6.7	14	5	7	5	9.1	10	3.8	2.5	2.7	5.7	16	15.7	23.7
Copper, Total	ug/l	44.4	28.7	40.7	26.2	48.9	45.6 J	25.5 J	29.3 J	114	109	31	55	31	45	22	52.5	44	35.8	82	26.6	42.9	107	50.1	75.2
Zinc, Dissolved	ug/l	14	15	15	11	12	13	10	16	40	80	12	40	20	30	10	22	20	12	9	11	20	60	29	39
Zinc, Total	ug/l	103	65 J	132	81	123	105 J	68 J	77 J	390	280	110	170	80	150	70	133	130	91	360	80	123	360	110	223
Nutrients																									
Phosphorus, Total	mg/l	0.255	0.132	0.223	0.15	0.209	0.267 J	0.285	0.163	0.593	0.338	0.17	0.183	0.101	0.158	0.06	0.164	0.184	0.129	0.343	0.11	0.238	0.395	0.109	0.238
Nitrate + Nitrite	mg/l	0.129 J	0.171 J	0.144 J	0.083 J	0.115 J	0.048 J	0.176	0.321	0.679	0.553	0.379	0.395	0.101	0.193	0.091	0.089	0.184	0.095	0.059	0.086	0.143	0.659	0.403	0.593
Nitrogen, Total Kjeldahl	mg/l	1.3	1 U	1.2	1.1	1 U	1.2	2.5	1.3	6.9	2.8	2.3	2.5	1.9	2.7	1.6	2.2	1.8	1.2	1.1	1.1	1.9	3.7	2.1	2
Bacteria																									
Fecal Coliform	cfu/100ml	195 J	260	88	1520	600	1900	600	18 J	4640	2670 R	68	6000 J	10700 J	200	15200	240	36 J	320	101	29	2250	1200 J	240 J	60
Polycyclic Aromatic Hydrocarbons (PAHs)																									
1-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
2-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthylene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Pyrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(G,H,I)Perylene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.1 U	0.1 U	0.1 U	0.18	0.1 U	0.17	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.1 U	0.13	0.1 U
Benzofluoranthenes, Total	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.13	0.13	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.16	0.1 U	0.1 U	0.1 U
Chrysene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.11	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.1 U	0.13	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.1 U	0.1 U	0.1 U
Dibenzo(A,H)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dibenzofuran	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Fluoranthene	ug/l	0.1	0.1 U	0.12	0.13	0.2	0.16	0.1 U	0.1 U	0.19	0.24	0.1 U	0.2	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.12	0.1 U	0.1	0.2	0.1 U	0.14	0.11
Fluorene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Indeno(1,2,3-Cd)Pyrene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Naphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Phenanthrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.1 U	0.1 U	0.1 U	0.14	0.17	0.1 U	0.16	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.11	0.1 U	0.1 U	0.16	0.1 U	0.1	0.1 U
Pyrene	ug/l	0.11	0.1 U	0.12	0.2	0.28	0.17	0.1 U	0.1 U	0.2	0.28	0.13	0.3	0.1 U	0.1 U	0.12	0.1 U	0.22	0.17	0.1 U	0.11	0.29	0.1	0.19	0.15
Suspended Sediment Concentration																									
Sed. Conc. > 500 um	mg/l	56.2	0.99	26.4	12.25	23.35	139.79 J	17.29	53.28	17.5	4.9	6.6	197.7	14	36.3	101.8	224.4	97.4 J	30.7	21.1	15.9 J	51.8	22.4	5.2	15.1
Sed. Conc. 500 to 250 um	mg/l	18.91	2.43	71.13	21.36	27.05	93.47 J	25.89	32.56	13.2	10	4.3	13.7	6.6	12.8	11.3	18.3	21.8 J	30.2	10.7	8.7 J	9.4	12.2	5.8	915.5
Sed. Conc. 250 to 62.5 um	mg/l	44	6.41	106.11	42.16	51.25	92.32 J	43.39	0.01 U	51.8	37.3	26.1	41.7	21	27.1	4	44.6	25.7 J	49.9	39.3	34	34.7	39	15.7	19
Sed. Conc. 62.5 to 3.9 um	mg/l	0.01 U	0.01 U	0.36	0.01 U	84.04	74.79	49.8 U	31.74	179.6	64.4	16.2	15.1	0.1 U	53.1	19.5	34.9	21.1 J	37.9	170.6 J	35.7 J	57.3 J	131.7 J	43.1 J	14.8 J
Sed. Conc. < 3.9 um	mg/l	65.29	36.66	65.45	50.53	29.99	11.18	49.8 U	5.21	16.1	5.6	2.9	30.8	30.4	9.8	3.3	5.8	3.4 J	8.3	34 J	6.3 J	9.9 J	20.7 J	0.9 J	7.1 J
Sed. Conc. Total	mg/l	184.4	46.49	269.45	126.3	215.68	411.55 J	136.57	122.8	278.1	122.1	56.3	299.2	72	139.1	139.9	328	169.3 J	156.9	275.6	100.7 J	163.1	226	70.7	971.5

* - The grab sample (pH, bacteria, PAHs) for events with an asterisk were not collected during the event's composite sample period. See Section 4.1.1 for exact grab sample dates for these events.

Table C3. Analytical Results – SS3.

	Event ID	SE01	SE02	SE03*	SE04	SE05*	SE06	SE07*	SE08	SE09	SE10*	SE11*	SE12	SE13	SE14*	SE15	SE16	SE17	SE18	SE19*	SE20	SE21	SE22*	SE23	SE24*
	Event Date	10/25/14	11/21/14	12/6/14	12/10/14	1/15/15	2/6/15	2/9/15	3/14/15	5/13/15	7/26/15	10/10/15	10/25/15	11/1/15	11/8/15	11/15/15	11/17/15	12/2/15	12/18/15	1/16/16	1/22/16	3/2/16	3/23/16	7/9/16	9/2/16
Analyte	Units																								
Conventionals																									
Solids, Total Suspended	mg/l	102	47.4	77	44.5	154	114	75	80	270	216	21.8	85.8	260	116	226	94.6	54	107	245	141 J	126	119	131	101
Total Organic Carbon	mg/l	10.6	12.4	7.57	7.49	28.2	12.3	10.1	11.6	49.2	64	5.01	16.6	12.2	14	7.37	16.6	12	10.1	34.5	11.6	58.8	36	40.8	37.8
Chemical Oxygen Demand	mg/l	112	59.6	11.1	23.3	74.1	51.4	54.3	114	325	274	23.6	76.2	78.1	131	48.1	76.3	60.3	50.4	260	85.2 J	105	75.2	131	133
pH	pH	6.8	6.9	6.7	7.4	8.4	6.5	7.9	7.8	7.8	8	7.2	7.2	7.4	7.7	7.6	7.9	7.4	8	7.7	7.7	7.7	7.7	7.9	7.5
Hardness	ug/l	45000	33000	36000	34000	43000	43000	38000	31000	83000	68000	20000	48000	58000	46000	32000	42000	36000	80000	48000	38000	57000	58000	59000	58300
Metals																									
Copper, Dissolved	ug/l	5.6	5.5	4.1	3	4.1	3.4	5.3	4.5	11	36	4.9	9	3.7	7	3.5	5.6	7	3.1	2.8	2.6 J	3.6	10	12.1	21.3
Copper, Total	ug/l	48.1	26.5	27.7	20.4	46.5	41.3	22	20.1	129	133	14.9	58	56	102	33	43.7	33	64.4	68	32.5	51.7	65	84	98.4
Zinc, Dissolved	ug/l	15	17	13	11	8	9 J	10	13	30	90	13	30	12	20	8	18	20	10	9	10	13	40	33	46
Zinc, Total	ug/l	142	69	86	63	160	136	57	77	520	400	39	230	240	210	150	132	120	184	320	114	187	240	250	332
Nutrients																									
Phosphorus, Total	mg/l	0.282	0.142	0.157	0.112	0.228	0.252	0.129 J	0.998	0.675	0.493	0.067	0.254	0.402	0.276	0.192	0.269	0.137	0.95	0.366	0.161 J	0.603	0.31	0.168	0.656
Nitrate + Nitrite	mg/l	0.076 J	0.159 J	0.159 J	0.081 J	0.133 J	0.046 J	0.166	0.179	0.527	0.33	0.116	0.256	0.019	0.184	0.085	0.099	0.138	0.075	0.077	0.086	0.066	0.329	0.05	0.431
Nitrogen, Total Kjeldahl	mg/l	1.2	1 U	1.1	1 U	1.6	1.4	0.87	7.7	8.5	3.8	1.2	3.2	5.9	2.6	2.8	2.1	1.5	1.3	2.2	1.2 J	3.2	2.4	3.1	3.2
Bacteria																									
Fecal Coliform	cfu/100ml	445 J	1380	72	205	1200	15	1350	16 J	5400	9000	600	2900 J	300 J	135	1020	260	24 J	200	36	160	200	40 J	2300 J	70
Polycyclic Aromatic Hydrocarbons (PAHs)																									
1-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	20	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
2-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	27	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	6.8 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthylene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	2	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.76 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Pyrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(G,H,I)Perylene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.1 U
Benzofluoranthenes, Total	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.12	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.11	0.1 U	0.1 U	0.1 U
Chrysene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dibenzo(A,H)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dibenzofuran	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	3.1	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Fluoranthene	ug/l	0.1 U	0.1 U	0.1 U	0.11	0.1 U	0.1 U	0.1 U	0.1 U	0.22	0.14	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	1.1	0.1 U	0.14	0.11	0.1 U	0.13	0.1
Fluorene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	4.6	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Indeno(1,2,3-Cd)Pyrene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Naphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	2.4	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Phenanthrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	2.4	0.1 U	0.1	0.1 U	0.1 U	0.1 U	0.1 U
Pyrene	ug/l	0.1	0.1 U	0.1 U	0.18	0.1 U	0.1 U	0.1 U	0.1 U	0.23	0.18	0.1	0.15	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	6	0.1 U	0.15	0.15	0.1 U	0.16	0.13
Suspended Sediment Concentration																									
Sed. Conc. > 500 um	mg/l	17.87	4.17	107.06	21.01	15.24	244.6 J	30.86	26.17	56.7	19.6	0.7	261.8	349.9	627.2	12.9	608.3	50.3 J	1574.2	126.9	446.9 J	672.6	13.4	384.8	915.5
Sed. Conc. 500 to 250 um	mg/l	14.86	4.28	61.34	14.87	13.77	72.56 J	15.48	52.03	29.1	17.9	1.4	91.5	148.7	50.6	18.2	90	21.2 J	615.4	35	110 J	192.1	8.1	128.6	164
Sed. Conc. 250 to 62.5 um	mg/l	51.33	15.31	73.31	30.7	44.68	106.9 J	34.75	82.32	113.9	67.5	7	66.2	120.9	46.4	53.2	49.9	24.9 J	205.9	82.2	72.6	96.8	36.5	145.1	70.3
Sed. Conc. 62.5 to 3.9 um	mg/l	0.01 U	0.01 U	0.01 U	0.01 U	35.39	142.57 J	43.06 U	67.06	218.5	128.5	0.1 U	36	52.2	59.5	22.8	33.6	13.3 J	42.5	117.3 J	52.9 J	59.6 J	49.9 J	56.2 J	7.8 J
Sed. Conc. < 3.9 um	mg/l	75.98	46.65	74.73	32.66	67.5	48.29 J	43.06 U	11.02	25.1	5.7	10	5.2	8.4	10.5	3.8	5.2	2 J	9.4	16.5 J	7.8 J	8.3 J	8.3 J	0.9 J	1.1 J
Sed. Conc. Total	mg/l	160.04	70.41	316.44	99.24	176.58	614.9 J	124.16	239.2	443.2	239.2	19	460.7	680	794.3	110.8	787	111.8 J	2447.4	377.9	690.1 J	1029.5	116.1	715.6	1158.7

* - The grab sample (pH, bacteria, PAHs) for events with an asterisk were not collected during the event's composite sample period. See Section 4.1.1 for exact grab sample dates for these events.

Table C4. Analytical Results – SS4.

Event ID		SE01	SE02	SE03*	SE04	SE05*	SE06	SE07*	SE08	SE09	SE10*	SE11*	SE12	SE13	SE14*	SE15	SE16	SE17	SE18	SE19*	SE20	SE21	SE22*	SE23	SE24*
Event Date		10/25/14	11/21/14	12/6/14	12/10/14	1/15/15	2/6/15	2/9/15	3/14/15	5/13/15	7/26/15	10/10/15	10/25/15	11/1/15	11/8/15	11/15/15	11/17/15	12/2/15	12/18/15	1/16/16	1/22/16	3/2/16	3/23/16	7/9/16	9/2/16
Analyte	Units																								
Conventionals																									
Solids, Total Suspended	mg/l	63.6	40.5	62.4	51.1	138	78.6	78.4	50.8	243	145	36.8	50.8	82.1	78.2	133	55.5	52.2	47.6	156	938 J	79.3	111	152	74
Total Organic Carbon	mg/l	5.77	10.2	9.58	4.79	21.6	9.02	9.3	11.1	41.7	58.8	5.49	12	5.88	8.15	4.84	13.2	10.6	5.08	23.9	7.66	11.3	26.8	84.6	38
Chemical Oxygen Demand	mg/l	69.6	40.1	12.7	10 U	71.1	69.4 J	37.2	127	263	249	32.8	61.6	30.7	79	46.8	61.6	39.4	39.9	113	46.1	48.9	141 J	256	106
pH	pH	6.8	6.7	6.7	7.5	8.5	6.4	7.8	7.8	8.2	8	7.4	7.1	7.4	7.7	7.5	7.9	7.4	8	7.7	7.6	7.7	7.8	7.9	7.4
Hardness	ug/l	32000	30000	35000	28000	45000	36000	48000	33000	70000	57000	23000	42000	32000	40000	32000	39000	32000	28000	45000	41000	32000	60000	66000	44300
Metals																									
Copper, Dissolved	ug/l	3.5	4.8	3.5	2.3	3.4	2.8	5.1	4.5	13	31	4.9	7	3.7	5.7	3.7	6.4	6	2.3	2.3	2.4	4.3	10	13.4	23
Copper, Total	ug/l	30.9	21.2	22.8	13.4	39	24.9	21.1	19.8	103	106	19.9	33	21	33	24	36	29	18.4	49	25.1	27.5	66	96	73
Zinc, Dissolved	ug/l	10	14	11	10	8	9	6	11	30	80	12	20	9	15	7	17	20	9	7	9	16	30	33	44.9
Zinc, Total	ug/l	79	55	85	43	137	71	55	75	390	260	53	110	70	120	180	107	100	62	240	87	99	230	230	219
Nutrients																									
Phosphorus, Total	mg/l	0.14	0.109	0.135	0.074	0.224	0.189	0.126	1.3	0.495	0.34	0.068	0.167	0.106	0.226	0.095 J	0.161	0.164	0.102	0.198	0.144	0.924	0.256	0.497	0.384
Nitrate + Nitrite	mg/l	0.057 J	0.121 J	0.143 J	0.052 J	0.104	0.05	0.163	0.17	0.422	0.266	0.112	0.252	0.035	0.148	0.086	0.075	0.117	0.05	0.06	0.083	0.078	0.26	0.029	0.492
Nitrogen, Total Kjeldahl	mg/l	1	1 U	1 U	1 U	1.4	1 J	0.94	9.6	4.6	3.3	1.5	2.1	1.8	1.8	1.2	2	1.5	0.87	1.4	1.2	3.8	1.6	3.4	3.3
Bacteria																									
Fecal Coliform	cfu/100ml	110 J	160	64	135	880	15	20000 R	8 J	17400	580000	180	1150 J	975 J	225	1220	185	76 J	80	16	200	230	260 J	280 J	125
Polycyclic Aromatic Hydrocarbons (PAHs)																									
1-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
2-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthylene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Pyrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(G,H,I)Perylene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzofluoranthenes, Total	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.2 U	0.1 U	0.1 U	0.1 U	0.1 U
Chrysene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dibenzo(A,H)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dibenzofuran	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Fluoranthene	ug/l	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.11	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1	0.1 U	0.1 U	0.1 U
Fluorene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Indeno(1,2,3-Cd)Pyrene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Naphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Phenanthrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Pyrene	ug/l	0.1 U	0.1 U	0.1 U	0.19	0.1 U	0.14	0.1 U	0.1 U	0.12	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.16	0.12	0.1 U	0.1 U	0.16	0.1 U	0.1 U	0.11
Suspended Sediment Concentration																									
Sed. Conc. > 500 um	mg/l	15.7	1.08	78.83	7.26	185.37	55.97 J	24.13	135.62	18.1	8.5	9.6	462.5	70.4	274.8	71.2	47.2	33.8 J	375.1	70.9	241.3 J	37.1	63.8	NM	19
Sed. Conc. 500 to 250 um	mg/l	7.38	1.84	10.45	9.21	93.9	43.17 J	6.16	37.73	11.4	10.5	2.4	42.3	15.5	36.2	8.1	25.3	8.7 J	31.9	15.4	50.9	26.5	36.6	NM	18.3
Sed. Conc. 250 to 62.5 um	mg/l	24.66	7.14	44.4	38.16	70.74	45.07	31.97	22.99	65.3	37.1	12.5	28.2	32.1	27.4	17.9	40.1	19.3 J	30.1	33.4	41.2	35.6	64.8	NM	41
Sed. Conc. 62.5 to 3.9 um	mg/l	0.01 U	0.01 U	0.01 U	0.01 U	17.86	50.58	42.9 U	26.23	164.8	76.8	12.5	23.3	22.3	39.9	19.7	24.6	13.6 J	19.7	89.9 J	31.4 J	39.5	45.4	NM	3.6 J
Sed. Conc. < 3.9 um	mg/l	43.78	35.96	42.71	31.71	65.21	10.8	42.9 U	4.63	17.2	4.2	3.3	6.2	5	6.8	3	4.1	2.8 J	4.5	15.6 J	4.6 J	6.4	7.9	NM	0.6 J
Sed. Conc. Total	mg/l	91.52	46.02	176.39	86.34	433.08	205.6	105.16	227.2	276.8	137.1	40.3	562.5	145.3	385.2	119.9	141.3	78.2 J	461.3	225.3	369.4 J	145.1	218.5	NM	82.5

Notes: The grab sample (pH, bacteria, PAHs) for events with an asterisk were not collected during the event's composite sample period. See Section 4.1.1 for exact grab sample dates for these events.

Table C5. Analytical Results – SS5.

Event ID		SE01	SE02	SE03*	SE04	SE05*	SE06	SE07*	SE08	SE09	SE10*	SE11*	SE12	SE13	SE14*	SE15	SE16	SE17	SE18	SE19*	SE20	SE21	SE22*	SE23	SE24*
Event Date		10/25/14	11/21/14	12/6/14	12/10/14	1/15/15	2/6/15	2/9/15	3/14/15	5/13/15	7/26/15	10/10/15	10/25/15	11/1/15	11/8/15	11/15/15	11/17/15	12/2/15	12/18/15	1/16/16	1/22/16	3/2/16	3/23/16	7/9/16	9/2/16
Analyte	Units																								
Conventionals																									
Solids, Total Suspended	mg/l	64.5	97.6	85.8	75	216	75	61.1	49.5	290	163	22.4	71.8	50	124 J	59	125	68.8	102	240	110	90	208	160	83.3
Total Organic Carbon	mg/l	8.83	12.4	19.4	14.7	49	10.4 J	11.1	6.1	48.6	55.1	4.97	14.4	15.5	24.3	17.2	24.6	16.6	22.8	37.6 J	9.22	17.6	38.7	34	38.8
Chemical Oxygen Demand	mg/l	75.7	48.9	12.7	10.5	158	61.4	45.6	35.8	314	219	32.2	83.8 J	73.4	104 J	62.6	93	63.9	80.4	160 J	55.9	120 J	80.6	123	NM
pH	pH	6.9	6.7	6.5	7.2	8.5	6.5	8	7.9	8	8	7.4	7.1	7.3	7.7	7.5	7.9	7.4	8.1	7.7	7.8	7.7	7.8	7.8	7.6
Hardness	ug/l	32000	30000	31000	36000	57000	35000	52000	24000	73000	54000	20000	37000	39000	40000	30000	43000	32000	32000	44000	35000	34000	75000	59000	50300
Metals																									
Copper, Dissolved	ug/l	5.1	6.5	4.2	2.7	12.3	4	5.6	5	16	39	5.6	10	6	8	7	11	10	3.7	3.5	2.6	6.5	12	18.3	30.2
Copper, Total	ug/l	33.5	31.2	37.7	24.3	75	34.5	24	24.3	119	125	17.3	44	35	49	33	49.3	41	33.3	72	31.4	42.6	107	96	72.5
Zinc, Dissolved	ug/l	15	29	16	12	21	9	8	11	50	80	13	30	20	30	20	24	20	14	7	10	21	40	33	45.1
Zinc, Total	ug/l	86	79	128	87	239	92	65 J	72	420	360	41	130	110	180	130	127	130	108	310	104	121	380	230	180
Nutrients																									
Phosphorus, Total	mg/l	0.267	0.188	0.205	0.176	0.441	0.183	0.199	0.166	0.56	0.409	0.104	0.627	0.439	0.262	0.191	0.262	0.199	0.934	0.383	0.245 J	0.249	0.442	0.533	0.368
Nitrate + Nitrite	mg/l	0.121 J	0.108 J	0.114 J	0.088 J	0.411	0.047 J	0.212	0.132	0.553	0.554	0.128	0.287	0.071	0.294	0.093	0.079	0.168	0.082	0.092	0.107	0.087	0.376	0.378	0.907
Nitrogen, Total Kjeldahl	mg/l	1.1	1.2	1.1	1.3	3.1	1.3	1.3	0.97	6.8	3.6	1.3	4.7	2.7	3	2.1	2.8	1.8	9.4 J	0.61	1.4	2.6	2.2	3.4	4.5
Bacteria																									
Fecal Coliform	cfu/100ml	260 J	80	420	260	8.5	25	3500	84 J	2240 J	210	587	1700 J	1020 J	1180	500	190	40 J	280	60	20 U	1000	40 J	4600 J	1000 U
Polycyclic Aromatic Hydrocarbons (PAHs)																									
1-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
2-Methylnaphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Acenaphthylene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Benzo(A)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.11	0.1 U	0.1 U	0.1 U
Benzo(A)Pyrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.1 U	0.1 U	0.1 U
Benzo(G,H,I)Perylene	ug/l	0.1 UJ	0.1 U	0.1 U	0.13	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.21	0.1 U	0.1 U	0.1 U
Benzofluoranthenes, Total	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.2 U	0.3	0.1 U	0.1 U	0.1 U
Chrysene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.12	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.22	0.1 U	0.1 U	0.1 U
Dibenzo(A,H)Anthracene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Dibenzofuran	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Fluoranthene	ug/l	0.1 U	0.1 U	0.1 U	0.15	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.26	0.1 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 J	0.1 U	0.1 U	0.43	0.1 U	0.13	0.11
Fluorene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Indeno(1,2,3-Cd)Pyrene	ug/l	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Naphthalene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Phenanthrene	ug/l	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.11	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.3	0.1 U	0.1 U	0.1 U
Pyrene	ug/l	0.12	0.1 U	0.1 U	0.22	0.1 U	0.1 U	0.1 U	0.1 U	0.14	0.25	0.17 J	0.1 U	0.1 U	0.11	0.1 U	0.1 U	0.12	0.18 J	0.1 U	0.1 U	0.47	0.12	0.13	0.16
Suspended Sediment Concentration																									
Sed. Conc. > 500 um	mg/l	33.6	52.8	64	10.14	15.33	9.02 J	21.51	29.6	10.3	6.5	0.7 J	103.4	127.1	133.4	45	72.7	53.8 J	90.7	18.5	200.1 J	32.9 J	228.3	NM	14.8 J
Sed. Conc. 500 to 250 um	mg/l	10.12	9.92	6.65	4.36	12.56	3.36 J	14.37	22.5	6.9	12.2	0.5 J	28.5	11.9	21	9	19.7	8.9 J	56.5	14.4	47.5 J	10	76.1	NM	7.9
Sed. Conc. 250 to 62.5 um	mg/l	20.87	27.01	19.94	16.03	37.14	19.3 J	29.48	30.8	23.4	42.5	5.7	25.1	26	43.8	25.2	33.1	22.8 J	47.3	38.9	48.3	26.8	90.2	NM	38.3
Sed. Conc. 62.5 to 3.9 um	mg/l	0.01 U	0.01 U	0.01 U	0.01 U	136.3	62.57 J	44.93 U	23.7	144.7	101.9	0.1 U	23	35.8	52.5	45.1	35	14.1 J	43.5	130 J	51.8 J	57.6 J	82.8	NM	12 J
Sed. Conc. < 3.9 um	mg/l	41.58	72.58	59.82	60.89	58.75	12.82 J	44.93 U	4.2	11.8	7.6	14.6	4.2	6	8.5	5.4	3.9	2.4 J	8.3	24.4 J	7.5 J	9.4 J	18.4	NM	1.4 J
Sed. Conc. Total	mg/l	106.17	162.31	150.41	91.42	260.11	107.07 J	110.29	110.9	197.1	170.7	21.5	184.1	206.9	259.2	129.7	164.4	102 J	246.3	226.3	355.3 J	136.6 J	495.9	NM	74.4

Notes: * - The grab sample (pH, bacteria, PAHs) for events with an asterisk were not collected during the event's composite sample period. See Section 4.1.1 for exact grab sample dates for these events.

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Appendix D: Individual Storm Reports and Event Hydrographs

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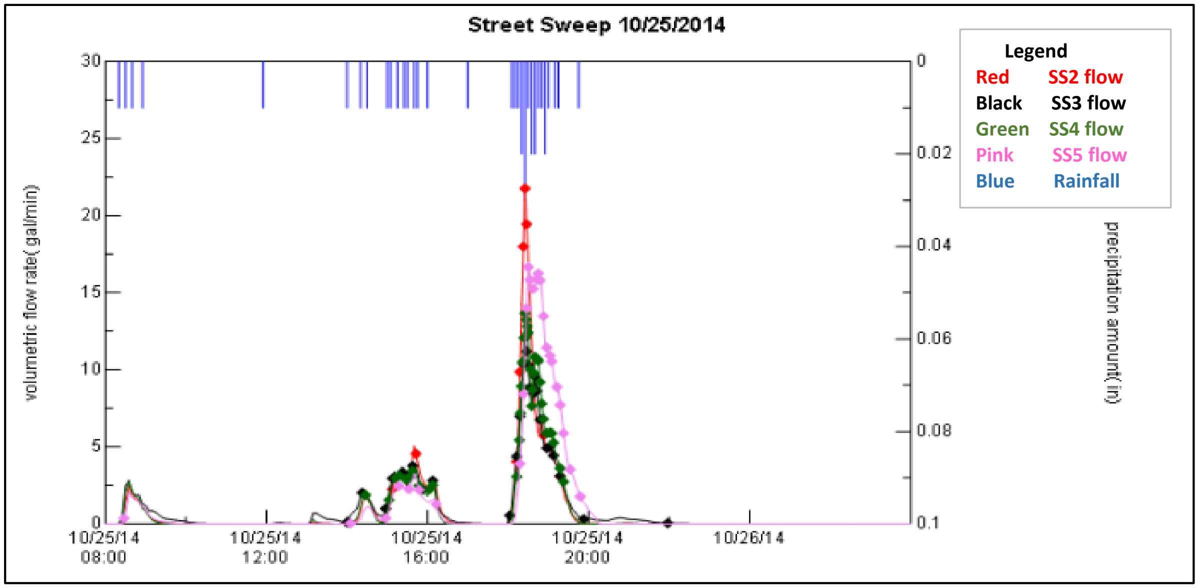
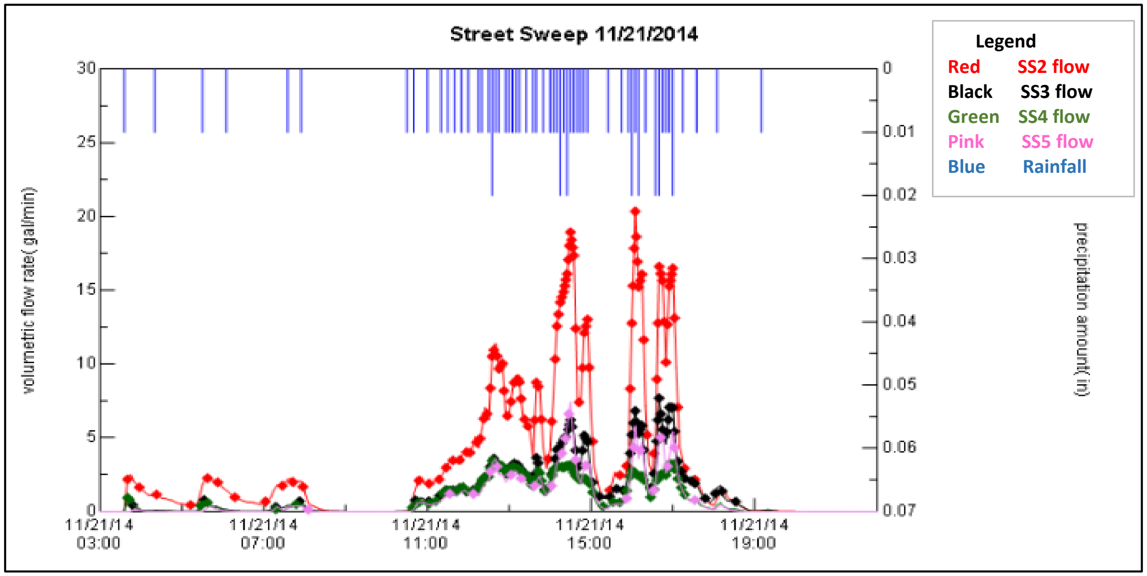
Street Sweeping Effectiveness Study
Individual Storm Report
SE-01: October 25, 2014



Flow and Sample Statistics	
Precip Start	10/25/2014 8:20
Precip Stop	10/25/2014 19:45
Storm Event Duration (hrs)	11.4
Event Rainfall (in)	0.38
Storm Event Rainfall Mean (in/hr)	0.0333
Event Rainfall Max (in/hr)	4.32
Antecedent Dry Period (hr)	10.2

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	10/25/2014 8:25	10/25/2014 8:25	10/25/2014 8:25	10/25/2014 8:25
Stop	10/25/2014 22:10	10/26/2014 3:40	10/25/2014 21:40	10/25/2014 21:30
Flow Duration (hrs)	11.3	18.2	8.5	10.5
Event Total Flow Mean (gpm)	1.4	0.9	1.7	1.8
Event Total Flow Max (gpm)	21.8	12.1	13.7	16.7
Event Total Flow Volume (gal)	949.3	955.6	874.1	1133.2
No. Composite Sample Aliquots	10	27	36	25
First Sample Time	10/25/2014 15:07	10/25/2014 14:00	10/25/2014 14:27	10/25/2014 8:27
Last Sample Time	10/25/2014 19:17	10/25/2014 21:57	10/25/2014 19:22	10/25/2014 19:47
Sample Duration (hrs)	4.2	8.0	4.9	11.3
Event Flow Volume Sampled (%)	84.3	87.4	87.3	98.0

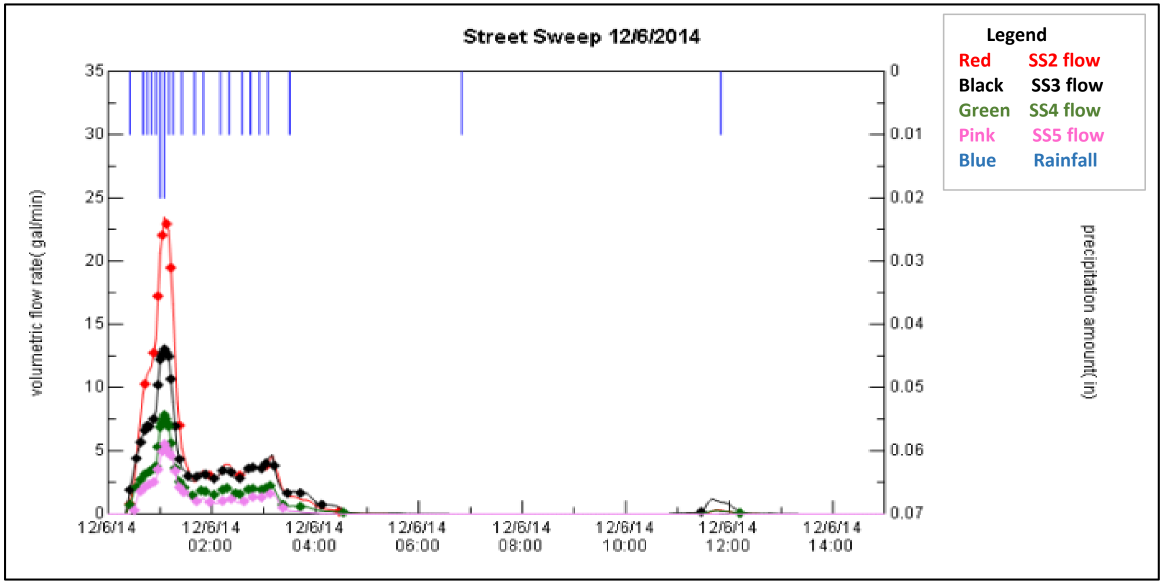
Street Sweeping Effectiveness Study
Individual Storm Report
SE-02: November 21, 2014



Flow and Sample Statistics	
Precip Start	11/21/2014 3:35
Precip Stop	11/21/2014 19:10
Storm Event Duration (hrs)	15.6
Event Rainfall (in)	0.66
Storm Event Rainfall Mean (in/hr)	0.04
Event Rainfall Max (in/hr)	2.88
Antecedent Dry Period (hr)	26.1

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	11/21/2014 3:40	11/21/2014 3:35	11/21/2014 3:40	11/21/2014 3:45
Stop	11/21/2014 20:55	11/21/2014 21:00	11/21/2014 20:30	11/21/2014 19:25
Flow Duration (hrs)	16.3	17.5	16.0	13.3
Event Total Flow Mean (gpm)	3.3	1.2	0.9	1.1
Event Total Flow Max (gpm)	20.4	7.7	3.4	7.4
Event Total Flow Volume (gal)	3233.2	1268.3	832.2	880.4
No. Composite Sample Aliquots	100	84	100	22
First Sample Time	11/21/2014 3:40	11/21/2014 3:47	11/21/2014 3:40	11/21/2014 8:05
Last Sample Time	11/21/2014 17:32	11/21/2014 18:32	11/21/2014 17:17	11/21/2014 17:32
Sample Duration (hrs)	13.9	14.8	13.6	9.5
Event Flow Volume Sampled (%)	97.5	98.5	95.3	95.2

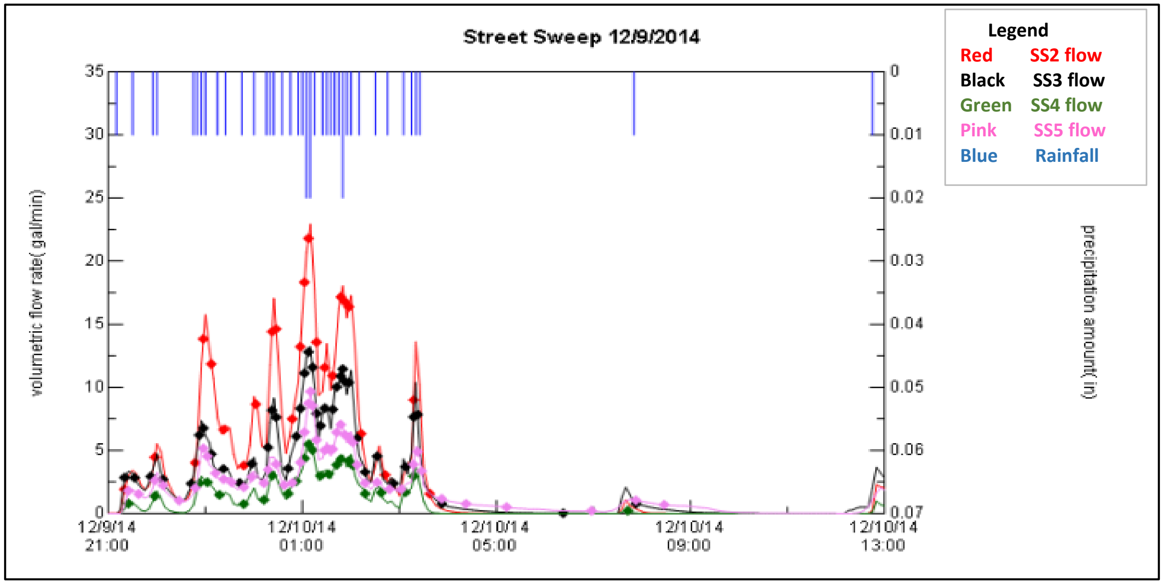
Street Sweeping Effectiveness Study
Individual Storm Report
SE-03: December 6, 2014



Flow and Sample Statistics	
Precip Start	12/6/2014 0:25
Precip Stop	12/6/2014 6:50
Storm Event Duration (hrs)	6.4
Event Rainfall (in)	0.22
Storm Event Rainfall Mean (in/hr)	0.03
Event Rainfall Max (in/hr)	2.88
Antecedent Dry Period (hr)	13.9

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	12/6/2014 0:20	12/6/2014 0:20	12/6/2014 0:20	12/6/2014 0:25
Stop	12/6/2014 13:10	12/6/2014 14:50	12/6/2014 14:30	12/6/2014 12:30
Flow Duration (hrs)	9.0	14.6	11.0	6.1
Event Total Flow Mean (gpm)	2.3	1.1	0.8	0.9
Event Total Flow Max (gpm)	23.5	13.0	7.8	5.5
Event Total Flow Volume (gal)	1223.8	980.0	497.5	316.8
No. Composite Sample Aliquots	12	33	36	23
First Sample Time	12/6/2014 0:25	12/6/2014 0:25	12/6/2014 0:25	12/6/2014 0:30
Last Sample Time	12/6/2014 4:27	12/6/2014 11:27	12/6/2014 12:12	12/6/2014 3:22
Sample Duration (hrs)	4.0	11.0	11.8	2.9
Event Flow Volume Sampled (%)	98.5	95.1	98.8	96.6

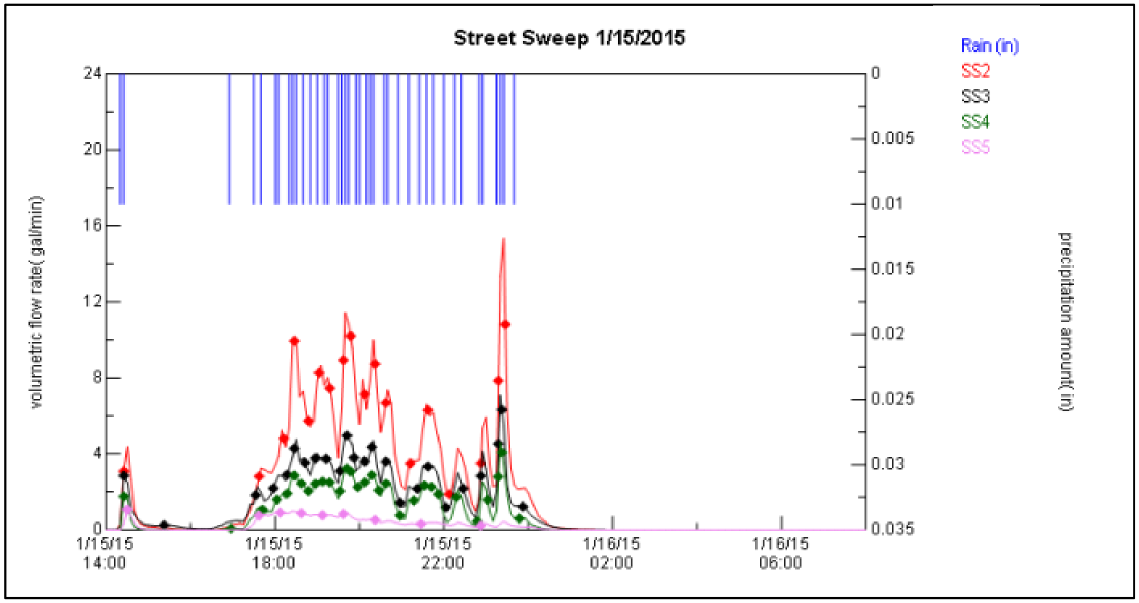
Street Sweeping Effectiveness Study
Individual Storm Report
SE-04: December 9-10, 2014



Flow and Sample Statistics	
Precip Start	12/9/2014 21:10
Precip Stop	12/10/2014 7:50
Storm Event Duration (hrs)	10.7
Event Rainfall (in)	0.41
Storm Event Rainfall Mean (in/hr)	0.04
Event Rainfall Max (in/hr)	2.88
Antecedent Dry Period (hr)	10.0

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	12/9/2014 21:10	12/9/2014 21:10	12/9/2014 21:15	12/9/2014 21:10
Stop	12/10/2014 12:40	12/10/2014 12:40	12/10/2014 12:40	12/10/2014 12:40
Flow Duration (hrs)	12.2	15.6	9.2	15.5
Event Total Flow Mean (gpm)	3.8	2.0	1.3	1.5
Event Total Flow Max (gpm)	22.9	13.2	5.8	9.7
Event Total Flow Volume (gal)	2793.5	1909.9	692.9	1401.3
No. Composite Sample Aliquots	24	39	24	46
First Sample Time	12/9/2014 21:20	12/9/2014 21:20	12/9/2014 21:25	12/9/2014 21:25
Last Sample Time	12/10/2014 3:37	12/10/2014 7:52	12/10/2014 7:42	12/10/2014 8:27
Sample Duration (hrs)	6.3	10.5	10.3	11.0
Event Flow Volume Sampled (%)	98.4	96.9	99.0	95.8

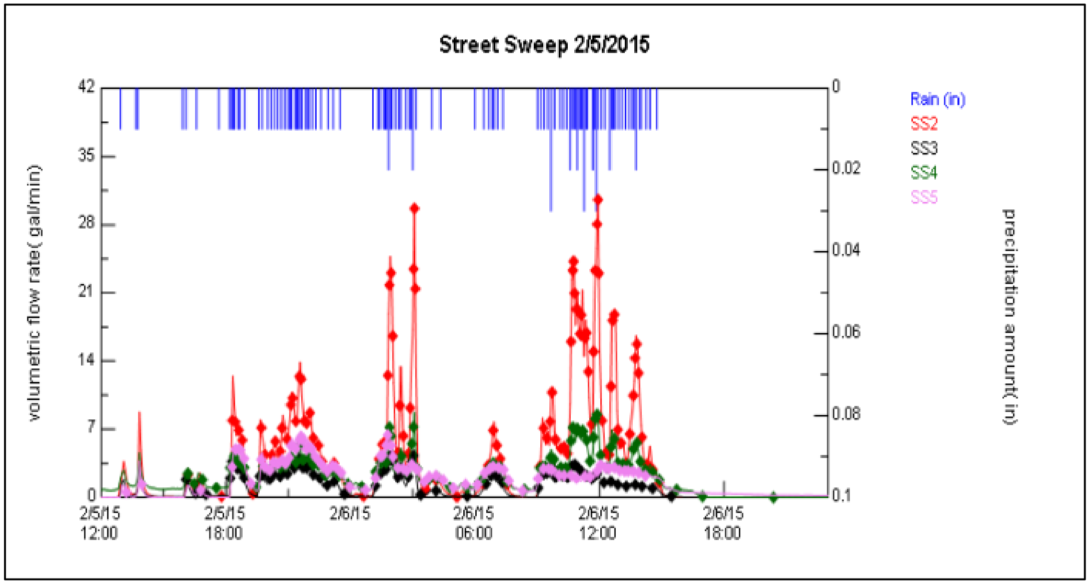
Street Sweeping Effectiveness Study
Individual Storm Report
SE-05: January 15, 2015



Flow and Sample Statistics	
Precip Start	1/15/2015 14:20
Precip Stop	1/15/2015 23:40
Storm Event Duration (hrs)	9.3
Event Rainfall (in)	0.4
Storm Event Rainfall Mean (in/hr)	0.04
Event Rainfall Max (in/hr)	0.12
Antecedent Dry Period (hr)	100.4

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	1/15/2015 14:20	1/15/2015 14:15	1/15/2015 14:20	1/15/2015 14:20
Stop	1/16/2015 3:30	1/16/2015 7:40	1/16/2015 2:25	1/16/2015 1:25
Flow Duration (hrs)	13.2	17.5	12.2	10.3
Event Total Flow Mean (gpm)	2.7	1.1	1.0	0.4
Event Total Flow Max (gpm)	15.4	7.1	4.6	1.1
Event Total Flow Volume (gal)	2162.8	1195.8	738.0	220.7
No. Composite Sample Aliquots	18	24	30	9
First Sample Time	1/15/2015 14:25	1/15/2015 14:25	1/15/2015 14:25	1/15/2015 14:30
Last Sample Time	1/15/2015 23:27	1/15/2015 23:52	1/15/2015 23:47	1/15/2015 22:52
Grab Sample Time 1	2/5/2015 9:00	2/5/2015 9:15	2/5/2015 9:25	2/5/2015 10:10
Sample Duration (hrs)	9.0	9.5	9.4	8.4
Event Flow Volume Sampled (%)	93.9	96.4	97.1	87.8

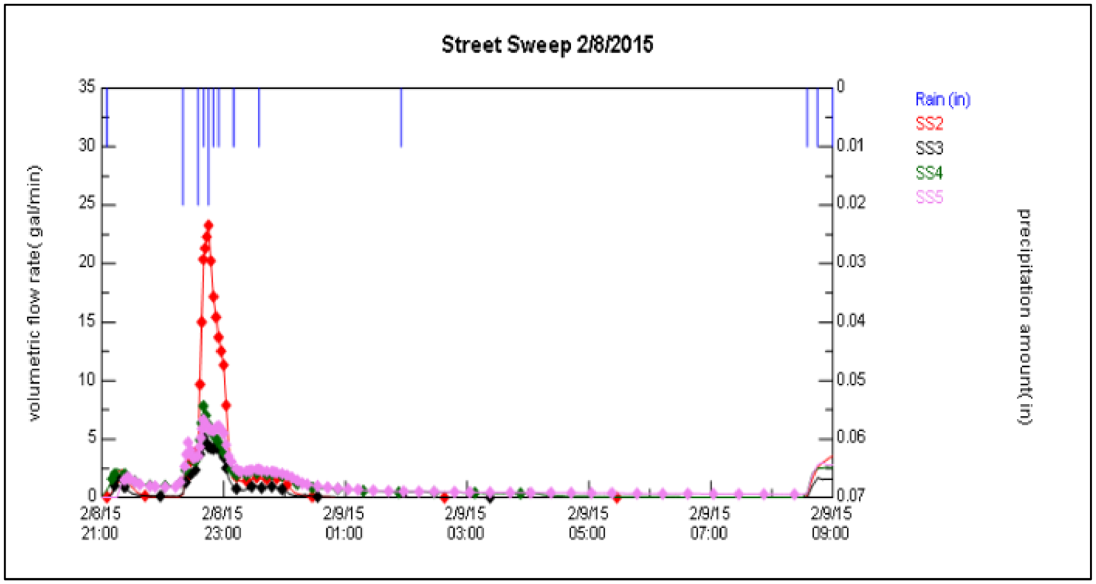
Street Sweeping Effectiveness Study
Individual Storm Report
SE-06: February 5, 2015



Flow and Sample Statistics	
Precip Start	2/5/2015 12:55
Precip Stop	2/6/2015 14:45
Storm Event Duration (hrs)	25.8
Event Rainfall (in)	1.2
Storm Event Rainfall Mean (in/hr)	0.05
Event Rainfall Max (in/hr)	0.36
Antecedent Dry Period (hr)	4.25

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	2/5/2015 12:50	2/5/2015 12:50	2/5/2015 12:50	2/5/2015 12:50
Stop	2/6/2015 16:25	2/6/2015 20:45	2/6/2015 17:35	2/6/2015 22:40
Flow Duration (hrs)	27.7	32.0	28.8	33.9
Event Total Flow Mean (gpm)	4.2	1.1	2.5	1.7
Event Total Flow Max (gpm)	30.6	4.8	8.8	6.8
Event Total Flow Volume (gal)	7001.9	2071.4	4246.9	3519.4
No. Composite Sample Aliquots	98	67	79	82
First Sample Time	2/5/2015 16:10	2/5/2015 16:05	2/5/2015 16:10	2/5/2015 13:12
Last Sample Time	2/6/2015 14:52	2/6/2015 15:27	2/6/2015 16:57	2/6/2015 14:12
Grab Sample Time	2/5/2015 22:00	2/5/2015 21:40	2/5/2015 21:45	2/5/2015 21:30
Sample Duration (hrs)	22.7	23.4	24.8	25.0
Event Flow Volume Sampled (%)	97.2	95.4	93.2	91.6

Street Sweeping Effectiveness Study
Individual Storm Report
SE-07: February 8, 2015

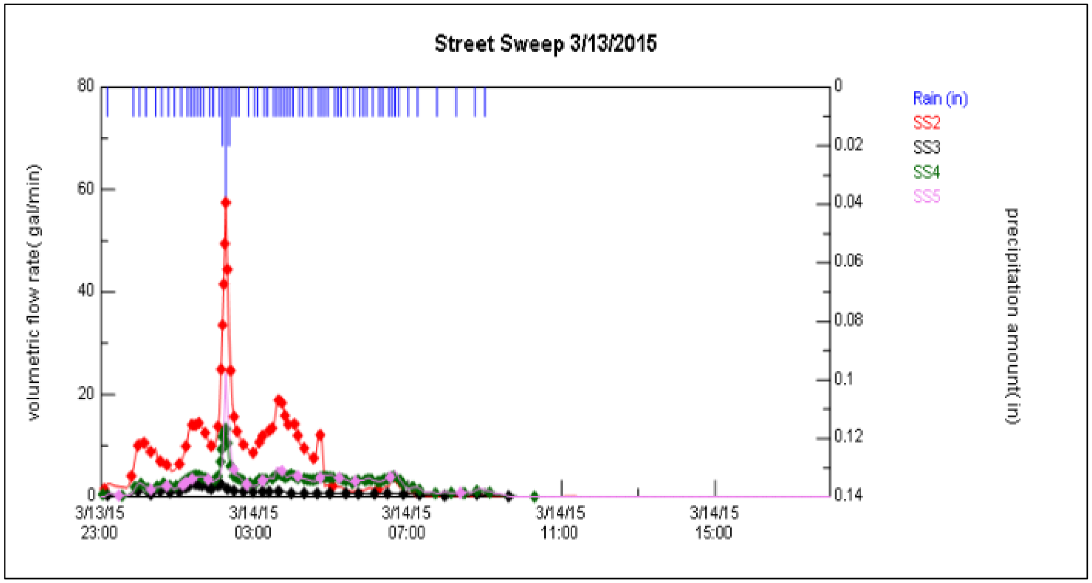


Flow and Sample Statistics	
Precip Start	2/8/2015 21:05
Precip Stop	2/9/2015 1:55
Storm Event Duration (hrs)	4.8
Event Rainfall (in)	0.13
Storm Event Rainfall Mean (in/hr)	0.03
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	23.1

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	2/8/2015 21:05	2/8/2015 21:10	2/8/2015 21:00	2/8/2015 21:00
Stop	2/9/2015 8:35	2/9/2015 2:55	2/9/2015 8:35	2/9/2015 8:35
Flow Duration (hrs)	4.0	5.8	11.7	11.7
Event Total Flow Mean (gpm)	2.7	0.7	0.8	1.0
Event Total Flow Max (gpm)	23.3	5.1	7.8	6.7
Event Total Flow Volume (gal)	645.6	232.1	567.6	671.2
No. Composite Sample Aliquots	29	25	33	84
First Sample Time	2/8/2015 21:05	2/8/2015 21:12	2/8/2015 21:10	2/8/2015 21:22
Last Sample Time	2/9/2015 5:27	2/9/2015 0:32	2/9/2015 3:52	2/9/2015 8:22
Grab Sample Time 1	3/15/2015 13:30	3/15/2015 14:45	3/15/2015 14:20	3/15/2015 13:50
Sample Duration (hrs)	8.4	3.3	6.7	11.0
Event Flow Volume Sampled (%)	99.9	96.0	94.4	97.8

1 grabs collected outside storm event, see section 4.1.1

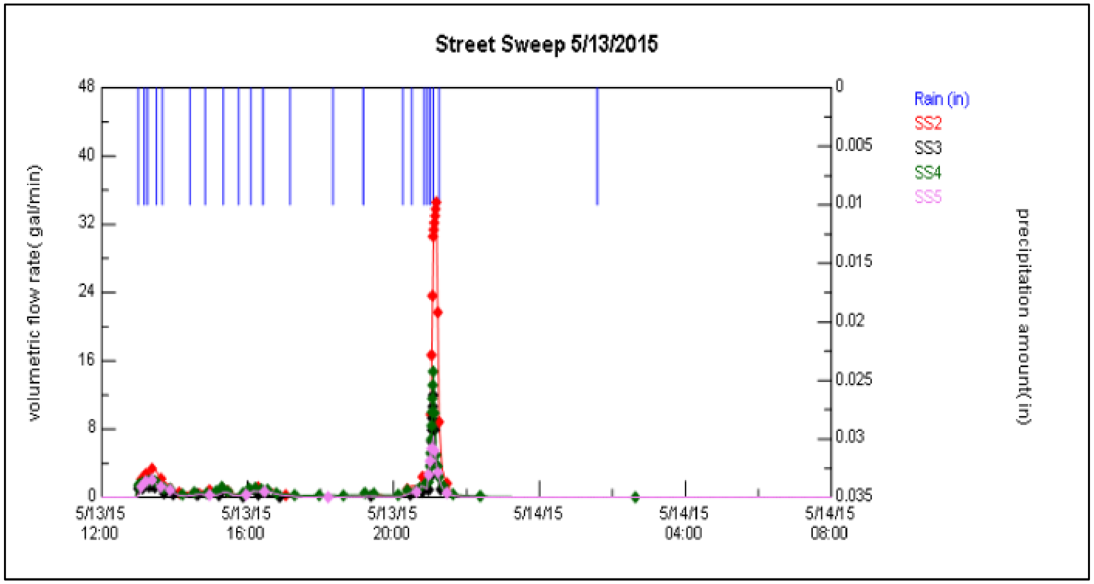
Street Sweeping Effectiveness Study
Individual Storm Report
SE-08: March 13, 2015



Flow and Sample Statistics	
Precip Start	3/13/2015 23:10
Precip Stop	3/14/2015 9:00
Storm Event Duration (hrs)	9.8
Event Rainfall (in)	0.70
Storm Event Rainfall Mean (in/hr)	0.07
Event Rainfall Max (in/hr)	0.48
Antecedent Dry Period (hr)	63.8

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	3/13/2015 23:10	3/13/2015 23:10	3/13/2015 23:10	3/13/2015 23:10
Stop	3/14/2015 17:00	3/14/2015 14:10	3/14/2015 17:00	3/14/2015 12:20
Flow Duration (hrs)	16.7	15.1	17.9	13.0
Event Total Flow Mean (gpm)	4.1	0.6	1.6	2.2
Event Total Flow Max (gpm)	57.5	2.5	13.3	24.2
Event Total Flow Volume (gal)	4125.6	521.0	1685.9	1742.7
No. Composite Sample Aliquots	41	35	81	17
First Sample Time	3/13/2015 23:47	3/13/2015 23:10	3/13/2015 23:32	3/13/2015 23:27
Last Sample Time	3/14/2015 7:12	3/14/2015 9:37	3/14/2015 10:17	3/14/2015 8:22
Grab Sample Time	3/14/2015 8:17	3/14/2015 8:30	3/14/2015 8:50	3/14/2015 9:00
Sample Duration (hrs)	7.4	10.5	10.8	8.9
Event Flow Volume Sampled (%)	96.4	97.7	98.8	95.4

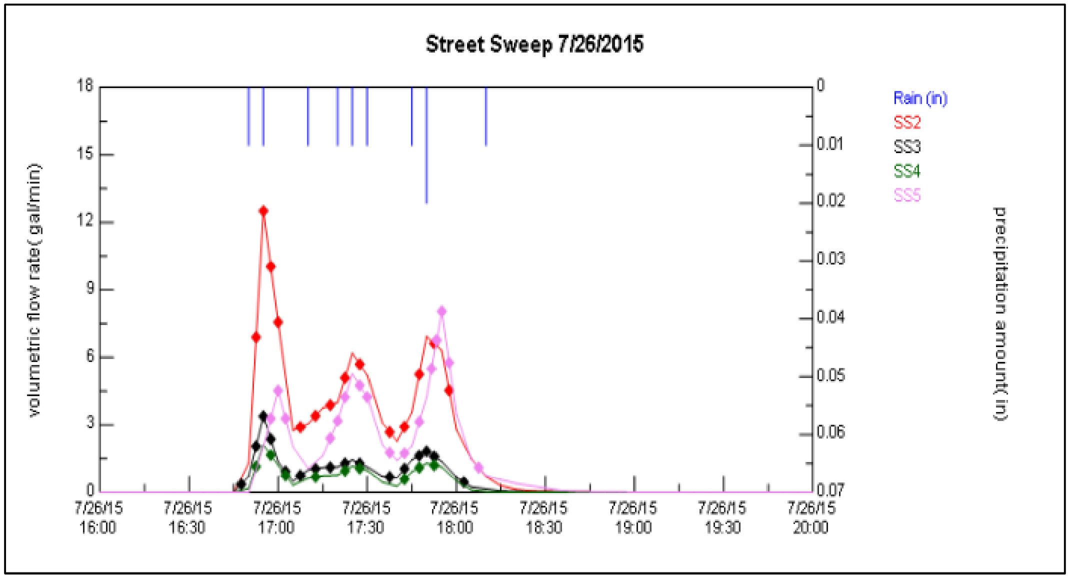
Street Sweeping Effectiveness Study
Individual Storm Report
SE-09: May 13, 2015



Flow and Sample Statistics	
Precip Start	5/13/2015 13:00
Precip Stop	5/14/2015 1:35
Storm Event Duration (hrs)	12.6
Event Rainfall (in)	0.22
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.12
Antecedent Dry Period (hr)	13.6

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	5/13/2015 12:55	5/13/2015 12:55	5/13/2015 12:55	5/13/2015 12:55
Stop	5/13/2015 23:00	5/13/2015 23:10	5/14/2015 7:30	5/14/2015 0:20
Flow Duration (hrs)	10.2	10.3	18.7	11.5
Event Total Flow Mean (gpm)	1.3	0.4	0.4	0.4
Event Total Flow Max (gpm)	34.6	12.0	14.8	7.2
Event Total Flow Volume (gal)	802.8	221.6	483.0	304.9
No. Composite Sample Aliquots	24	29	49	16
First Sample Time	5/13/2015 13:05	5/13/2015 13:00	5/13/2015 13:00	5/13/2015 13:05
Last Sample Time	5/13/2015 21:27	5/13/2015 21:17	5/14/2015 2:37	5/13/2015 21:27
Grab Sample Time	5/13/2015 14:30	5/13/2015 14:55	5/13/2015 15:00	5/13/2015 15:25
Sample Duration (hrs)	8.4	8.3	13.6	8.4
Event Flow Volume Sampled (%)	96.7	96.0	97.2	95.0

Street Sweeping Effectiveness Study
Individual Storm Report
SE-10: July 26, 2015

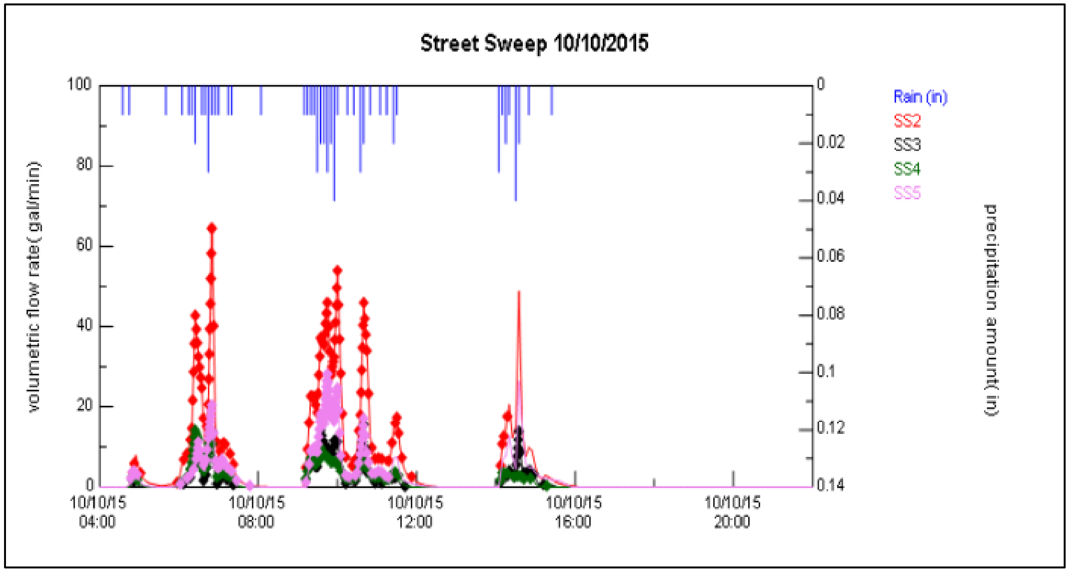


Flow and Sample Statistics	
Precip Start	7/26/2015 16:50
Precip Stop	7/26/2015 18:10
Storm Event Duration (hrs)	1.3
Event Rainfall (in)	0.10
Storm Event Rainfall Mean (in/hr)	0.08
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	901.8

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	7/26/2015 16:50	7/26/2015 16:50	7/26/2015 16:50	7/26/2015 16:50
Stop	7/26/2015 19:00	7/26/2015 18:45	7/26/2015 18:20	7/26/2015 19:15
Flow Duration (hrs)	2.3	2.0	1.6	2.5
Event Total Flow Mean (gpm)	2.7	0.8	0.7	1.6
Event Total Flow Max (gpm)	12.5	3.4	2.1	8.1
Event Total Flow Volume (gal)	370.7	95.2	64.4	246.5
No. Composite Sample Aliquots	14	15	9	16
First Sample Time	7/26/2015 16:52	7/26/2015 16:52	7/26/2015 16:52	7/26/2015 16:57
Last Sample Time	7/26/2015 17:57	7/26/2015 18:02	7/26/2015 17:52	7/26/2015 18:07
Grab Sample Time 1	4/13/2015 15:10	4/13/2015 14:55	4/13/2015 14:45	4/13/2015 14:25
Sample Duration (hrs)	1.1	1.2	1.0	1.2
Event Flow Volume Sampled (%)	84.1	84.8	80.6	87.0

1 grabs collected outside storm event, see section 4.1.1

Street Sweeping Effectiveness Study
Individual Storm Report
SE-11: October 10, 2015

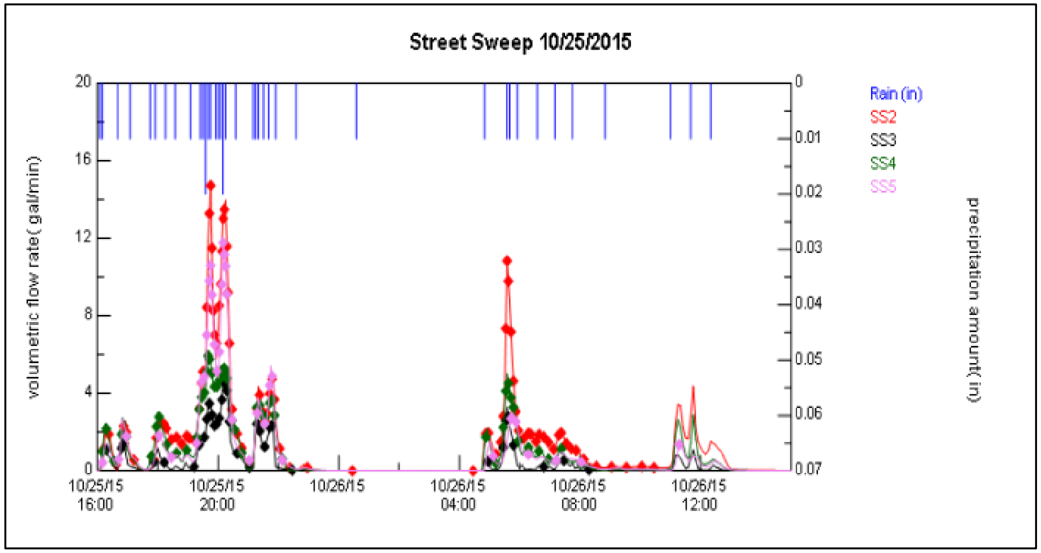


Flow and Sample Statistics	
Precip Start	10/10/2015 4:35
Precip Stop	10/10/2015 15:25
Storm Event Duration (hrs)	10.8
Event Rainfall (in)	0.68
Storm Event Rainfall Mean (in/hr)	0.06
Event Rainfall Max (in/hr)	0.48
Antecedent Dry Period (hr)	62.1

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	10/10/2015 4:35	10/10/2015 4:45	10/10/2015 4:45	10/10/2015 4:30
Stop	10/10/2015 21:20	10/10/2015 15:50	10/10/2015 16:20	10/10/2015 17:50
Flow Duration (hrs)	16.8	8.8	10.2	12.8
Event Total Flow Mean (gpm)	5.5	2.3	2.1	3.2
Event Total Flow Max (gpm)	64.6	15.6	14.2	28.2
Event Total Flow Volume (gal)	5510.8	1216.4	1265.5	2484.3
No. Composite Sample Aliquots	100	86	81	100
First Sample Time	10/10/2015 4:50	10/10/2015 4:50	10/10/2015 4:50	10/10/2015 4:47
Last Sample Time	10/10/2015 14:17	10/10/2015 15:12	10/10/2015 15:17	10/10/2015 11:17
Grab Sample Time 1	12/3/2015 6:45	12/3/2015 7:00	12/3/2015 7:15	12/3/2015 7:30
Sample Duration (hrs)	9.5	10.4	10.5	6.5
Event Flow Volume Sampled (%)	85.9	98.4	98.7	70.4

1 grabs collected outside storm event, see section 4.1.1

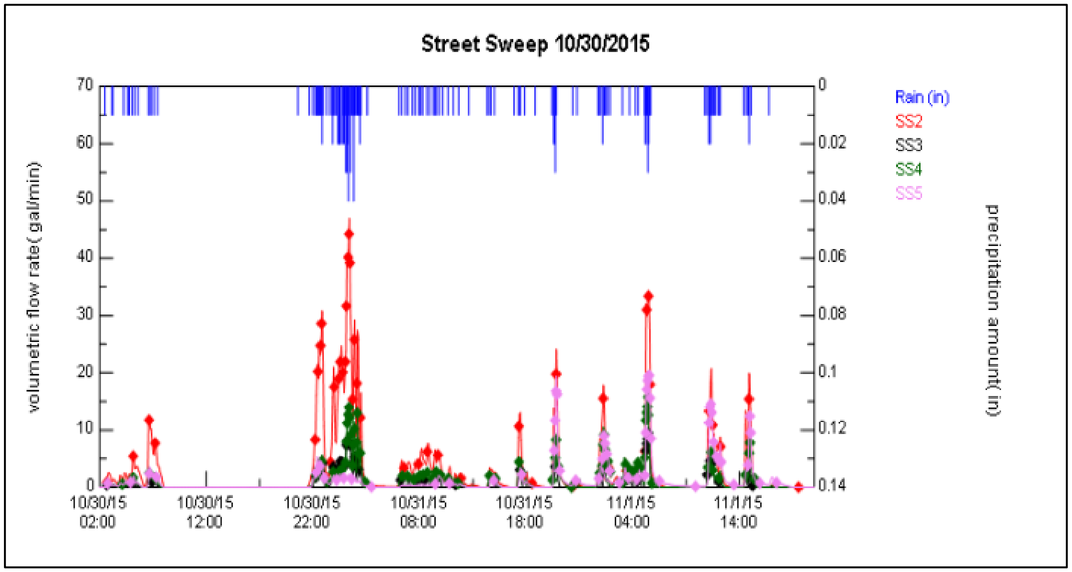
Street Sweeping Effectiveness Study
Individual Storm Report
SE-12: October 25, 2015



Flow and Sample Statistics	
Precip Start	10/25/2015 16:10
Precip Stop	10/26/2015 12:20
Storm Event Duration (hrs)	20.2
Event Rainfall (in)	0.40
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	164.3

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	10/25/2015 16:05	10/25/2015 16:05	10/25/2015 16:05	10/25/2015 16:05
Stop	10/26/2015 14:25	10/26/2015 13:35	10/26/2015 14:25	10/26/2015 14:25
Flow Duration (hrs)	17.3	16.6	22.4	18.0
Event Total Flow Mean (gpm)	1.6	0.5	0.8	1.0
Event Total Flow Max (gpm)	14.7	4.7	6.0	11.8
Event Total Flow Volume (gal)	1699.6	502.7	1076.8	1102.9
No. Composite Sample Aliquots	84	35	51	34
First Sample Time	10/25/2015 16:12	10/25/2015 16:17	10/25/2015 16:10	10/25/2015 16:10
Last Sample Time	10/26/2015 10:27	10/26/2015 8:17	10/26/2015 8:02	10/26/2015 11:17
Grab Sample Time	10/25/2015 18:00	10/25/2015 17:45	10/25/2015 17:25	10/25/2015 17:12
Sample Duration (hrs)	18.3	16.0	15.9	19.1
Event Flow Volume Sampled (%)	87.8	89.7	88.3	95.4

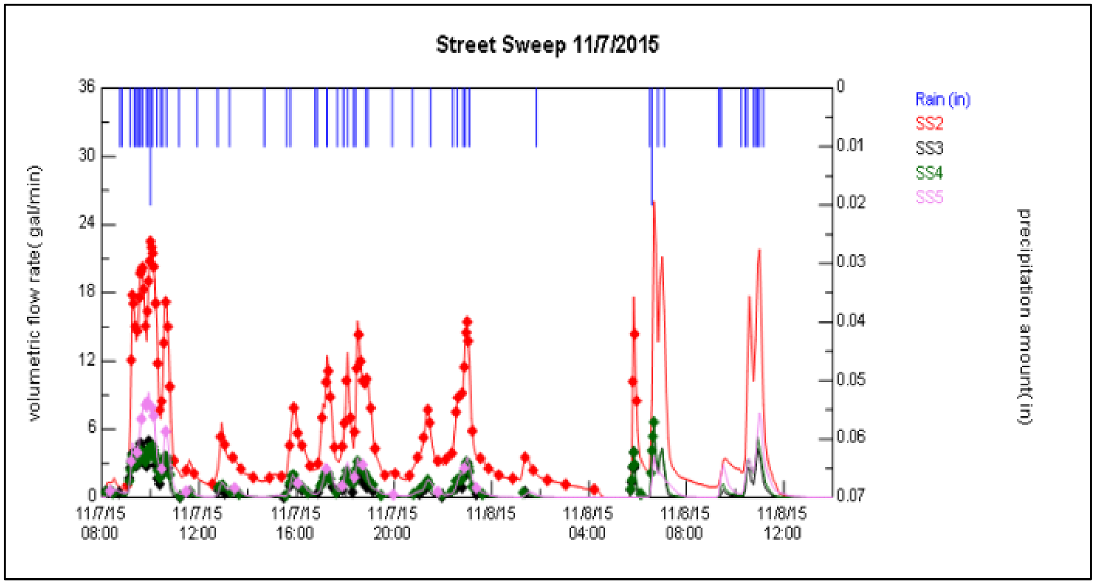
Street Sweeping Effectiveness Study
Individual Storm Report
SE-13: October 30, 2015



Flow and Sample Statistics	
Precip Start	10/30/2015 3:10
Precip Stop	11/1/2015 16:45
Storm Event Duration (hrs)	61.6
Event Rainfall (in)	1.68
Storm Event Rainfall Mean (in/hr)	0.03
Event Rainfall Max (in/hr)	0.48
Antecedent Dry Period (hr)	31.2

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	10/30/2015 2:35	10/30/2015 2:35	10/30/2015 2:35	10/30/2015 2:40
Stop	11/1/2015 19:40	11/1/2015 17:15	11/1/2015 18:25	11/1/2015 20:55
Flow Duration (hrs)	54.0	28.8	48.3	54.3
Event Total Flow Mean (gpm)	3.6	1.3	1.4	1.3
Event Total Flow Max (gpm)	47.0	9.6	15.8	19.6
Event Total Flow Volume (gal)	11508.6	2219.6	4193.3	4274.5
No. Composite Sample Aliquots	43	42	76	54
First Sample Time	10/30/2015 2:40	10/30/2015 2:40	10/30/2015 4:07	10/30/2015 2:45
Last Sample Time	11/1/2015 19:32	11/1/2015 15:12	11/1/2015 15:22	11/1/2015 17:27
Grab Sample Time	10/31/2015 9:23	10/31/2015 10:40	10/31/2015 10:15	10/31/2015 9:45
Sample Duration (hrs)	64.9	60.5	59.3	62.7
Event Flow Volume Sampled (%)	100.0	99.9	98.4	99.0

Street Sweeping Effectiveness Study
Individual Storm Report
SE-14: November 7, 2015

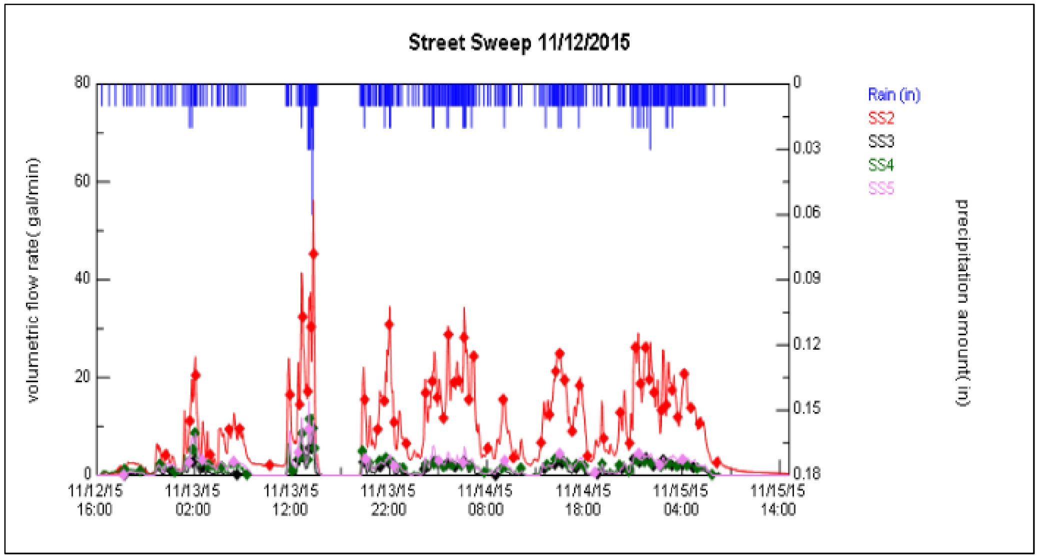


Flow and Sample Statistics	
Precip Start	11/7/2015 8:45
Precip Stop	11/8/2015 11:10
Storm Event Duration (hrs)	26.4
Event Rainfall (in)	0.58
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	117.7

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	11/7/2015 8:40	11/7/2015 8:40	11/7/2015 8:40	11/7/2015 8:40
Stop	11/8/2015 13:50	11/8/2015 13:50	11/8/2015 13:50	11/8/2015 13:50
Flow Duration (hrs)	29.3	29.3	27.1	29.3
Event Total Flow Mean (gpm)	4.2	0.6	0.8	1.0
Event Total Flow Max (gpm)	26.0	6.8	6.6	9.3
Event Total Flow Volume (gal)	7445.8	1010.0	1302.1	1677.7
No. Composite Sample Aliquots	92	73	98	20
First Sample Time	11/7/2015 9:02	11/7/2015 8:42	11/7/2015 9:07	11/7/2015 9:12
Last Sample Time	11/8/2015 5:57	11/8/2015 5:52	11/8/2015 6:40	11/7/2015 23:22
Grab Sample Time 1	12/7/2015 11:25	12/7/2015 11:15	12/7/2015 11:05	12/7/2015 10:50
Sample Duration (hrs)	20.9	21.2	21.5	14.2
Event Flow Volume Sampled (%)	73.7	70.4	75.4	69.1

1 grabs collected outside storm event, see section 4.1.1

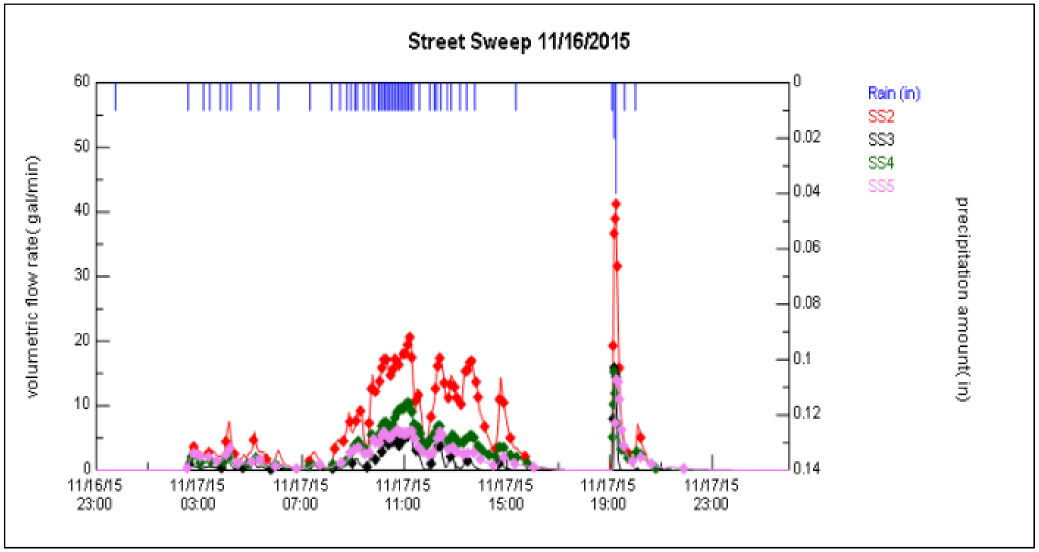
Street Sweeping Effectiveness Study
Individual Storm Report
SE-15: November 12, 2015



Flow and Sample Statistics	
Precip Start	11/12/2015 16:30
Precip Stop	11/15/2015 8:20
Storm Event Duration (hrs)	63.8
Event Rainfall (in)	3.47
Storm Event Rainfall Mean (in/hr)	0.05
Event Rainfall Max (in/hr)	0.72
Antecedent Dry Period (hr)	38.9

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	11/12/2015 16:25	11/12/2015 16:25	11/12/2015 16:25	11/12/2015 16:35
Stop	11/15/2015 14:15	11/15/2015 8:40	11/15/2015 9:05	11/15/2015 8:45
Flow Duration (hrs)	66.9	60.9	62.8	59.3
Event Total Flow Mean (gpm)	8.9	1.1	1.7	2.0
Event Total Flow Max (gpm)	56.2	10.9	12.6	15.2
Event Total Flow Volume (gal)	35783.7	3852.7	6293.6	7085.9
No. Composite Sample Aliquots	57	32	52	16
First Sample Time	11/12/2015 18:25	11/12/2015 18:50	11/12/2015 18:50	11/12/2015 18:45
Last Sample Time	11/15/2015 7:32	11/15/2015 5:07	11/15/2015 7:02	11/15/2015 4:02
Grab Sample Time	11/13/2015 12:40	11/13/2015 12:15	11/13/2015 12:25	11/13/2015 12:00
Sample Duration (hrs)	61.1	58.3	60.2	57.3
Event Flow Volume Sampled (%)	98.6	96.7	97.8	94.0

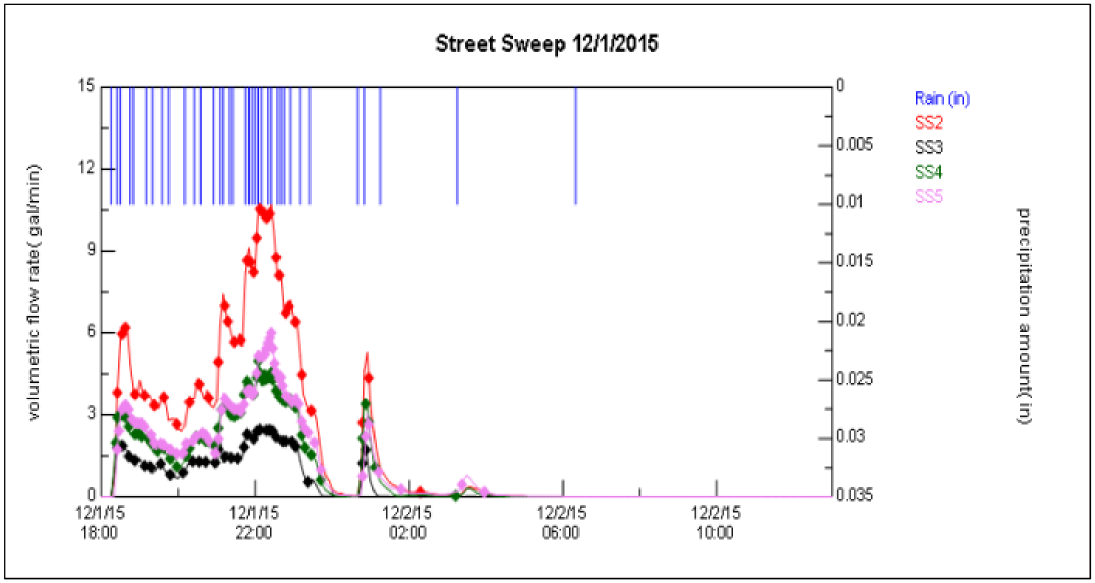
Street Sweeping Effectiveness Study
Individual Storm Report
SE-16: November 16, 2015



Flow and Sample Statistics	
Precip Start	11/16/2015 23:45
Precip Stop	11/17/2015 20:00
Storm Event Duration (hrs)	20.3
Event Rainfall (in)	0.58
Storm Event Rainfall Mean (in/hr)	0.03
Event Rainfall Max (in/hr)	0.48
Antecedent Dry Period (hr)	8.8

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	11/16/2015 23:45	11/16/2015 23:45	11/17/2015 2:10	11/16/2015 23:45
Stop	11/17/2015 23:10	11/17/2015 20:55	11/17/2015 23:00	11/18/2015 1:45
Flow Duration (hrs)	23.3	18.8	19.2	25.9
Event Total Flow Mean (gpm)	4.4	0.9	2.4	1.4
Event Total Flow Max (gpm)	41.3	15.9	15.3	14.1
Event Total Flow Volume (gal)	6197.7	1026.4	2765.2	2238.4
No. Composite Sample Aliquots	62	30	79	64
First Sample Time	11/17/2015 2:47	11/17/2015 2:37	11/17/2015 2:42	11/17/2015 2:32
Last Sample Time	11/17/2015 20:12	11/17/2015 19:15	11/17/2015 20:47	11/17/2015 21:52
Grab Sample Time	11/17/2015 11:10	11/17/2015 10:50	11/17/2015 10:25	11/17/2015 10:05
Sample Duration (hrs)	17.4	16.6	18.1	19.3
Event Flow Volume Sampled (%)	98.2	97.8	98.7	99.0

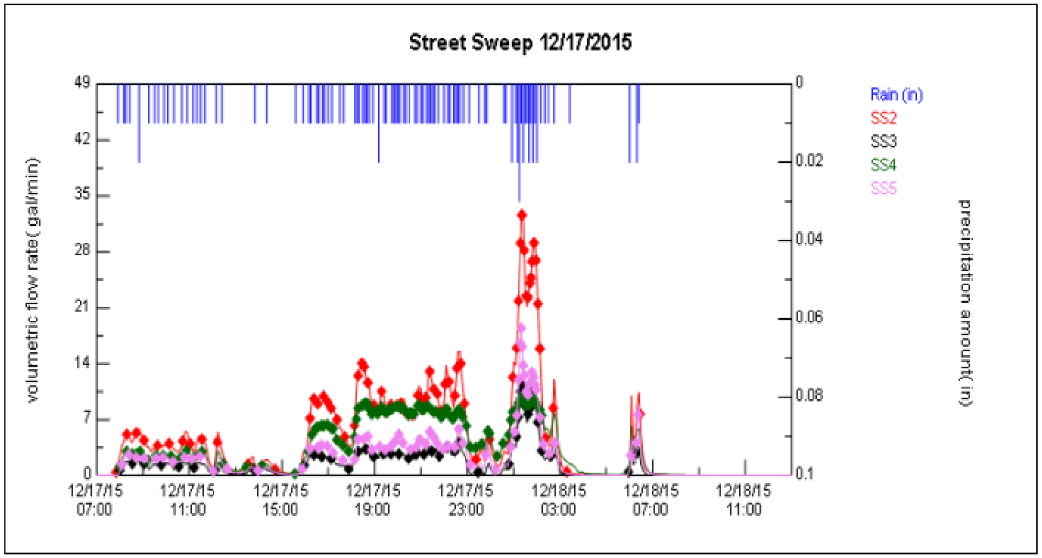
Street Sweeping Effectiveness Study
Individual Storm Report
SE-17: December 1, 2015



Flow and Sample Statistics	
Precip Start	12/1/2015 18:15
Precip Stop	12/2/2015 6:20
Storm Event Duration (hrs)	12.1
Event Rainfall (in)	0.36
Storm Event Rainfall Mean (in/hr)	0.03
Event Rainfall Max (in/hr)	0.12
Antecedent Dry Period (hr)	178.8

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	12/1/2015 18:15	12/1/2015 18:20	12/1/2015 18:15	12/1/2015 18:10
Stop	12/2/2015 5:50	12/2/2015 4:25	12/2/2015 4:40	12/2/2015 12:10
Flow Duration (hrs)	11.7	10.1	10.5	17.2
Event Total Flow Mean (gpm)	2.6	0.8	1.5	1.0
Event Total Flow Max (gpm)	10.7	2.6	5.0	6.0
Event Total Flow Volume (gal)	1848.6	498.8	926.8	1041.9
No. Composite Sample Aliquots	34	34	61	69
First Sample Time	12/1/2015 18:25	12/1/2015 18:25	12/1/2015 18:22	12/1/2015 18:25
Last Sample Time	12/2/2015 2:17	12/2/2015 0:52	12/2/2015 3:12	12/2/2015 3:57
Grab Sample Time	12/1/2015 20:50	12/1/2015 21:10	12/1/2015 21:30	12/1/2015 21:50
Sample Duration (hrs)	7.9	6.5	8.8	9.5
Event Flow Volume Sampled (%)	97.7	95.4	97.7	98.5

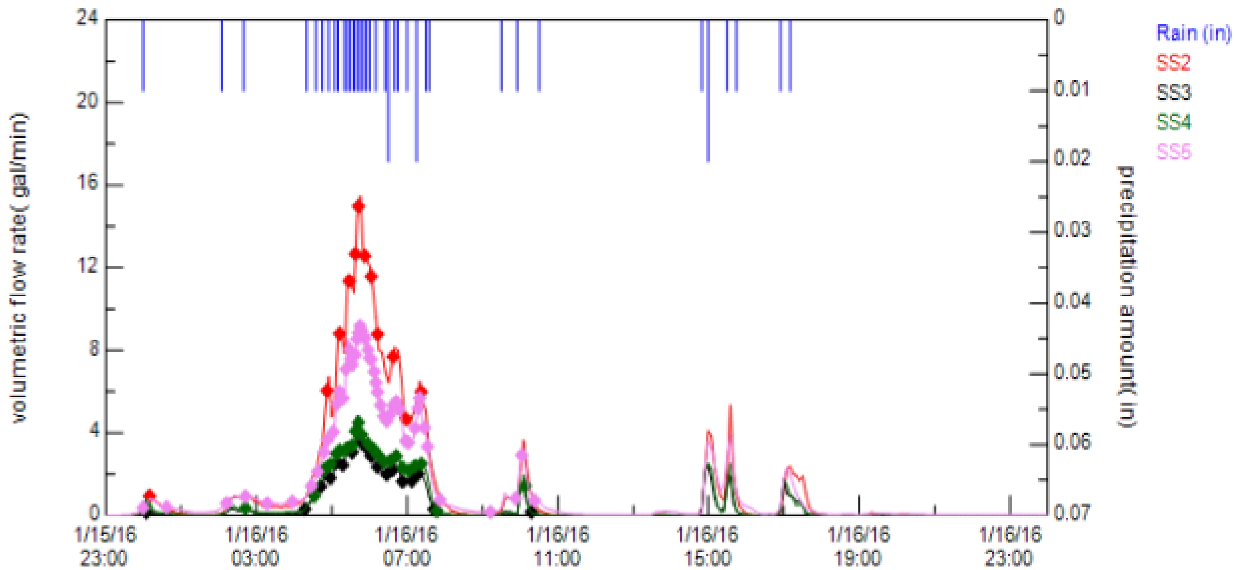
Street Sweeping Effectiveness Study
Individual Storm Report
SE-18: December 17, 2015



Flow and Sample Statistics	
Precip Start	12/17/2015 7:55
Precip Stop	12/18/2015 6:25
Storm Event Duration (hrs)	22.5
Event Rainfall (in)	1.09
Storm Event Rainfall Mean (in/hr)	0.05
Event Rainfall Max (in/hr)	0.36
Antecedent Dry Period (hr)	30.8

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	12/17/2015 7:50	12/17/2015 7:50	12/17/2015 7:50	12/17/2015 7:55
Stop	12/18/2015 12:20	12/18/2015 7:40	12/18/2015 11:00	12/18/2015 10:25
Flow Duration (hrs)	28.3	22.8	27.3	26.6
Event Total Flow Mean (gpm)	4.6	1.7	3.4	2.2
Event Total Flow Max (gpm)	32.6	12.6	9.8	18.4
Event Total Flow Volume (gal)	7762.1	2358.3	5516.3	3482.3
No. Composite Sample Aliquots	71	43	100	69
First Sample Time	12/17/2015 7:50	12/17/2015 8:00	12/17/2015 8:00	12/17/2015 8:05
Last Sample Time	12/18/2015 6:27	12/18/2015 6:17	12/18/2015 2:12	12/18/2015 6:22
Grab Sample Time	12/17/2015 9:45	12/17/2015 10:25	12/17/2015 10:15	12/17/2015 10:00
Sample Duration (hrs)	22.6	22.3	18.2	22.3
Event Flow Volume Sampled (%)	99.4	98.1	90.1	98.1

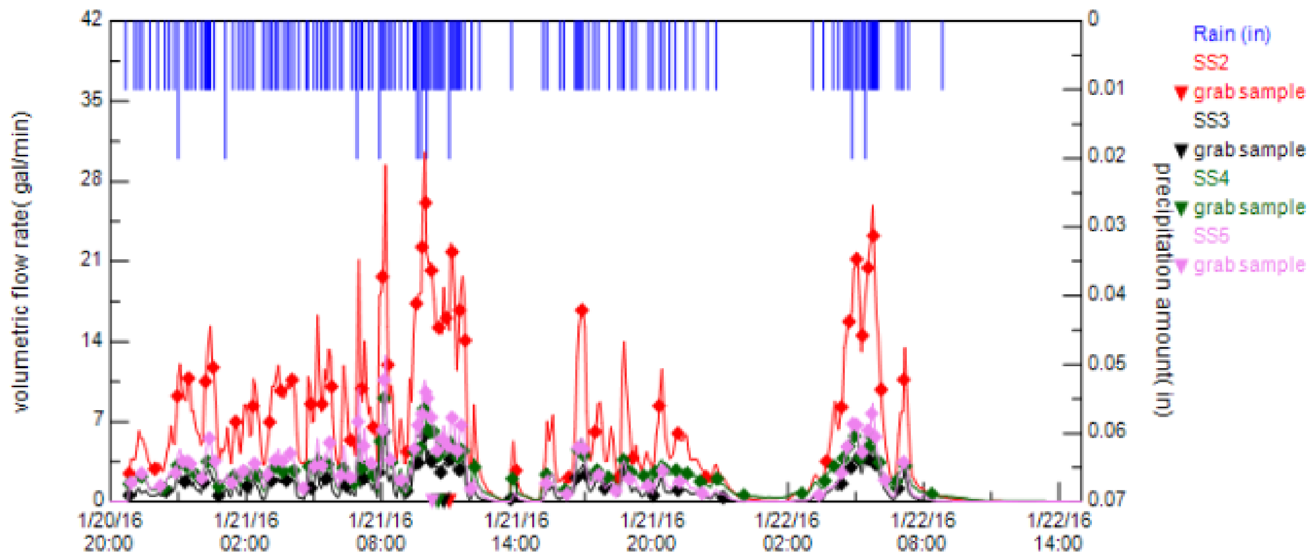
Street Sweeping Effectiveness Study
Individual Storm Report
SE-19: January 16, 2016



Flow and Sample Statistics	
Precip Start	1/16/2016 0:00
Precip Stop	1/16/2016 17:10
Storm Event Duration (hrs)	17.2
Event Rainfall (in)	0.39
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	60.6

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	1/15/2016 23:55	1/15/2016 23:55	1/15/2016 23:55	1/15/2016 23:55
Stop	1/16/2016 21:00	1/16/2016 23:10	1/16/2016 20:35	1/16/2016 23:10
Flow Duration (hrs)	18.3	23.3	18.0	23.3
Event Total Flow Mean (gpm)	1.7	0.4	0.7	1.1
Event Total Flow Max (gpm)	15.5	4.4	4.8	9.2
Event Total Flow Volume (gal)	1879.6	589.4	706.4	1509.7
No. Composite Sample Aliquots	12	20	24	51
First Sample Time	1/16/2016 0:10	1/16/2016 0:05	1/16/2016 0:05	1/16/2016 0:00
Last Sample Time	1/16/2016 7:22	1/16/2016 10:17	1/16/2016 10:07	1/16/2016 10:22
Grab Sample Time				
Sample Duration (hrs)	7.2	10.2	10.0	10.4
Event Flow Volume Sampled (%)	78.7	81.4	82.9	83.2

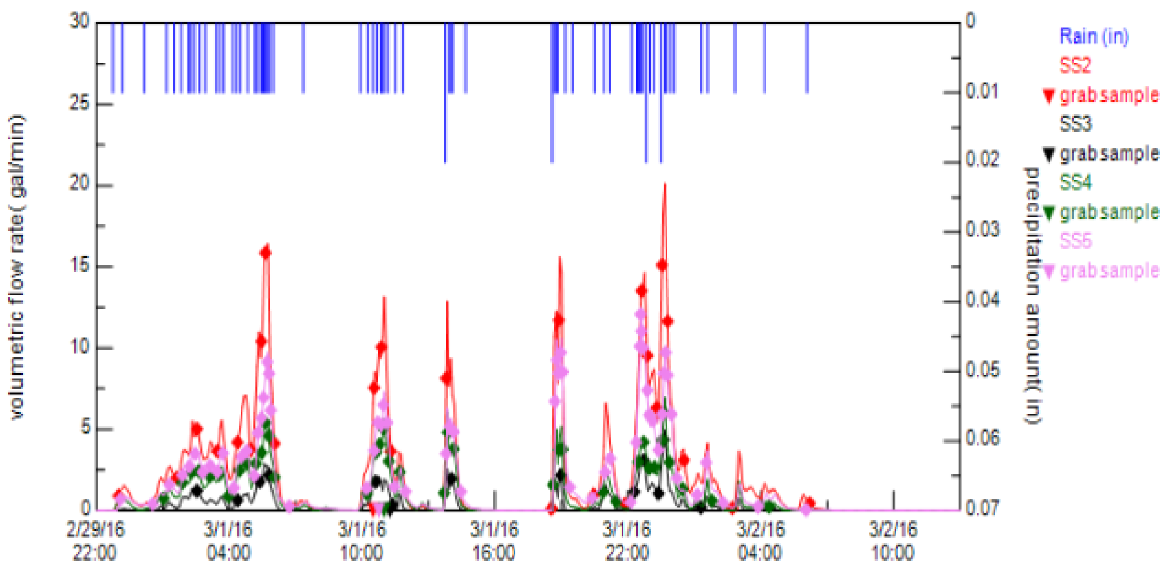
Street Sweeping Effectiveness Study
Individual Storm Report
SE-20: January 20-22, 2016



Flow and Sample Statistics	
Precip Start	1/20/2016 20:40
Precip Stop	1/22/2016 8:50
Storm Event Duration (hrs)	36.2
Event Rainfall (in)	1.54
Storm Event Rainfall Mean (in/hr)	0.04
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	23.9

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	1/20/2016 20:35	1/20/2016 20:35	1/20/2016 20:40	1/20/2016 20:45
Stop	1/22/2016 14:45	1/22/2016 14:45	1/22/2016 14:50	1/22/2016 11:20
Flow Duration (hrs)	42.3	42.3	42.3	38.7
Event Total Flow Mean (gpm)	5.5	1.0	2.0	2.1
Event Total Flow Max (gpm)	30.5	6.2	9.1	12.8
Event Total Flow Volume (gal)	14061.3	2628.5	4971.3	4821.7
No. Composite Sample Aliquots	47	35	66	64
First Sample Time	1/20/2016 20:50	1/20/2016 20:50	1/20/2016 20:50	1/20/2016 20:55
Last Sample Time	1/22/2016 7:07	1/22/2016 6:52	1/22/2016 8:22	1/22/2016 7:07
Grab Sample Time	1/21/2016 11:00	1/21/2016 10:45	1/21/2016 10:30	1/21/2016 10:15
Sample Duration (hrs)	34.3	34.0	35.5	34.2
Event Flow Volume Sampled (%)	98.2	97.3	98.7	98.2

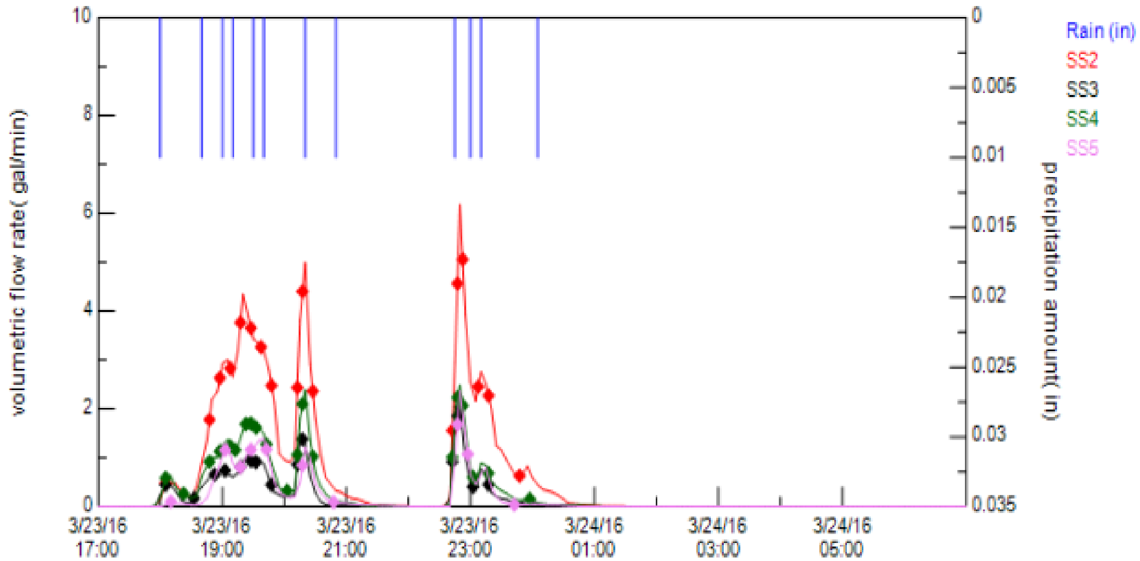
Street Sweeping Effectiveness Study
Individual Storm Report
SE-21: February 29 - March 2, 2016



Flow and Sample Statistics	
Precip Start	2/29/2016 22:45
Precip Stop	3/2/2016 6:05
Storm Event Duration (hrs)	31.3
Event Rainfall (in)	0.74
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.24
Antecedent Dry Period (hr)	20.1

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	2/29/2016 22:45	2/29/2016 22:55	2/29/2016 22:40	2/29/2016 22:45
Stop	3/2/2016 12:05	3/2/2016 12:00	3/2/2016 12:00	3/2/2016 12:05
Flow Duration (hrs)	32.8	33.2	37.0	37.4
Event Total Flow Mean (gpm)	2.4	0.4	0.9	1.4
Event Total Flow Max (gpm)	20.1	4.9	7.0	12.1
Event Total Flow Volume (gal)	4803.7	817.3	1920.7	3121.9
No. Composite Sample Aliquots	25	13	38	63
First Sample Time	2/29/2016 23:00	3/1/2016 2:32	3/1/2016 1:02	2/29/2016 23:05
Last Sample Time	3/2/2016 6:12	3/2/2016 1:17	3/2/2016 4:22	3/2/2016 6:02
Grab Sample Time	3/1/2016 10:30	3/1/2016 11:15	3/1/2016 11:00	3/1/2016 10:45
Sample Duration (hrs)	31.2	22.8	27.3	31.0
Event Flow Volume Sampled (%)	99.7	87.4	96.4	99.6

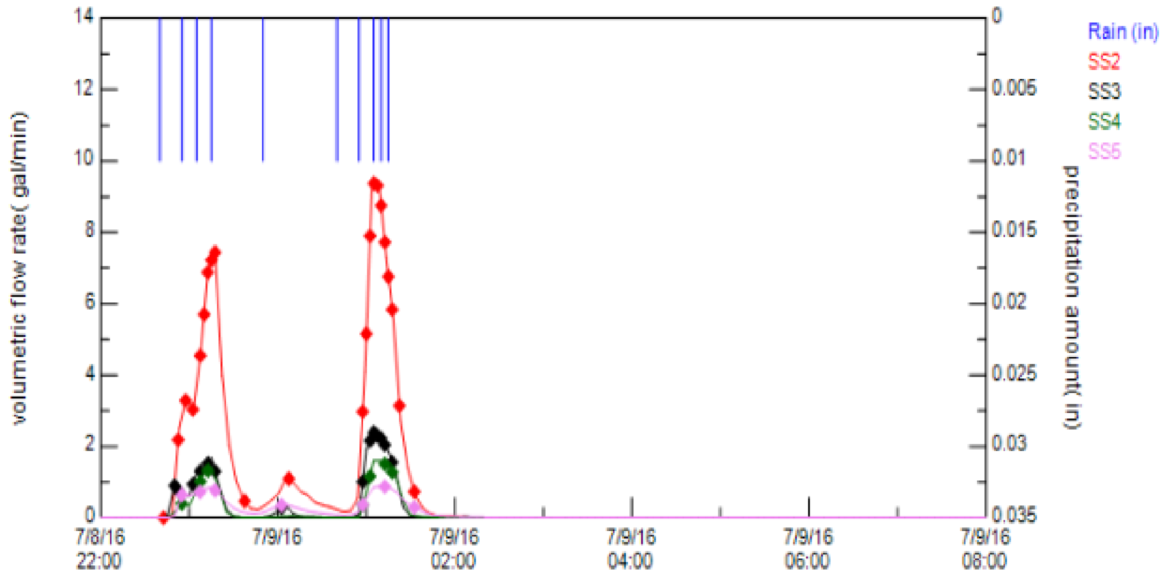
Street Sweeping Effectiveness Study
Individual Storm Report
SE-22: March 23, 2016



Flow and Sample Statistics	
Precip Start	3/23/2016 18:00
Precip Stop	3/24/2016 0:05
Storm Event Duration (hrs)	6.1
Event Rainfall (in)	0.12
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.12
Antecedent Dry Period (hr)	46.2

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	3/23/2016 17:55	3/23/2016 17:55	3/23/2016 17:55	3/23/2016 18:05
Stop	3/24/2016 6:05	3/24/2016 1:00	3/24/2016 1:25	3/24/2016 0:50
Flow Duration (hrs)	12.3	6.5	7.6	6.3
Event Total Flow Mean (gpm)	0.7	0.3	0.5	0.4
Event Total Flow Max (gpm)	6.2	2.0	2.5	2.4
Event Total Flow Volume (gal)	502.1	131.9	211.3	136.3
No. Composite Sample Aliquots	17	15	20	10
First Sample Time	3/23/2016 18:05	3/23/2016 18:05	3/23/2016 18:05	3/23/2016 18:10
Last Sample Time	3/23/2016 23:47	3/23/2016 23:17	3/23/2016 23:57	3/23/2016 23:42
Grab Sample Time				
Sample Duration (hrs)	5.7	5.2	5.9	5.5
Event Flow Volume Sampled (%)	95.2	91.8	96.7	97.8

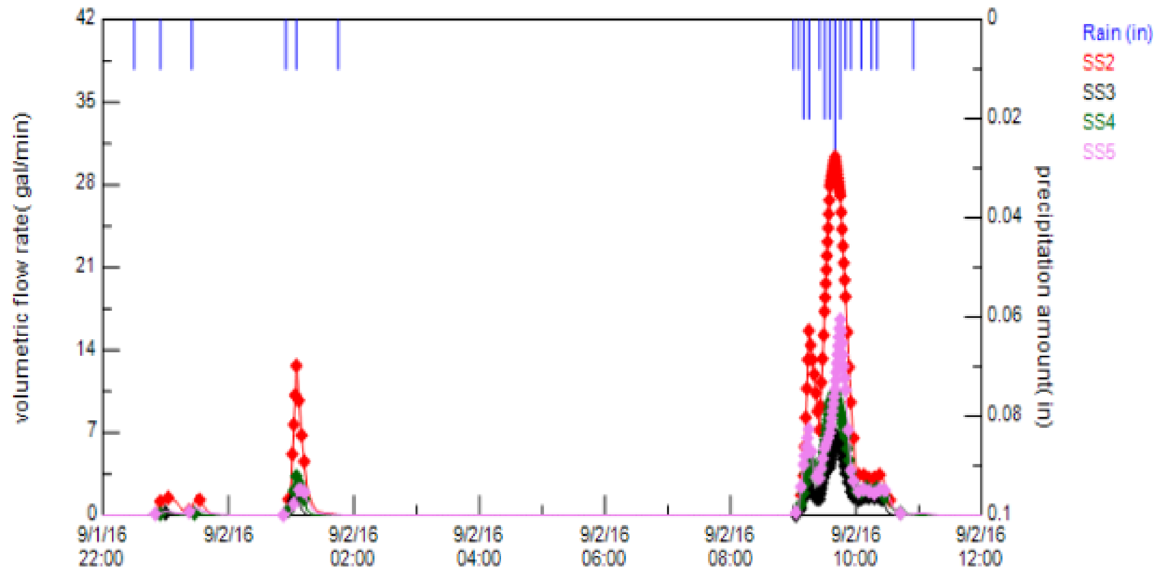
Street Sweeping Effectiveness Study
Individual Storm Report
SE-23: July 9, 2016



Flow and Sample Statistics	
Precip Start	7/8/2016 22:40
Precip Stop	7/9/2016 1:15
Storm Event Duration (hrs)	2.6
Event Rainfall (in)	0.10
Storm Event Rainfall Mean (in/hr)	0.04
Event Rainfall Max (in/hr)	0.12
Antecedent Dry Period (hr)	17.8

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	7/8/2016 22:48	7/8/2016 22:45	7/8/2016 22:50	7/8/2016 22:50
Stop	7/9/2016 2:26	7/9/2016 7:00	7/9/2016 1:50	7/9/2016 3:20
Flow Duration (hrs)	3.8	4.2	2.8	4.6
Event Total Flow Mean (gpm)	1.8	0.4	0.4	0.2
Event Total Flow Max (gpm)	9.4	2.4	1.6	0.9
Event Total Flow Volume (gal)	420.4	94.1	63.8	68.1
No. Composite Sample Aliquots	21	14	7	7
First Sample Time	7/8/2016 22:52	7/8/2016 22:50	7/8/2016 22:55	7/8/2016 22:55
Last Sample Time	7/9/2016 1:32	7/9/2016 1:17	7/9/2016 1:17	7/9/2016 1:32
Grab Sample Time				
Sample Duration (hrs)	2.7	2.5	2.4	2.6
Event Flow Volume Sampled (%)	96.5	89.1	86.2	90.3

Street Sweeping Effectiveness Study
Individual Storm Report
SE-24: September 2, 2016



Flow and Sample Statistics	
Precip Start	9/1/2016 22:30
Precip Stop	9/2/2016 10:20
Storm Event Duration (hrs)	11.8
Event Rainfall (in)	0.27
Storm Event Rainfall Mean (in/hr)	0.02
Event Rainfall Max (in/hr)	0.36
Antecedent Dry Period (hr)	602.1

Flow and Sample Statistics	SS2	SS3	SS4	SS5
Start	9/1/2016 22:25	9/1/2016 22:50	9/1/2016 22:50	9/1/2016 22:25
Stop	9/2/2016 11:25	9/2/2016 10:35	9/2/2016 11:15	9/2/2016 11:45
Flow Duration (hrs)	6.1	2.6	4.7	7.3
Event Total Flow Mean (gpm)	3.1	1.5	1.5	1.2
Event Total Flow Max (gpm)	30.4	6.8	10.5	16.6
Event Total Flow Volume (gal)	1144.2	229.2	411.0	507.1
No. Composite Sample Aliquots	73	53	70	52
First Sample Time	9/1/2016 22:55	9/1/2016 23:00	9/1/2016 22:55	9/1/2016 22:50
Last Sample Time	9/2/2016 10:32	9/2/2016 10:25	9/2/2016 10:42	9/2/2016 10:42
Grab Sample Time				
Sample Duration (hrs)	11.6	11.4	11.8	11.9
Event Flow Volume Sampled (%)	99.1	98.5	99.5	98.8

Appendix E: GEOSYNTEC STATISTICAL ANALYSIS MEMO

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Memorandum

Date: 02 October 2017

To: Doug Hutchinson, Seattle Public Utilities

From: Aaron Poresky, Lucas Nguyen, and Marc Leisenring

Subject: Analysis and Interpretation of Street Sweeping Effectiveness Study Data

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INTRODUCTION

Geosyntec conducted a technical review of the Street Sweeping Water Quality Effectiveness Study, including study design, site selection, data collection methods, and data analysis methods. The purpose of the review was to conduct an independent assessment of the study results. The purpose of this memorandum is to detail the statistical analyses applied to analyze and interpret the dataset to quantify the effect of street sweeping. This analysis is consistent with the recommended methods described in the Geosyntec memorandum titled "Recommendations for Analysis and Interpretation of Street Sweeping Effectiveness Study Data" dated May 18, 2017.

OVERVIEW OF STUDY DESIGN

For reference in reviewing this memorandum, the study design included monitoring of four sites over two years to obtain both before and after and paired sites. Sites included:

- Control Sites: SS2 and SS5 – these sites were consistently swept in both Year 1 and Year 2.
- Impact Sites: SS3 and SS4 – these sites were consistently swept in Year 1, but sweeping was discontinued in Year 2.

Flow weighted composited and grab samples of runoff were collected prior to entry into the storm sewer from 10 storms in Year 1 and 14 storms in Year 2. The same 24 storm events were sampled at each site. Grab samples sometimes occurred during different storms than composite samples. Only indicator bacteria and PAHs (e.g., fluoranthene and pyrene) were grab sampled. The remaining constituents were analyzed based on flow-weighted composite samples. A precipitation gage at SS5 was used to support this study.

STATISTICAL ANALYSIS METHDOLOGY AND INTERMEDIATE RESULTS

This section describes the steps that were used to prepare and analyze the data. Intermediate results are presented in line with each step.

Step 1. Prepare Data for Analysis

Geosyntec reviewed and processed hydrologic metrics, other event metrics, and water quality data from the study to prepare the data for analysis. Processing included combining hydrologic and water quality datasets into combined data structure, grouping data by sampling events, grouping data by control and impact sites, calculating particulate metals concentration (as difference of total and dissolved concentrations), calculating normalized event loads, and other steps. Water quality parameters of interest included:

- Chemical Oxygen Demand
- Dissolved Copper
- Total Copper
- Particulate Copper
- Fecal Coliform
- Nitrate + Nitrite
- Nitrogen, Total Kjeldahl
- Phosphorus, Total
- Fluoranthene
- Pyrene
- Sediment Conc. < 3.9 um
- Sediment Conc. 62.5 to 3.9 um
- Sediment Conc. 250 to 62.5 um
- Sediment Conc. 500 to 250 um
- Sediment Conc. > 500 um
- Sediment Conc. Total
- Solids, Total Suspended
- Total Organic Carbon
- Dissolved Zinc
- Total Zinc
- Particulate Zinc

Parameters are consistently presented in alphabetical order throughout this memorandum and the attachments.

The following parameters were not evaluated because these parameters are not typically stormwater pollutants of concern, would not likely be affected by street sweeping, and/or have a high percentage of non-detect samples.

- Calcium
- Hardness
- Magnesium
- pH
- Remaining PAHs

Key data fields that were added to assist with the inspection of the sampling data included:

- Antecedent 1 week precipitation total
- Antecedent 3 week precipitation total
- Time since last sweeping
- Time since last sweeping event or precipitation event
- Tributary area

- Normalized load based on measured volume and concentration, divided by tributary area
- Normalized load based on measured precipitation depth and concentration (this field was also used in the net summation of normalized load analysis described in Step 6)

Data preparation also included removing certain sediment concentration data points that were believed to be of poor quality: values for sediment concentration fractions < 3.9 um and 3.9 to 62.5 um were removed for all sites for event 7, and values for the 3.9 to 62.5 um size fraction were removed for events 1, 2, 3, and 4. These values were reported as mostly below detection but are believed to have been biased by the laboratory measurement methods. The decision to keep or exclude data applied to all sites for a given storm event in order to maintain symmetry and comparability. Removed data were entirely within the 2014/2015 monitoring season (Year 1).

Step 2. Produce and Inspect Expanded Scatter Plots and Time Series Plots

Time series plots and scatter plots were developed and used to aid in data exploration and interpretation of statistical results. In addition, Spearman's Rho correlation coefficients and confidence interval ellipsoids were used to evaluate the strength of correlations. These analyses were not used directly in the final analysis and interpretation of datasets, but they influenced the development of statistical methods and provided insights into trends and distributions of datasets. For example, the scatter plots indicated correlation between water quality and certain event metrics (e.g., antecedent dry period, recent rainfall totals, time since sweeping), suggesting that certain factors would likely lead to co-variation in water quality response among the sites. This supported the selection of the Analysis of Covariation statistical method as discussed in Step 7. Time series plots and scatter plots are provided in Attachment 1.

Step 3: Inspect and Remove Likely Outliers

A potential outlier was considered a likely outlier if it is more than two standard deviations away from the average of the overall dataset, based on an assumed log-normal distribution. The application of this test in log-space result in inclusions of (i.e., not discarding) high values that could reasonably be expected to arise from a log normal population. If inclusion of a suspected outliner data point would result in a positive bias regarding the effectiveness of sweeping (for example, a very high result in the second year for unswept sites), then less inclusive criteria than described above were considered to exclude the subject point and this added degree of conservatism was noted in interpretation.

Several data points were identified as potential outliers, but only a single point was considered a likely outlier. The point in question occurred during Event SE-10 on April 13, 2015 at site SS4. The fecal coliform density in this sample (580,000 cfu/100ml) exceeded two standard deviations of the dataset and was more than an order of magnitude greater than the next highest value (20,000 cfu/100ml). Time series plots showing potential outliers that were considered are provided in Attachment 2 with annotation regarding the basis for keeping or excluding potential outliers.

Step 4: Conduct Wilcoxon Signed-Rank Test on Paired Data within Years

The Wilcoxon Signed Rank Test was used to evaluate similarity between sites within years. The Wilcoxon Signed Rank Test is a non-parametric version of the paired t-test that is used to test the null hypothesis that two related paired samples come from the same distribution. Data collected at different sites during the same storm event are considered "paired" for this test. An alpha significance value of 0.1 was used to interpret p-values resulting from this test.

Within each year, there are 6 comparisons between sites that are meaningful (SS2:SS3, SS2:SS4, SS2:SS5, SS3:SS4, SS3:SS5, SS4:SS5). These comparisons were used to inform whether the control and impact sites pooled (combined via an arithmetic average for a given storm) or individual sites data should be discarded for some parameters.

The overall purpose of this step was to determine whether it is appropriate to pool the data from control and impact sites for analysis, or whether it would be appropriate to discard one of the control or impact sites due to lack of similarity. The following questions were answered using this test:

1. **Are the two control sites statistically different from each other in either Year 1 or Year 2?** For the overwhelming majority of parameters, the two control sites are not statistically different from each other in either Year 1 or Year 2, as shown in Table 1. Three constituents (total phosphorus, sediment conc. 500 to 250 um, and total organic carbon) show statistical differences between the sites for one year, but not for both years. Overall, three out of 42 comparisons indicated difference between control sites. Based on this preponderance of evidence, the two control sites (SS2 and SS5) were averaged/pooled for comparing to the impact sites for all constituents.

Table 1: Wilcoxon Signed Rank Test of control sites in year 1 and year 2 (red highlight indicates p < 0.1 indicating a statistically significant difference)

Control vs Control (SS2 vs. SS5)		
	Year 1	**Year 2**
Constituent	**p value**	
Chemical Oxygen Demand	0.575	0.116
Copper, Dissolved	0.767	0.279
Copper, Particulate	0.646	0.683
Copper, Total	0.575	0.972
Fecal Coliform	0.441	0.470
Fluoranthene	0.225	0.500
Nitrate + Nitrite-N	0.386	0.331
Nitrogen, Total Kjeldahl	0.838	0.196
Phosphorus, Total	0.721	0.004
Pyrene	0.116	0.656
Sediment Conc. < 3.9 um	0.646	0.158

Control vs Control (SS2 vs. SS5)		
	Year 1	Year 2
Constituent	p value	
Sediment Conc. 62.5 to 3.9 um	0.686	0.917
Sediment Conc. 250 to 62.5 um	0.333	0.600
Sediment Conc. 500 to 250 um	0.047	0.552
Sediment Conc. > 500 um	0.646	0.701
Sediment Conc. Total N	0.241	0.861
Solids, Total Suspended	0.959	0.245
Total Organic Carbon	0.721	0.056
Zinc, Dissolved	0.594	0.859
Zinc, Particulate	0.575	0.507
Zinc, Total	0.386	0.507

2. **Are either of the impact sites statistically different from the control sites in Year 1?** Comparing the impact sites to the control sites for Year 1 showed some significant differences, as shown in Table 2. Overall, site SS3 is much more similar to the control sites than SS4 for Year 1. For fourteen of the twenty-one parameters SS3 showed statistical similarity to both the control sites, whereas SS4 showed statistical similarity to the control sites in only 7 parameters.

Table 2: Wilcoxon test of impact sites compared to control sites in year 1 (red highlight indicates $p < 0.1$ indicating a statistically significant difference)

Year 1 Impact vs Control			
		Impact Site	
		SS3	SS4
Constituent	Control Site	p value	
Chemical Oxygen Demand	SS2	0.799	0.646
	SS5	0.169	0.441
Copper, Dissolved	SS2	0.047	0.007
	SS5	0.074	0.005
Copper, Particulate	SS2	0.285	0.007
	SS5	0.575	0.005
Copper, Total	SS2	0.203	0.005
	SS5	0.333	0.005
Fecal Coliform	SS2	0.515	0.575
	SS5	0.441	0.889
Fluoranthene	SS2	0.080	0.080
	SS5	1.000	0.655

Year 1 Impact vs Control			
		Impact Site	
		SS3	SS4
Constituent	Control Site	p value	
Nitrate + Nitrite N	SS2	0.093	0.009
	SS5	0.333	0.074
Nitrogen, Total Kjeldahl	SS2	0.314	0.514
	SS5	0.767	0.074
Phosphorus, Total	SS2	0.646	0.139
	SS5	0.575	0.093
Pyrene	SS2	0.116	0.028
	SS5	0.715	0.279
Sediment Conc. < 3.9 um	SS2	0.038	0.214
	SS5	0.260	0.214
Sediment Conc. 62.5 to 3.9 um	SS2	0.500	0.138
	SS5	0.500	0.225
Sediment Conc. 250 to 62.5 um	SS2	0.241	0.646
	SS5	0.017	0.241
Sediment Conc. 500 to 250 um	SS2	0.799	0.114
	SS5	0.028	0.333
Sediment Conc. > 500 um	SS2	0.114	0.386
	SS5	0.285	0.445
Sediment Conc. Total N	SS2	0.114	0.386
	SS5	0.139	0.508
Solids, Total Suspended	SS2	0.575	0.093
	SS5	0.959	0.093
Total Organic Carbon	SS2	0.721	0.093
	SS5	0.767	0.047
Zinc, Dissolved	SS2	0.093	0.008
	SS5	0.263	0.018
Zinc, Particulate	SS2	0.285	0.037
	SS5	0.878	0.013
Zinc, Total	SS2	0.314	0.021
	SS5	0.799	0.007

3. **Are the two impact sites statistically different from each other in Year 1 or Year 2?** For both Year 1 and Year 2 the impact sites show significant differences between each other for most constituents. This result is consistent with the results presented in Table 2 which showed that SS4 was more often different from the control sites in Year 1 than SS3.

Table 3: Wilcoxon test of impact sites in year 1 and year 2 (red highlight indicates p < 0.1 indicating a statistically significant difference)

Impact vs Impact		
	Year 1	Year 2
Constituent	p value	
Chemical Oxygen Demand	0.139	0.109
Copper, Dissolved	0.038	0.213
Copper, Particulate	0.005	0.011
Copper, Total	0.005	0.008
Fecal Coliform	0.484	0.925
Fluoranthene	0.465	0.068
Nitrate + Nitrite N	0.013	0.109
Nitrogen, Total Kjeldahl	0.123	0.041
Phosphorus, Total	0.017	0.064
Pyrene	0.465	0.203
Sediment Conc. < 3.9 um	0.007	0.013
Sediment Conc. 62.5 to 3.9 um	0.043	0.028
Sediment Conc. 250 to 62.5 um	0.022	0.023
Sediment Conc. 500 to 250 um	0.074	0.016
Sediment Conc. > 500 um	0.386	0.249
Sediment Conc. Total	0.059	0.046
Solids, Total Suspended	0.022	0.084
Total Organic Carbon	0.028	0.019
Zinc, Dissolved	0.018	0.012
Zinc, Particulate	0.021	0.011
Zinc, Total	0.005	0.011

Step 5: Summarize Results and Implications for Statistical Interpretation by Pollutant

As discussed above, the two control sites (SS2 and SS5) were pooled for all parameters. These sites are overwhelmingly similar. For the impact sites (SS3 and SS4), the comparison between sites differs by parameters. The before-after/control-impact study design is intended to help control for natural variability between sites. Therefore, pooling is generally considered appropriate even if sites are different. In cases where SS4 showed lack of similarity to the impact sites during Year 1 and lack of similarity to SS3 during Year 1 and Year 2 (Question 2 and 3 above are both yes), then it is also appropriate to evaluate SS3 as an individual impact site rather than pooling. Table 4 shows a summary of the results of Wilcoxon Signed Rank Tests and decisions about which impact dataset(s) to use. Within the various size fractions of sediment concentration, the decision was based on the preponderance of evidence for the whole group rather than allowing different decisions for each sediment size class.

Table 4: Summary of Wilcoxon Signed Rank Tests. "Yes" indicates that sites are similar, "No" indicates that sites are not similar.

Constituent	Control vs Control (Both)	Impact vs. Control Year 1		Impact vs. Impact Year 1	Impact vs. Impact Year 2	Impact Dataset(s) Used for Comparison to Control
		SS3	SS4			
Chemical Oxygen Demand	Yes	Yes	Yes	Yes	Yes	**Pooled**
Copper, Dissolved	Yes	No	No	No	Yes	**Pooled**
Copper, Particulate	Yes	Yes	No	No	No	**Pooled and SS3[1]**
Copper, Total	Yes	Yes	No	No	No	**Pooled and SS3[1]**
Fecal Coliform	Yes	Yes	Yes	Yes	Yes	**Pooled**
Fluoranthene	Yes	No	No	Yes	No	**Pooled**
Nitrate + Nitrite N	Yes	No	No	No	Yes	**Pooled**
Nitrogen, Total Kjeldahl	Yes	Yes	No	Yes	No	**Pooled**
Phosphorus, Total	No	Yes	No	No	No	**Pooled and SS3[1]**
Pyrene	Yes	Yes	No	Yes	Yes	**Pooled**
Sediment Conc. < 3.9 um	Yes	No	Yes	No	No	**Pooled**
Sediment Conc. 62.5 to 3.9 um	Yes	Yes	No	No	No	**Pooled**
Sediment Conc. 250 to 62.5 um	Yes	No	Yes	No	No	**Pooled**
Sediment Conc. 500 to 250 um	No	No	Yes	No	No	**Pooled**
Sediment Conc. > 500 um	Yes	Yes	Yes	Yes	Yes	**Pooled**
Sediment Conc. Total	Yes	Yes	Yes	No	No	**Pooled**
Solids, Total Suspended	Yes	Yes	No	No	No	**Pooled and SS3[1]**
Total Organic Carbon	No	Yes	No	No	No	**Pooled and SS3[1]**
Zinc, Dissolved	Yes	No	No	No	No	**Pooled**
Zinc, Particulate	Yes	Yes	No	No	No	**Pooled and SS3[1]**
Zinc, Total	Yes	Yes	No	No	No	**Pooled and SS3[1]**

1 – For this subset of parameters, comparisons were reported separately for pooled control vs. pooled impact and pooled control vs. SS3 impact. Both comparisons were deemed to be valid.

Step 6: Comparison of Medians and Summation of Loads

An arithmetic comparison of median concentrations and summation of normalized loads analyses were prepared for each pollutant. These analyses do not include a statistical test of difference. However, they provides an indication of the magnitude of potential change associated with discontinuing sweeping after correcting for the year-over-year change observed at the control sites. See the "Results" section for intermediate calculations and results of this analysis. This analysis was done based on pooled impact sites for all parameters, and was also done for the SS3 impact site for the parameters where it was also determined to be appropriate to compare to SS3 only.

Step 7: Analysis of Covariation (ANCOVA)

An ANCOVA analysis was conducted following procedures and assumptions similar to Selbig (2016) and as described by Helsel and Hirsch (2002). The analysis was based on pooled control vs. pooled impact for all parameters. This analysis was also conducted for pooled control vs. SS3 for certain parameters, as identified in Table 4 above.

The ANCOVA method was implemented as follows:

- Ordinary Least Squares (OLS) regression lines were developed based on the log-transformed data. The lines describe the relationship between control and impact in Year 1 and Year 2 (two lines). The datasets generally fit a log-normal distribution better than a normal distribution. In addition, conducting ANCOVA in a log-normal space is expected to yield more directly applicable findings.
- Residuals from the regression lines were used to calculate an F-statistic for use in an ANCOVA analysis.
- The first part of the ANCOVA was to test whether the slopes of the lines are significantly different ($p \le 0.1$).
- If slopes were not statistically different (i.e., "parallel slopes" assumption is met), then the slopes of the two lines were adjusted based on the best fit slope of the combined dataset (Year 1 and Year 2) and the best fit intercept for each year was recomputed based on the assumption of parallel lines (i.e., equal slopes).
- The second part of the ANCOVA was to test whether the intercepts of the parallel lines are different ($p \le 0.1$). If the intercepts were found to be different, then the magnitude of the difference was used to quantify the effect of sweeping. In log space, a consistent vertical offset between the lines translates to a consistent ratio (and percent difference) between swept and unswept conditions. If there was a vertical difference, but it was not found to be significant ($p > 0.1$), the magnitude of the difference was reported and the p-value was also be reported.

The results of the ANCOVA are presented in the "Results" section. The graphical representation of the ANCOVA results (scatter plots with linear regression lines) are presented in Attachment 3.

The underlying assumptions of the ANCOVA were inspected, including:

- Log-linear relationship between dependent variable (y) and covariate (x)
- Variance around the regression line is reasonably homogeneous in X (i.e., the residuals are homoscedastic)
- Normal distribution of residuals

These assumptions were evaluated graphically by inspecting the regression plots in Attachment 3 and the supporting scatter plots and histograms of regression residuals in Attachment 4. Based on this inspection, the assumptions appeared to be reasonably met for most parameters and site comparisons, but the degree of agreement varied.

Rationale for ANCOVA versus ANOVA

Both Analysis of Variation (ANOVA) and Analysis of Covariation (ANCOVA) are based on a similar statistical foundation stemming from linear regression. ANOVA treats all of the factors as categorical data. The ANOVA test is conducted to determine if there is a significant difference in response (for example, runoff quality) as a function of one or more categorical factors (for example site location, year of study). All data within a category are lumped and considered to be independent from data in other categories. The results of the test indicate whether there is a difference as a result of one or both factors, or a combination of the two factors. The ANOVA test itself does not elucidate the magnitude of the difference.

A simple one-way ANCOVA treats one of the factors as a categorical, and the other factor as a continuous covariate. This is the primary difference as compared to ANOVA. ANCOVA is used in cases where the data show that there is a relationship between the covariate and the response. Instead of pooling the covariate into two bins (as is effectively done in the ANOVA), this method preserves the full continuous spectrum of the covariate as part of the test. In this case of the Street Sweeping Effectiveness Study the variable are:

- Response – the concentration at the impact site(s)
- Co-variate – the concentration at the control site(s)
- Categorical variable – the study period (calibration vs. treatment phase; or year 1 vs. year 2)

The selection of this approach is informed by the observation that runoff concentrations are in part dependent on antecedent conditions, seasonal factors, storm event characteristics, and other factors that likely apply to the control and impact sites similarly. Therefore it is reasonable to expect covariation between sites, and this is indeed observed in the review of the datasets. A primary premise of the ANCOVA is that if the concentration at the control site (the covariate) is known for a given event (which it is), then this provides some predictive power for what concentration should be expected at the impact site. In other words, the type of event that would produce elevated metals concentration at the control site is likely to produce elevated metals concentrations at the impact site. This covariate relationship is accounted for in the ANCOVA method but it is not accounted for in the ANOVA method.

To account for this covariation, the ANCOVA forms a linear relationship (slope and intercept) between the control and impact sites during the calibration period (year 1) and a different linear relationship during the treatment period (year 2). Tests for statistical difference as a function of year are based on whether the slopes and/or intercepts of the best fit lines are statistically different. A typical outcome is to find that the slopes are not statistically different. This leads to a test of whether there is difference in the intercepts. If yes, then the magnitude of difference of the intercept supports direct interpretation of the difference between year 1 and year 2 that is attributable to discontinuing sweeping at the impact sites.

RESULTS

Results are presented below for the pooled control versus pooled impact (all parameters) and the pooled control versus SS3 impact (this includes only a subset of parameters identified as "Pooled and SS3" in Table 4). The results of three analyses are presented:

- Table 5 and Table 6 present analyses of net change in median concentrations. The net change in median concentrations was calculated by first calculating the median at each site in year 1 and year 2. The average percent difference between year 1 and year 2 was then calculated for control sites and impact sites independently. The difference in these average differences provided an indication of the net magnitude of change could be attributable to not sweeping (and therefore sweeping). This approach controls for overall year-over-year changes. This is a simple arithmetic method. It is not a statistical test. Table 5 presents results for all parameters based on the pooled impact and Table 6 presents results for the subset of parameters that were appropriate for analysis based on the SS3 impact.

- Table 7 and Table 8 present the results of the net change in summation of normalized load. The net change in summation of normalized loads was calculated by comparing the summation of normalized loads for the impact and control sites in year 1 and year 2 to calculate a percent difference between control and impact in each year. The year-over-year-difference of the differences between the control and impact was used to estimate the net magnitude of change could be attributable to not sweeping. Normalized loads were calculated for each storm based on the concentration for the event multiplied by the precipitation depth for the event. Precipitation depth was used rather than runoff volume to avoid propagating error associated with error in volumetric runoff measurements. Precipitation depth is not the only predictor of runoff volume, however the primary advantage was that it could be applied consistently across sites. Multiplying by precipitation depth rather than estimated runoff volume inherently normalizes for different tributary areas at each site. The summation of normalized load is the sum of the normalized load for all events at a given site within a given year. Table 7 presents results for all parameters based on the pooled impact and Table 8 presents results for the subset of parameters that were appropriate for analysis based on the SS3 impact.

- Table 9 and 10 present the results of the ANCOVA, as detailed in Step 7 above. These tables present the p-values associated with the analysis for parallel slopes. A p-value greater than 0.1 indicates that slopes are not statistically different and the parallel slopes assumption applies. For parameters adhering to the parallel slopes assumption, the tables also present the analysis of difference in intercepts. The effect of sweeping can be interpreted based on the magnitude of difference in intercepts in year 1 and 2 and the p-value of the test. A p-value of less than or equal to 0.1 indicates that the intercepts exhibit a statistically- significant difference. Intercept values are in natural log space. A fixed offset in natural log space implies a constant ratio of swept and unswept conditions which can be converted to a percent difference. Table 9 presents results for all parameters based on the pooled impact and Table 10 presents results for the subset of parameters that were appropriate for analysis based on the SS3 impact. Attachment 3 includes ANCOVA scatterplots and regression lines for each pollutant.

The results are interpreted and discussed in the Discussion section.

Table 5: Net Change in Median Concentration - Pooled Control and Pooled Impact

Parameter	Control Site					Impact Sites					Net Difference in Medians Potentially Attributable to Not Sweeping[1]
	Site	Year 1	Year 2	Yr-Yr %Diff	Avg Yr-Yr %Diff	Site	Year 1	Year 2	Yr-Yr %Diff	Avg Yr-Yr %Diff	
Chemical Oxygen Demand, mg/L	SS2	62	71	14%	30%	SS3	67	77	15%	-3%	-33%
	SS5	55	81	46%		SS4	70	55	-21%		
Copper, Dissolved, ug/L	SS2	5.7	6.9	21%	31%	SS3	4.9	5.3	7%	20%	-11%
	SS5	5.4	7.5	40%		SS4	4.0	5.3	33%		
Copper, Particulate, ug/L	SS2	37	36	-4%	8%	SS3	31	51	65%	42%	**34%**
	SS5	29	35	19%		SS4	21	25	19%		
Copper, Total, ug/L	SS2	43	45	5%	16%	SS3	35	57	65%	48%	**32%**
	SS5	34	43	27%		SS4	24	31	30%		
Fecal Coliform, MPN/100mL	SS2	600	240	-60%	-5%	SS3	445	200	-55%	9%	**14%**
	SS5	260	390	50%		SS4	123	213	73%		
Fluoranthene, ug/L	SS2	0.13	0.09	-26%	-5%	SS3	0.05	0.02	-48%	-18%	-14%
	SS5	0.03	0.04	17%		SS4	0.04	0.05	12%		
Nitrate + Nitrite N, mg/L	SS2	0.16	0.16	4%	-2%	SS3	0.16	0.09	-42%	-39%	-37%
	SS5	0.13	0.12	-7%		SS4	0.13	0.08	-36%		
Nitrogen, Total Kjeldahl, mg/L	SS2	1.3	2.0	56%	80%	SS3	1.3	2.5	92%	81%	**1%**
	SS5	1.3	2.7	104%		SS4	1.0	1.7	70%		
Phosphorus, Total, mg/L	SS2	0.24	0.17	-30%	13%	SS3	0.24	0.27	14%	7%	-6%
	SS5	0.20	0.32	56%		SS4	0.16	0.17	1%		
Pyrene, ug/L	SS2	0.15	0.13	-14%	17%	SS3	0.08	0.10	27%	20%	**3%**
	SS5	0.08	0.12	47%		SS4	0.07	0.08	12%		
Sediment Conc. < 3.9 um, mg/L	SS2	230	7.7	-74%	-78%	SS3	47	8.1	-83%	-84%	-6%
	SS5	42	7.5	-82%		SS4	32	4.6	-85%		

Parameter	Control Site					Impact Sites					Net Difference in Medians Potentially Attributable to Not Sweeping[1]
	Site	**Year 1**	**Year 2**	**Yr-Yr %Diff**	**Avg Yr-Yr %Diff**	**Site**	**Year 1**	**Year 2**	**Yr-Yr %Diff**	**Avg Yr-Yr %Diff**	
Sediment Conc. 62.5 to 3.9 um, mg/L	SS2	75	35	-53%	-55%	SS3	128	46	-64%	-59%	-4%
	SS5	101	43	-57%		SS4	50	23	-54%		
Sediment Conc. 250 to 62.5 um, mg/L	SS2	44	31	-30%	1%	SS3	59	68	15%	0%	-1%
	SS5	25	33	31%		SS4	38	32	-15%		
Sediment Conc. 500 to 250 um, mg/L	SS2	24	12	-50%	-3%	SS3	17	91	444%	293%	**296%**
	SS5	10	14	44%		SS4	10	25	142%		
Sediment Conc. > 500 um, mg/L	SS2	20	27	30%	162%	SS3	24	367	1457%	845%	**683%**
	SS5	18	73	295%		SS4	21	70	233%		
Sediment Conc. Total, mg/L	SS2	160	160	0%	20%	SS3	208	685	230%	111%	**91%**
	SS5	131	184	41%		SS4	157	145	-7%		
Solids, Total Suspended, mg/L	SS2	103	79	-23%	-2%	SS3	91	118	29%	20%	**22%**
	SS5	80	96	19%		SS4	71	79	11%		
Total Organic Carbon, mg/L	SS2	14	14	-2%	23%	SS3	12	15	28%	19%	-4%
	SS5	14	20	49%		SS4	10	11	11%		
Zinc, Dissolved, ug/L	SS2	15	20	38%	35%	SS3	13	16	19%	33%	-2%
	SS5	16	21	32%		SS4	11	16	48%		
Zinc, Particulate, ug/L	SS2	91	107	18%	26%	SS3	100	182	82%	59%	**32%**
	SS5	79	107	35%		SS4	67	90	35%		
Zinc, Total, ug/L	SS2	104	127	22%	33%	SS3	111	199	79%	60%	**26%**
	SS5	90	130	45%		SS4	77	109	41%		

1 – Positive (bolded values) indicate that median concentration increased associated with not sweeping; this implies that sweeping has positive effectiveness. For example, an 50% increase in concentration attributable to not sweeping is equivalent to a 33% decrease in concentration attributable to sweeping.

Table 6: Net Change in Median Concentrations - Pooled Control and SS3 Impact

Parameter	Control Site					Impact Sites				Net Difference in Medians Potentially Attributable to Not Sweeping[1]
	Site	Year 1	Year 2	Yr-Yr %Diff	Avg Yr-Yr %Diff	Site	Year 1	Year 2	Yr-Yr %Diff	
Copper, Particulate ug/l	SS2	37	36	-4%	8%	SS3	31	51	65%	**57%**
	SS5	29	35	19%						
Copper, Total ug/l	SS2	43	45	5%	16%	SS3	35	57	65%	**49%**
	SS5	34	43	27%						
Phosphorus, Total mg/l	SS2	0.24	0.17	-30%	13%	SS3	0.24	0.27	14%	**1%**
	SS5	0.20	0.32	56%						
Solids, Total Suspended mg/l	SS2	103	79	-23%	-2%	SS3	91	118	29%	**31%**
	SS5	80	96	19%						
Total Organic Carbon mg/l	SS2	14	14	-2%	23%	SS3	12	15	28%	**5%**
	SS5	14	20	49%						
Zinc, Particulate ug/l	SS2	91	107	18%	26%	SS3	100	182	82%	**56%**
	SS5	79	107	35%						
Zinc, Total ug/l	SS2	104	127	22%	33%	SS3	111	199	79%	**45%**
	SS5	37	36	45%						

1 – Positive (bolded values) indicate that median concentration increased associated with not sweeping; this implies that sweeping has positive effectiveness. For example, an 50% increase in concentration attributable to not sweeping is equivalent to a 33% decrease in concentration attributable to sweeping.

Table 7: Net Change in Summation of Normalized Load - Pooled Control and Pooled Impact

	Year 1			Year 2			Net Change in Normalized Load Potentially Attributable to Not Sweeping[2]
Chemical Name	**Control[1]**	**Impact[1]**	**%diff (impact compared to control)**	**Control[1]**	**Impact[1]**	**%diff (impact compared to control)**	
Chemical Oxygen Demand	325	360	11%	760	766	1%	-10%
Copper, Dissolved	29	22	-25%	77	54	-30%	-5%
Copper, Particulate	156	132	-15%	366	395	8%	**23%**
Copper, Total	186	154	-17%	443	449	1%	**18%**
Nitrate + Nitrite	0.7	0.6	-24%	1.7	1.2	-32%	-7%
Nitrogen, Total Kjeldahl	7.1	11.7	65%	28	26	-6%	-71%
Phosphorus, Total	1.0	1.6	53%	2.8	3.1	10%	-44%
Sediment Conc. < 3.9 um	132	149	13%	110	69	-37%	-50%
Sediment Conc. 62.5 to 3.9 um	190	212	11%	444	389	-12%	-24%
Sediment Conc. 250 to 62.5 um	162	229	42%	337	649	93%	**51%**
Sediment Conc. 500 to 250 um	115	149	30%	320	877	174%	**144%**
Sediment Conc. > 500 um	182	325	79%	889	3158	255%	**176%**
Sediment Conc. Total	786	1069	36%	2,100	5,141	145%	**109%**
Solids, Total Suspended	476	400	-16%	956	2,197	130%	**146%**
Total Organic Carbon	71	63	-12%	175	145	-17%	-5%
Zinc, Dissolved	76	60	-21%	215	148	-31%	-10%
Zinc, Particulate	442	440	-1%	1,208	1,619	34%	**35%**
Zinc, Total	519	501	-4%	1,423	1,767	24%	**28%**

Note: Normalized load is calculated by multiplying precipitation depth by concentration for each storm event. This is inherently normalized to different drainage areas. Comparisons within year are meaningful because the same amount of precipitation occurred. Grab sampled parameters (fluoranthene, pyrene, fecal coliform) were analyzed because grab samples were sometimes collected in different events than composite sampled parameters. Additionally, grab samples are less reliable for estimating load.

1 – This is a relative analysis; units are not important. For reference, units are mg/L-inches or ug/L-inches depending on the native units of the parameter (see Table 5).

2 – Positive (bolded values) indicate that normalized load increased associated with not sweeping; this implies that sweeping has positive effectiveness. For example, an 50% increase in load attributable to not sweeping is equivalent to a 33% decrease in load attributable to sweeping.

Table 8: Summation of Normalized Load - Pooled Control and SS3 Impact

Chemical Name	Year 1			Year 2			Net Change in Normalized Load Potentially Attributable to Not Sweeping[1]
	Control[1]	SS3[1]	%diff (impact compared to control)	Control[1]	SS3[1]	%diff (impact compared to control)	
Copper, Particulate	156	154	-2%	366	512	40%	**42%**
Copper, Total	186	177	-5%	443	566	28%	**32%**
Phosphorus, Total	1.03	1.59	54%	2.80	3.96	41%	-13%
Solids, Total Suspended	476	450	-5%	956	1,989	108%	**113%**
Total Organic Carbon	71	70	-2%	175	183	4%	**7%**
Zinc, Particulate	442	523	18%	1,208	1,909	58%	**40%**
Zinc, Total	519	587	13%	1,423	2,067	45%	**32%**

Note: Normalized load is calculated by multiplying precipitation depth by concentration for each storm event. This is inherently normalized to different drainage areas. Comparisons within year are meaningful because the same amount of precipitation occurred.

1 – This is a relative analysis; units are not important. For reference, units are mg/L-inches or ug/L-inches depending on the native units of the parameter (see Table 5).

2 – Positive (bolded values) indicate that normalized load increased associated with not sweeping; this implies that sweeping has positive effectiveness. For example, an 50% increase in load attributable to not sweeping is equivalent to a 33% decrease in load attributable to sweeping.

Table 9: ANCOVA Results for Pooled Control and Pooled Impact

Parameter	Slope		Intercept				
	p value	**Similar Slopes? (p>0.1)**	**p value**	**Intercepts Statistically Different? (p<=0.1)**	**Year 1 (log units)**	**Year 2 (log units)**	**Increase in Concentration Implied by Difference in Intercepts associated with Not Sweeping[1]**
Chemical Oxygen Demand	0.53	Yes	0.81	FALSE	-0.23	-0.27	-4%
Copper, Dissolved	0.94	Yes	0.40	FALSE	-0.14	-0.21	-6%
Copper, Particulate	0.15	Yes	0.09	TRUE	-0.34	-0.15	**21%**
Copper, Total	0.17	Yes	0.13	FALSE	-0.34	-0.19	**16%**
Fecal Coliform	0.01	No	-	-	-	-	-
Fluoranthene	0.55	Yes	0.75	FALSE	-2.05	-1.99	**6%**
Nitrate + Nitrite N	0.69	Yes	0.21	FALSE	-0.71	-0.96	-22%
Nitrogen, Total Kjeldahl	0.23	Yes	0.99	FALSE	0.33	0.33	0%
Phosphorus, Total	0.72	Yes	0.97	FALSE	-0.23	-0.22	**1%**
Pyrene	0.87	Yes	0.56	FALSE	-0.84	-0.67	**19%**
Sediment Conc. < 3.9 um	0.94	Yes	0.00	TRUE	0.80	-0.05	-56%
Sediment Conc. 62.5 to 3.9 um	0.38	Yes	0.32	FALSE	0.84	0.51	-27%
Sediment Conc. 250 to 62.5 um	0.86	Yes	0.69	FALSE	0.89	0.97	**9%**
Sediment Conc. 500 to 250 um	0.27	Yes	0.10	TRUE	0.97	1.63	**94%**
Sediment Conc. > 500 um	0.95	Yes	0.09	TRUE	1.36	2.38	**179%**
Sediment Conc. Total N	0.50	Yes	0.22	FALSE	-0.78	-0.44	**41%**
Solids, Total Suspended	0.24	Yes	0.29	FALSE	1.54	1.81	**31%**
Total Organic Carbon	0.82	Yes	0.71	FALSE	-0.42	-0.35	**7%**
Zinc, Dissolved	0.71	Yes	0.92	FALSE	-0.20	-0.21	-1%
Zinc, Particulate	0.20	Yes	0.17	FALSE	0.16	0.36	**22%**
Zinc, Total	0.17	Yes	0.17	FALSE	0.05	0.22	**18%**

1 – Positive (bolded values) indicate that concentrations increased associated with not sweeping; this implies that sweeping has positive effectiveness. Shaded values are statistically significant differences in intercepts. For example, an 50% increase in concentration attributable to not sweeping is equivalent to a 33% decrease in concentration attributable to sweeping.

Table 10: ANCOVA Results for Pooled Control and SS3 Impact

Parameter	Slope		Intercept				
	p value	Similar Slopes? (p>0.1)	p value	Intercepts Statistically Different? (p<=0.1)	Year 1 (log units)	Year 2 (log units)	Increase in Concentration Implied by Difference in Intercepts associated with Not Sweeping[1]
Copper, Particulate	0.24	Yes	0.13	FALSE	-0.22	0.02	**28%**
Copper, Total	0.22	Yes	0.16	FALSE	-0.12	0.08	**22%**
Phosphorus, Total	0.64	Yes	0.97	FALSE	0.02	0.03	**1%**
Solids, Total Suspended	0.18	Yes	0.36	FALSE	1.52	1.73	**24%**
Total Organic Carbon	0.98	Yes	0.55	FALSE	-0.15	-0.03	**12%**
Zinc, Particulate	0.27	Yes	0.25	FALSE	0.22	0.44	**25%**
Zinc, Total	0.25	Yes	0.23	FALSE	0.14	0.33	**21%**

1 – Positive (bolded values) indicate that concentrations increased associated with not sweeping; this implies that sweeping has positive effectiveness.
For example, an 50% increase in concentration attributable to not sweeping is equivalent to a 33% decrease in concentration attributable to sweeping.

DISCUSSION

Statistically Significant Findings

The following parameters were found to exhibit a statistically-significant change associated with discontinuing sweeping in Year 2 at a p-value of 0.1 (Table 11)

Table 11: ANCOVA Results (p<=0.1)

Parameter	p value	Increase in Concentration Attributable to Not Sweeping[1]	Reduction in Concentration Attributable to Sweeping[2]
Copper, Particulate	0.09	21%	17%
Sediment Conc. < 3.9 um	0.00	-56%	-133%
Sediment Conc. 500 to 250 um	0.10	94%	48%
Sediment Conc. > 500 um	0.09	179%	64%

1 – Positive indicate that concentrations increased associated with not sweeping; this implies that sweeping has positive effectiveness.
2 –Positive indicates that concentrations would be expected to decrease with sweeping.

Relatively few parameters showed statistically-significant effects of sweeping at $p<0.1$. This appears to be mostly attributable to the amount of variability between events and variability in the relationship between sites from event to event. Statistical significance is also highly dependent on sample size, particularly when data sets are highly variable. In the ANCOVA method, variability between events can be controlled in part. However when relationships between sites vary considerably by event, this variability makes it less likely that a statistically-significant difference can be detected.

Moderately-Significant Findings

Findings were considered moderately significant if the p-value was between 0.1 and 0.3 (Table 12)

Table 12: ANCOVA Results (p-value between 0.1 and 0.3)

Parameter	p value	Increase in Concentration Attributable to Not Sweeping[1]	Reduction in Concentration Attributable to Sweeping[2]
Copper, Total	0.13	16%	14%
Nitrate + Nitrite N	0.21	-22%	-28%
Sediment Conc. Total N	0.22	41%	29%
Solids, Total Suspended	0.29	31%	24%
Zinc, Particulate	0.17	22%	18%
Zinc, Total	0.17	18%	15%

1 – Positive indicate that concentrations increased associated with not sweeping; this implies that sweeping has positive effectiveness.
2 –Positive indicates that concentrations would be expected to decrease with sweeping.

Summary of Observations by Pollutant

The analysis of net change in median concentrations, net summation of normalized loads, and ANCOVA collectively support observations about apparent effects (and in some cases statically significant effects) of sweeping on pollutant concentrations and loads. The following paragraphs summarize observations by pollutant group.

<u>Metals (Cu and Zn)</u>

Copper and zinc exhibited similar effects as summarized below:

- Particulate Zn and Cu tended to be most affected by sweeping. Both showed about 20 percent higher concentration attributable to stopping sweeping in ANCOVA results. Particulate copper was slightly more statistically-significant (p=0.09) than particulate zinc (p=0.17). Comparison of medians and summation of loads suggested a slightly higher effect (closer to 30 percent in some cases) associated with not sweeping.

- Sweeping had negligible effect on dissolved Zn and Cu.

- Sweeping had moderately significant effect on total Cu and total Zn. This is consistent with the observed effect of sweeping on particulate metals but is tempered by the lack of effect on dissolved metals.

When comparing against only the SS3 impact site, the change in medians and summation of loads suggested effects in the range of 50 percent increase due to not sweeping. This is expected, as metals concentrations at SS4 tended to be lower than SS3 in both year 1 and year 2, which appears to have moderated the effect of sweeping when the impact site were pooled. The ANCOVA results for the SS3 impact indicated slightly higher magnitude of effects than the pooled impact (28 percent vs. 21 percent), but slightly less significance of these effects (p=0.13 vs. 0.09). This appears to be a consequence of more variability in the relationship between control sites and SS3 than the control sites and the pooled impact. The pooling of impact sites had the effect of moderating variability.

<u>Nutrients (N and P)</u>

Effects tended to be minor, but varied by parameter:

- Total phosphorus exhibited negligible effect across each of the analyses performed.

- Total Kjeldahl Nitrogen exhibited mixed effects of sweeping. The ANCOVA and net change in median concentration suggested negligible effect, while the summation of loads suggested that TKN load declines when sweeping is not performed, suggesting that TKN load could be elevated as a consequence of sweeping. However, this result is inconclusive.

- Nitrate plus nitrite-N results were similarly mixed. The ANCOVA suggested a moderately-significance decline in nitrate plus nitrite-N as a result of discontinuing sweeping (p=0.21, change=-22%). This suggests that sweeping could be responsible for increasing concentration of nitrate plus nitrite-N. A similar trend is observed in the net change in medians, but only a minor effect was observed in the net summation of loads.

None of the nutrient species analyzed exhibited statistically-significant effects at p<0.1.

Indicator Bacteria (FC)

Fecal coliform violated the parallel slopes assumption of the ANCOVA and could not be tested. Similarly, FC grab samples were not conducive to summation of loads analysis. The change in median concentrations was applied, but suggested very minor effect. It is noted that variability in the data is extremely high, as is common with indicator bacteria. Extremely high variability reduces the ability to detect statistically significant differences even more as compared to other pollutants.

Polycyclic Aromatic Hydrocarbons (PAHs)

Only fluoranthene and pyrene were detected with any regularity. The ANCOVA suggested negligible significance. The net change in medians suggested minor effects. Summation of loads could not be performed as these parameters were based on grab samples and therefore not representative of an entire storm event.

Sediment

Sediment concentration and TSS data suggested reasonably clear and consistent trends, including the effectiveness of sweeping for coarser particles, and lack of effectiveness or adverse impacts of sweeping on finer particles:

- The finest particle size bin (<3.9 micron) concentrations and loads decreased when sweeping was discontinued, suggesting that sweeping results in elevated fine particle concentrations. ANCOVA results showed a highly-significant (p=0.00) concentration reduction of 57 percent when sweeping was discontinued, which is similar to the 49 percent reduction based on net change in concentration. Summation of loads showed lower effect (10 percent reduction). It should be noted that this size fraction makes up a relatively small fraction of total sediment by mass as summarized in Table 13.

- The coarsest particle size bins (250 to 500, and 500+ micron) both exhibited an increase in concentration when sweeping was ceased, suggesting that sweeping is effective for these sizes. The ANCOVA yielded statistical significance (p =0.10 and 0.09, respectively) and 94% and 179% increases, respectively, associated with not sweeping. Normalize load analysis yielded 144% and 176% increases, respectively. Net change in concentrations was considerably higher.

- The ANCOVA found negligible significance for the middle size bins (3.9 to 62.5 and 62.5 to 250 micron). Net change in median concentrations and net summation of load suggested street sweeping may result in elevated concentrations of 3.9 to 62.5 micron particles and removal of 62.5 to 250 micron particles.

- Total sediment concentration and TSS exhibited similar effects. Both were moderately significant per the ANCOVA ($p = 0.29$ and 0.22, respectively) and showed 41% and 31% increase, respectively, associated with not sweeping. Similar findings, but with notably different magnitudes are supported by the net change in medians and net summation of loads. In each cases, it appears that sweeping is effective in reducing total sediment and TSS concentrations.

On a whole, fine sediment tends to increase with sweeping (more notably in concentrations than in loads), while coarse sediment tends to decrease (apparent in both concentrations and loads). The net effect suggests that discontinuing sweeping resulted in approximately 40 percent higher concentrations and perhaps 100 percent higher loads of total sediment. Effects were less for TSS, which, due to the laboratory test method, tends to be weighted toward smaller size fractions where sweeping appears to be less effective.

For reference, the average breakdown of sediment size fractions during year 2 in swept and unswept sites differed considerably. The swept sites exhibited slightly higher concentrations of finest sediment and larger proportion of fine sediment as a fraction of total sediment. The swept sites exhibits a much lower concentration of the coarsest two bins, and the proportion of sediment in these bins was much less as a fraction of the total (53 mg/L, 44% of total at swept sites vs. 277 mg/L, 75% of total at unswept sites).

Table 13. Estimated Distribution of Sediment Mass by Size Fraction

	Year 2, Control, Swept		Year 2, Impact, Unswept	
Sediment Size Fraction	**Average of Site Medians**	**Percent of Total**	**Average of Site Medians**	**Percent of Total**
Sediment Conc. < 3.9 um, mg/L	7.6	5%	6.3	2%
Sediment Conc. 62.5 to 3.9 um, mg/L	39.4	28%	34.8	9%
Sediment Conc. 250 to 62.5 um, mg/L	31.8	22%	50.2	14%
Sediment Conc. 500 to 250 um, mg/L	13.1	9%	58.0	16%
Sediment Conc. > 500 um, mg/L	49.6	35%	218.9	59%

TSS was also analyzed using the SS3 impact site only. Results were not appreciably different.

Chemical Oxygen Demand (COD)

Effect on COD was negligible and not significant.

Total Organic Carbon (TOC)

Effect on TOC was negligible and not significant.

Differences between Pooled Impact and SS3 Impact

Overall, isolating the SS3 impact site did not yield different qualitative observations compared to using the pooled impact dataset. Trends and magnitudes tended to be similar. In the case of total and particulate metals, the apparent magnitude of change resulting from not sweeping was higher when only evaluating the SS3 impact. The opposite was true for TSS. ANCOVA findings tended to be less statistically significant for the SS3 impact, and none of the comparisons of intercept yielded a p-value less than 0.1. Based on inspection of ANCOVA plots, it appears that there was more variability in the relationship between SS3 and the control sites than the relationship between the pooled impact and the control site. The ability to define a relationship between control and impact using a log-linear best fit line (specifically the goodness of fit to this line) is an important factor in calculating the p-value to test whether intercepts are significantly different.

Given these factors, there does not appear to be a statistical advantage to isolating the SS3 impact site versus using the pooled impact dataset. For simplicity in reporting, it may be advantageous to simply report pooled control versus pooled impact.

Conversion of Reporting Metrics

Most results are presented in terms of the amount of increase in concentration or load that was attributable to not sweeping SS3 and SS4 in year 2 (positive indicates increase). This can also be converted to an estimate of the amount of reduction in concentration or load associated with sweeping (positive indicates reduction). The mathematical conversion is as follows:

$$Reduction\ from\ Sweeping\ (\%) = 100\% - \frac{100\%}{100\% + Increase\ from\ Not\ Sweeping\ \%}$$

For example, if a parameter showed a 20% increase in concentration or load associated with not sweeping, then this converts to a 16.7% decrease in concentration or load attributable to sweeping

$$Reduction\ from\ Sweeping\ (\%) = 100\% - \frac{100\%}{100\% + 20\%} = 16.7\%$$

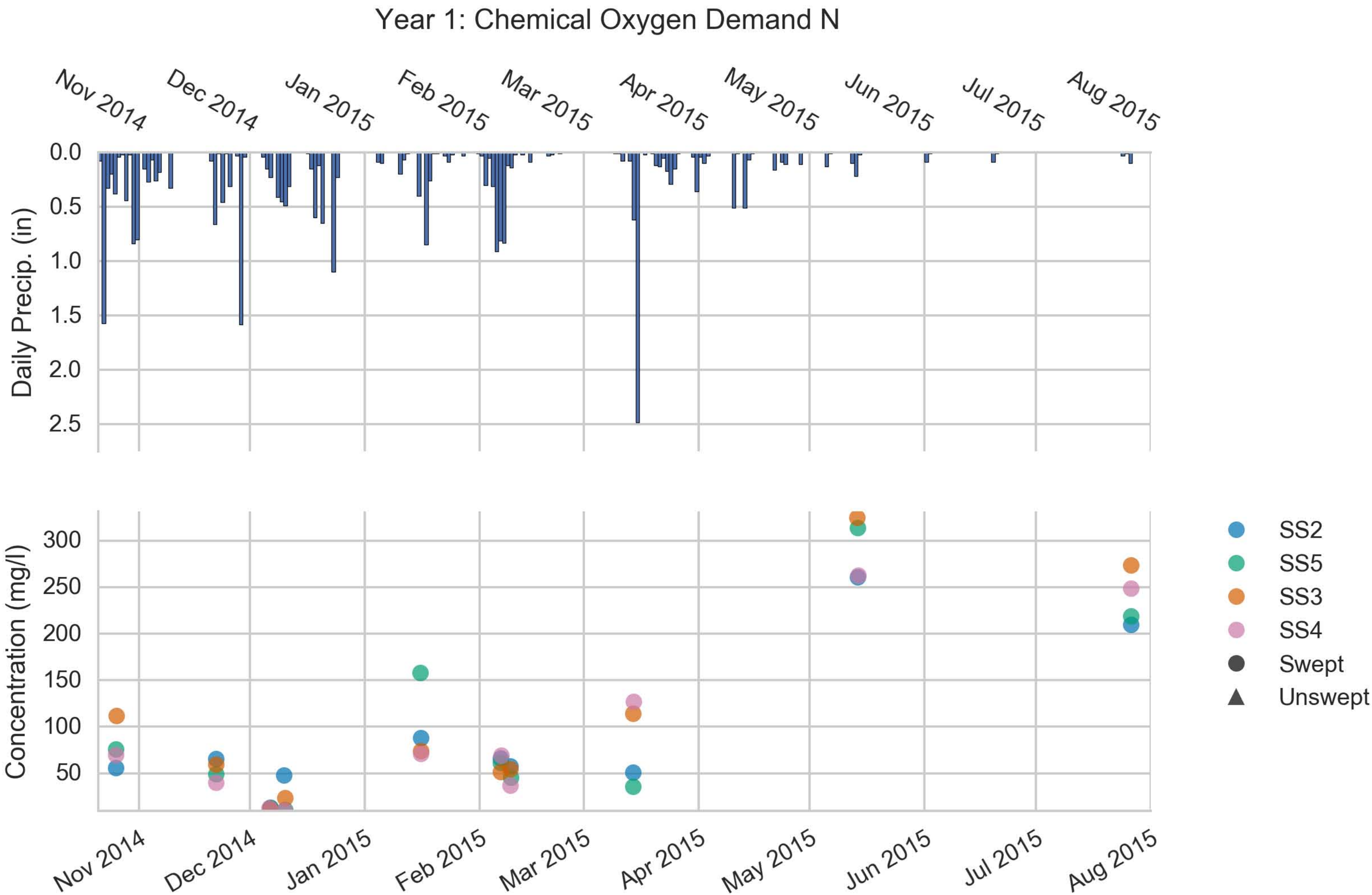
REFERENCES

Helsel, D.R. and Hirsch, R.M. (2002). *Statistical Methods in Water Resources*. U.S. Geological Survey, Techniques of Water-Resources Investigations Book 4, Chapter A3. Water Resources Division, USGS. Reston, VA

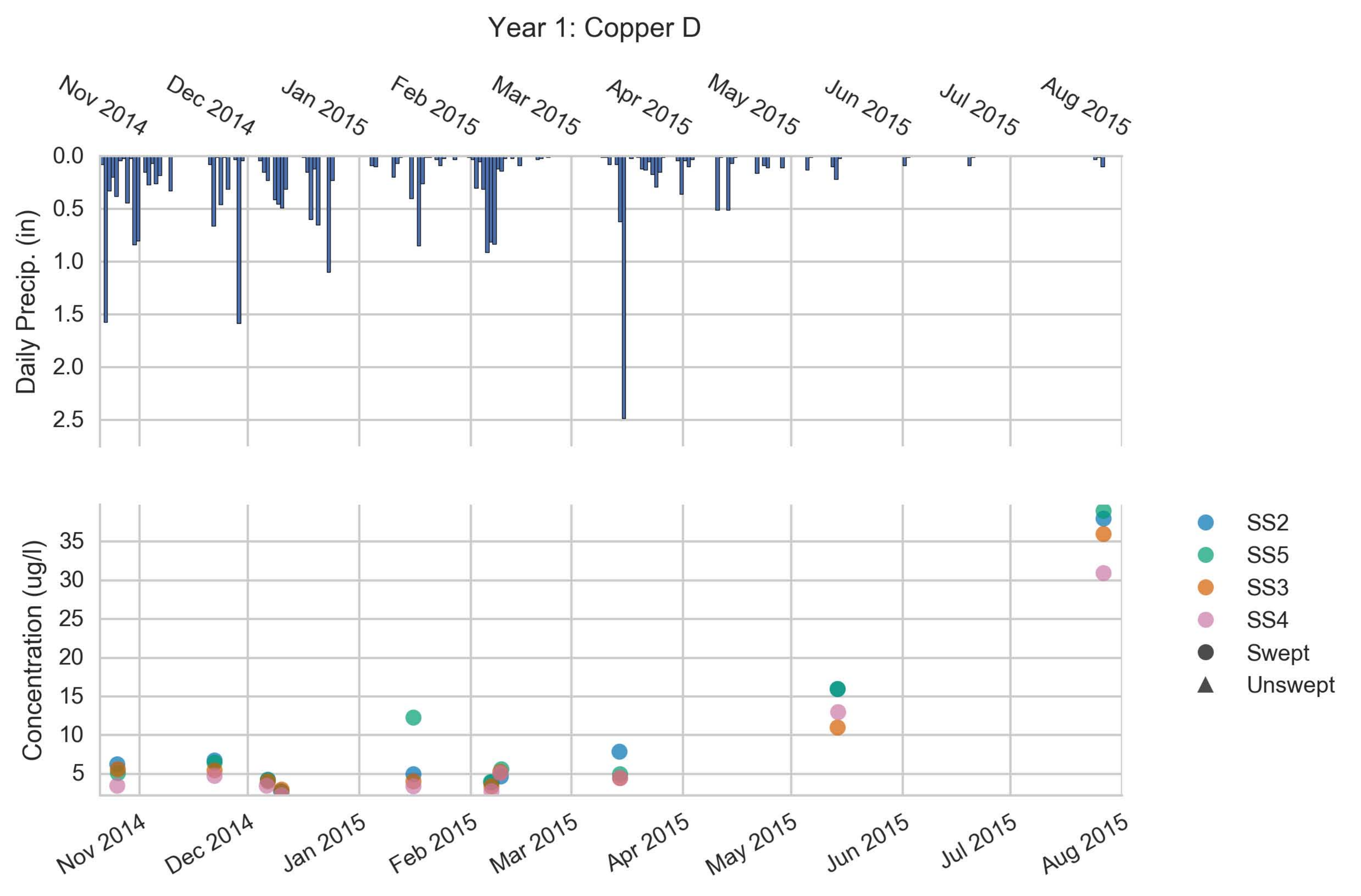
Selbig, W.R. (2016). "Evaluation of leaf removal as a means to reduce nutrient concentrations and loads in urban stormwater." Science of the Total Environment, 571 (2016) 124–133, http://dx.doi.org/10.1016/j.scitotenv.2016.07.003*****

Attachment 1a

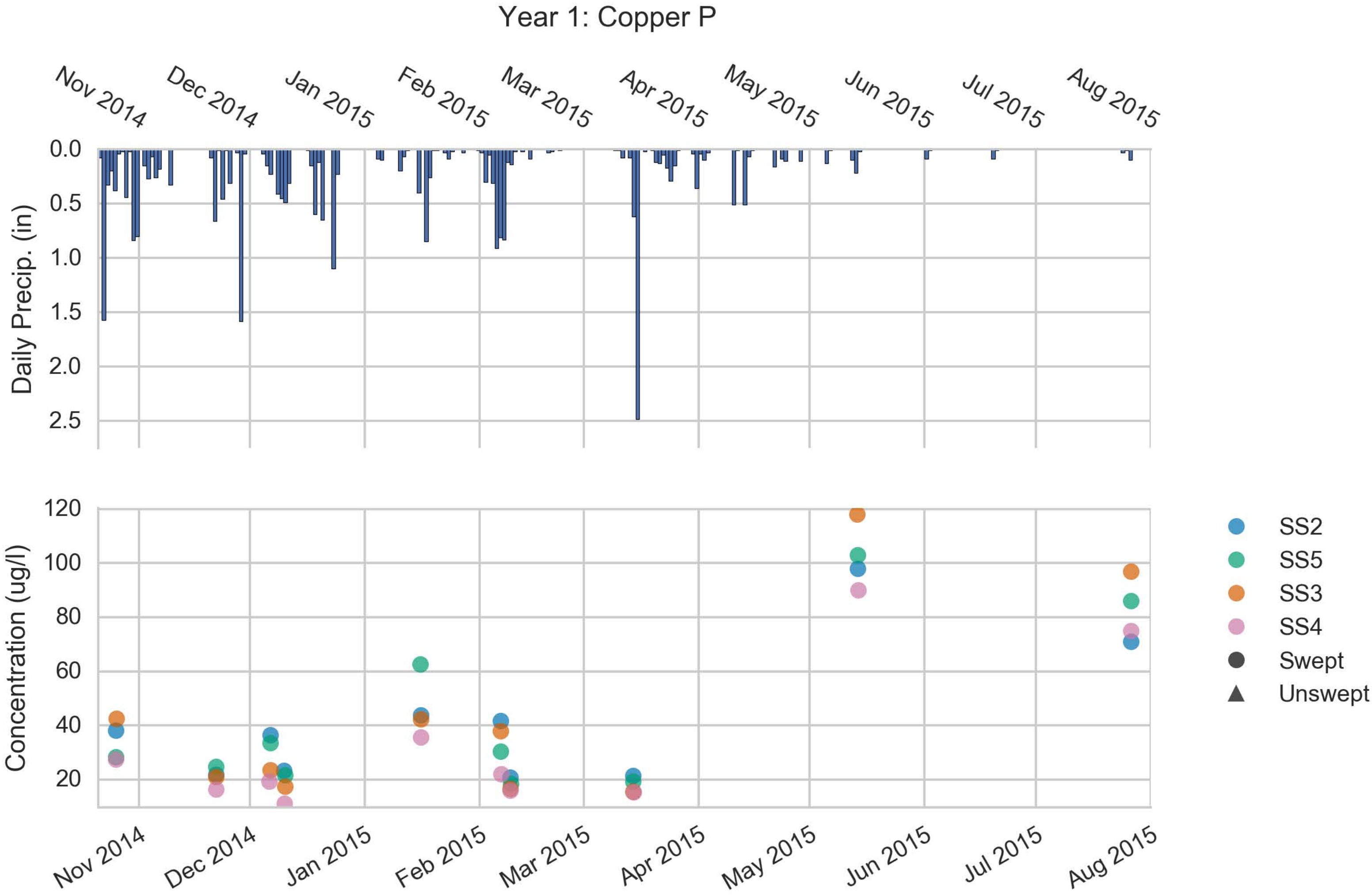
Time Series Plots

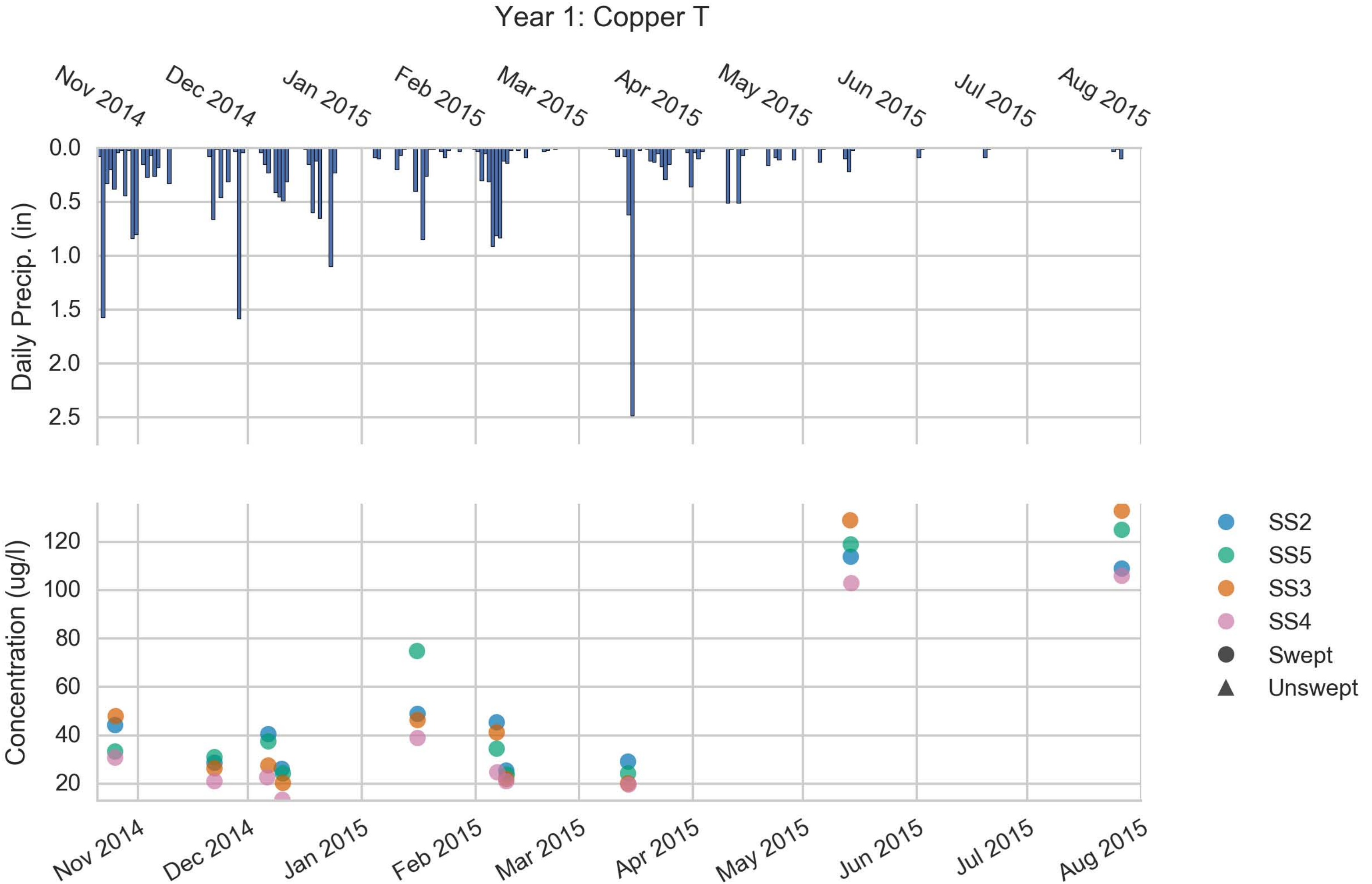


Year 1: Chemical Oxygen Demand N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
300
250
200
150
100
50
SS2
SS5
SS3
SS4
Swept
Unswept

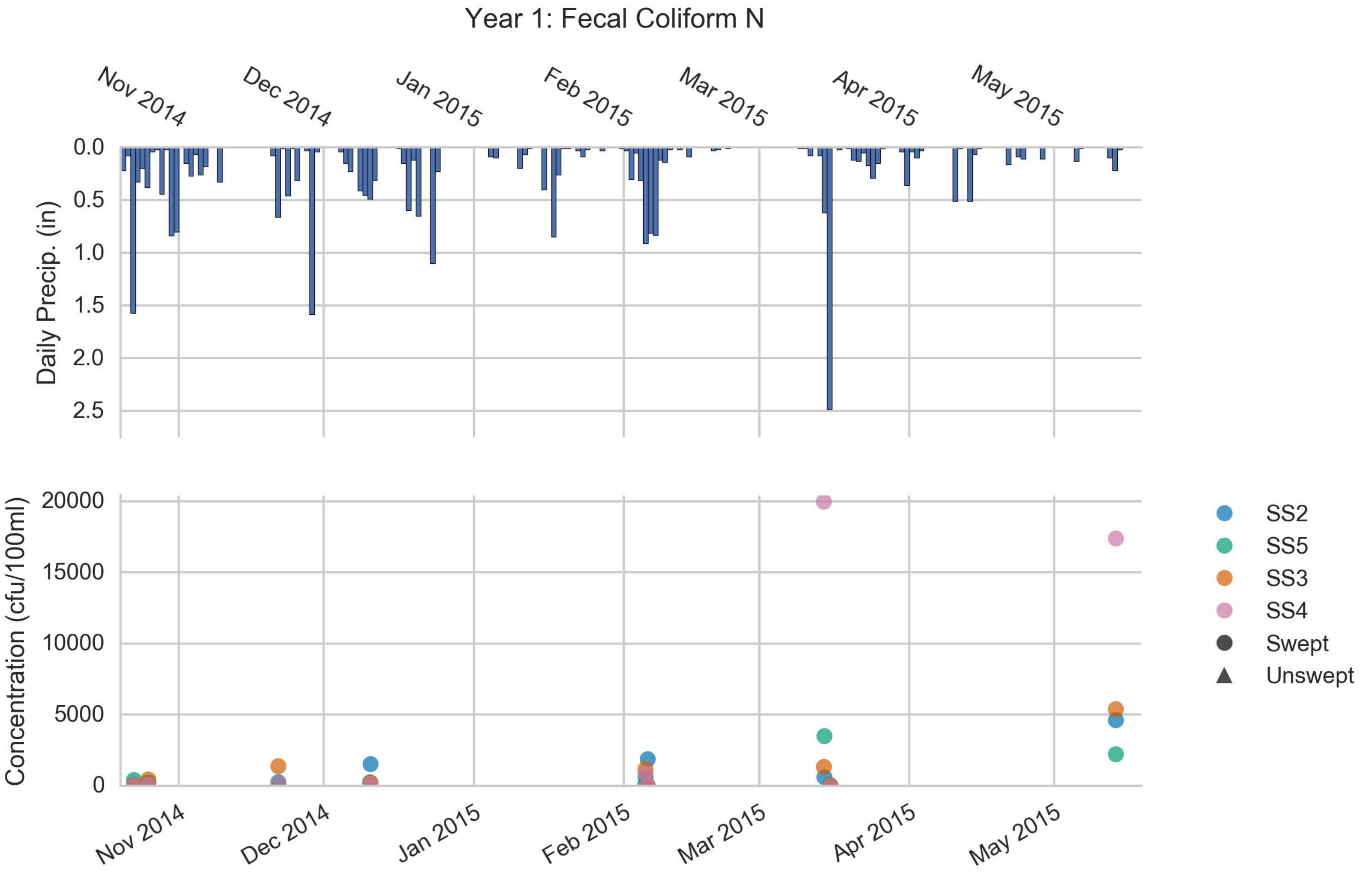


Year 1: Copper D
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
5
10
15
20
25
30
35
SS2
SS5
SS3
SS4
Swept
Unswept

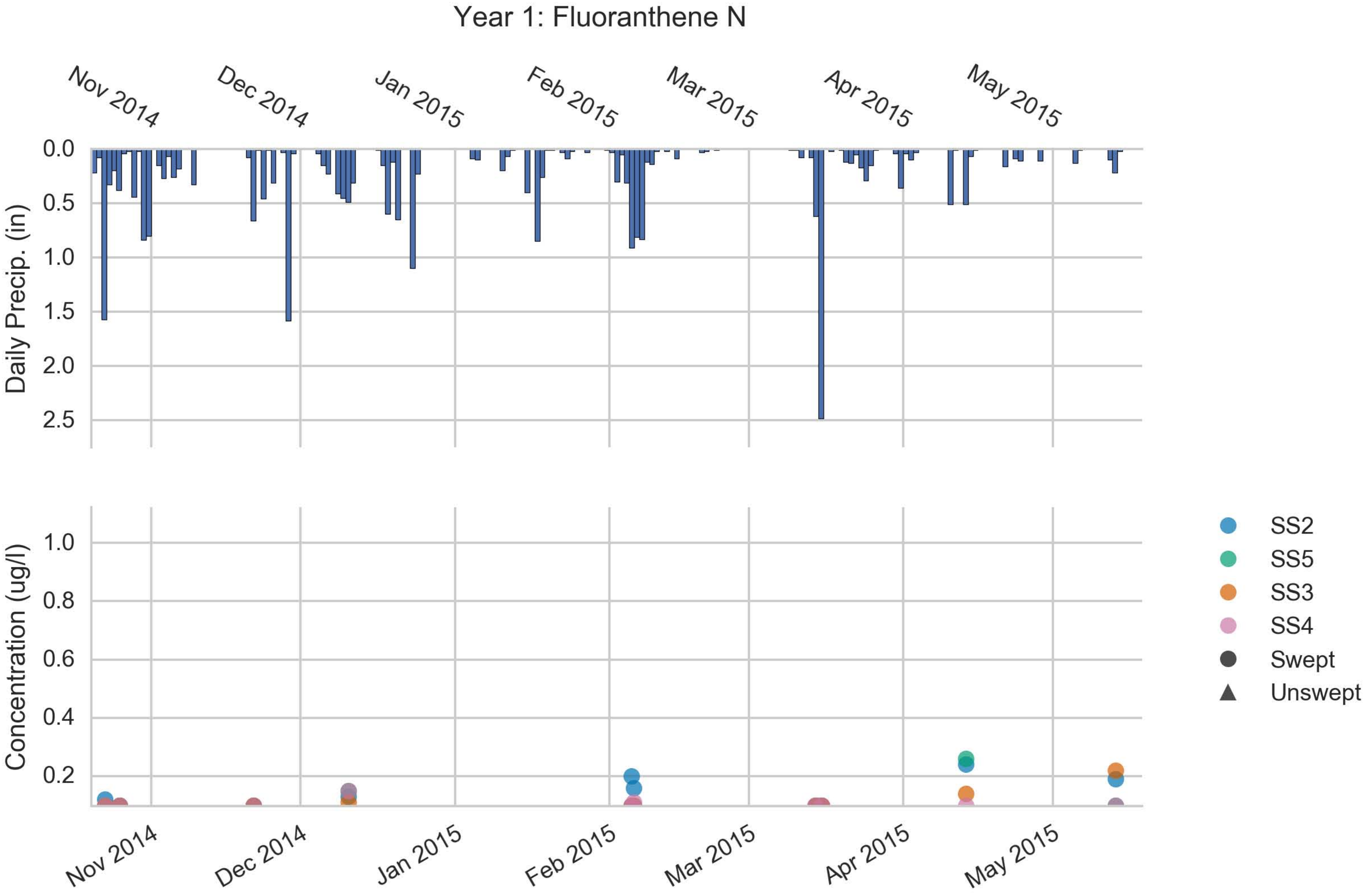

Year 1: Copper P
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
120
100
80
60
40
20
SS2
SS5
SS3
SS4
Swept
Unswept



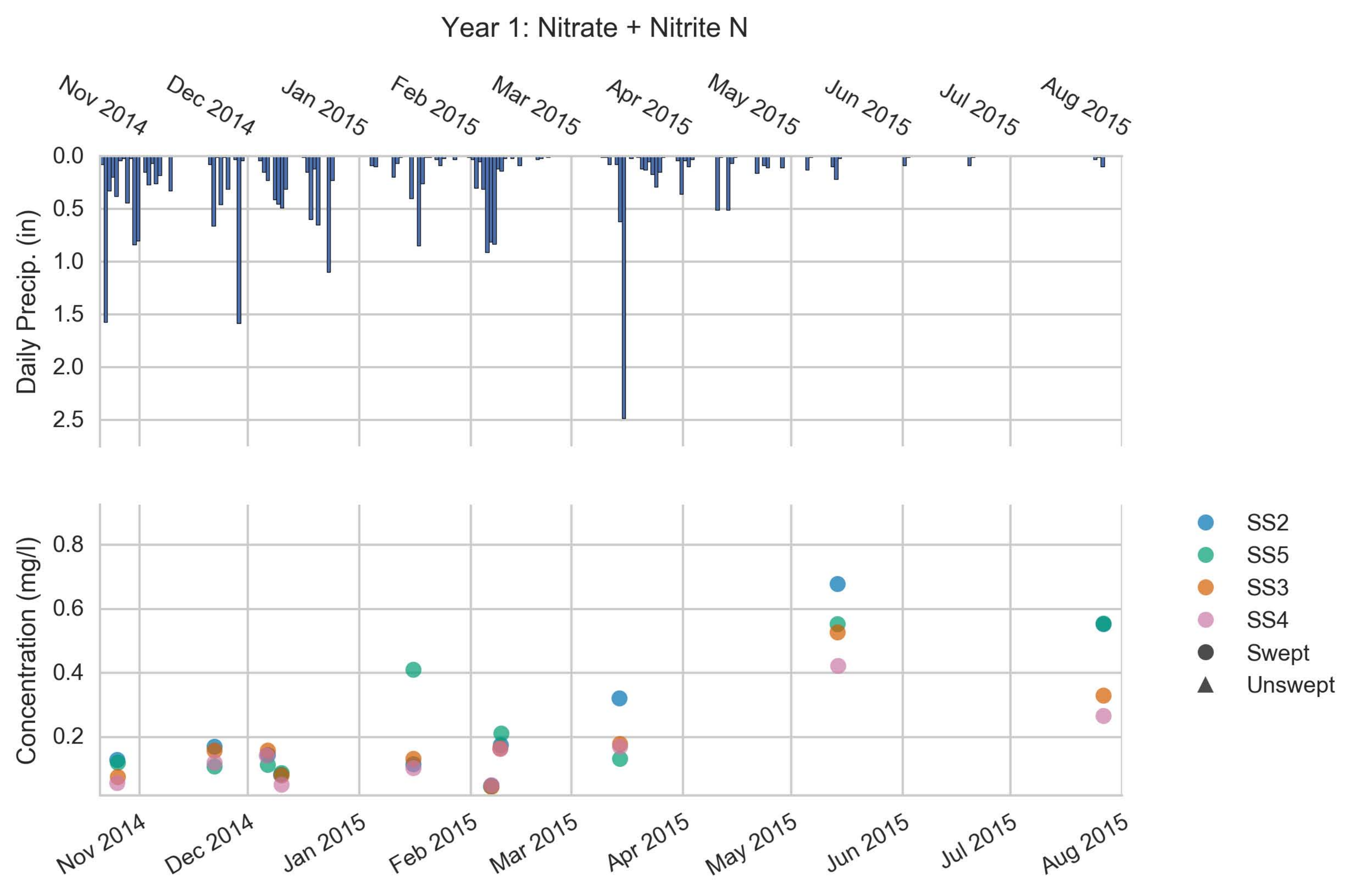
Year 1: Copper T
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
20
40
60
80
100
120
SS2
SS5
SS3
SS4
Swept
Unswept



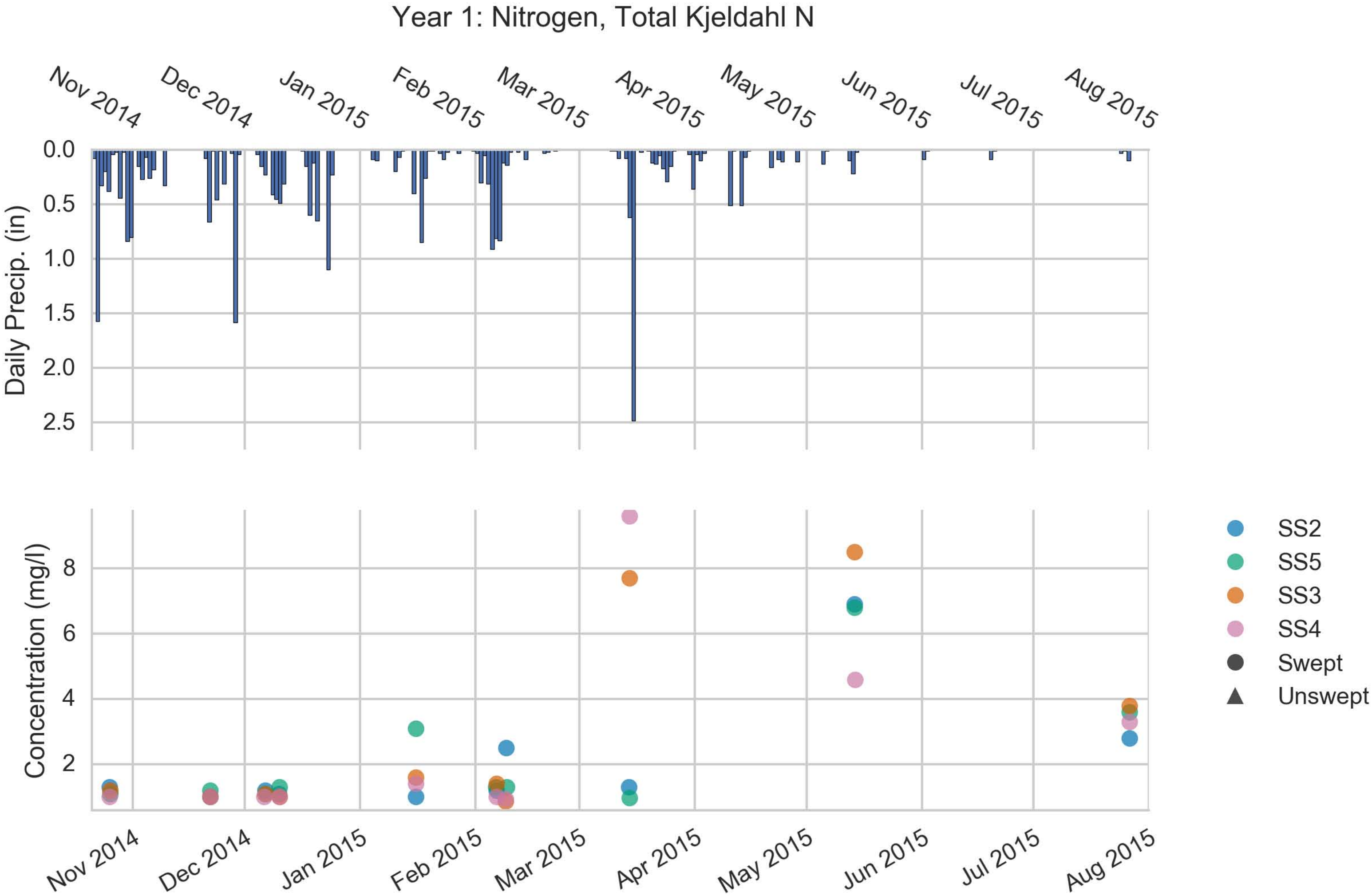
Year 1: Fecal Coliform N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (cfu/100ml)
20000
15000
10000
5000
0
SS2
SS5
SS3
SS4
Swept
Unswept

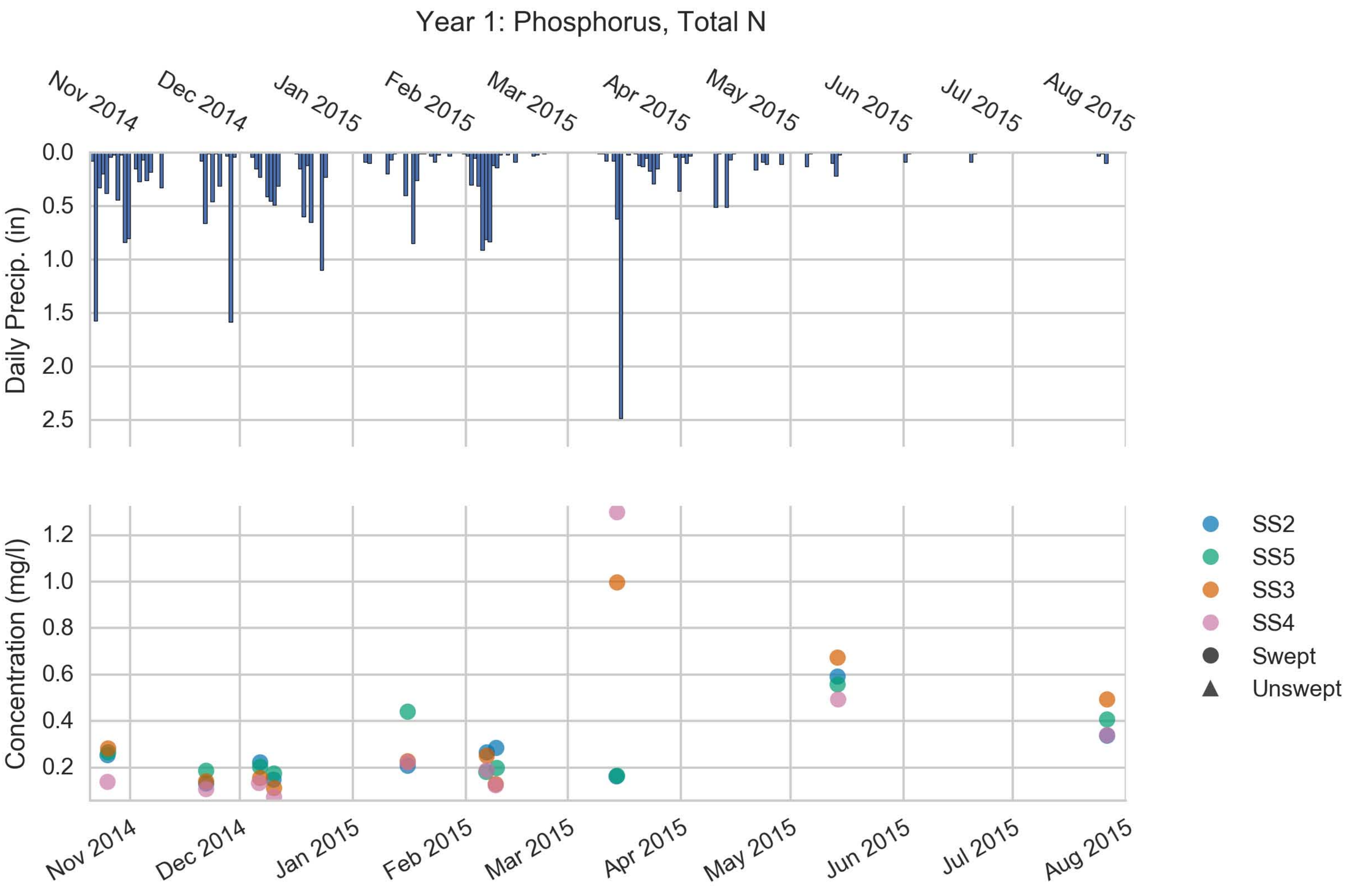


Year 1: Fluoranthene N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
0.2
0.4
0.6
0.8
1.0
SS2
SS5
SS3
SS4
Swept
Unswept

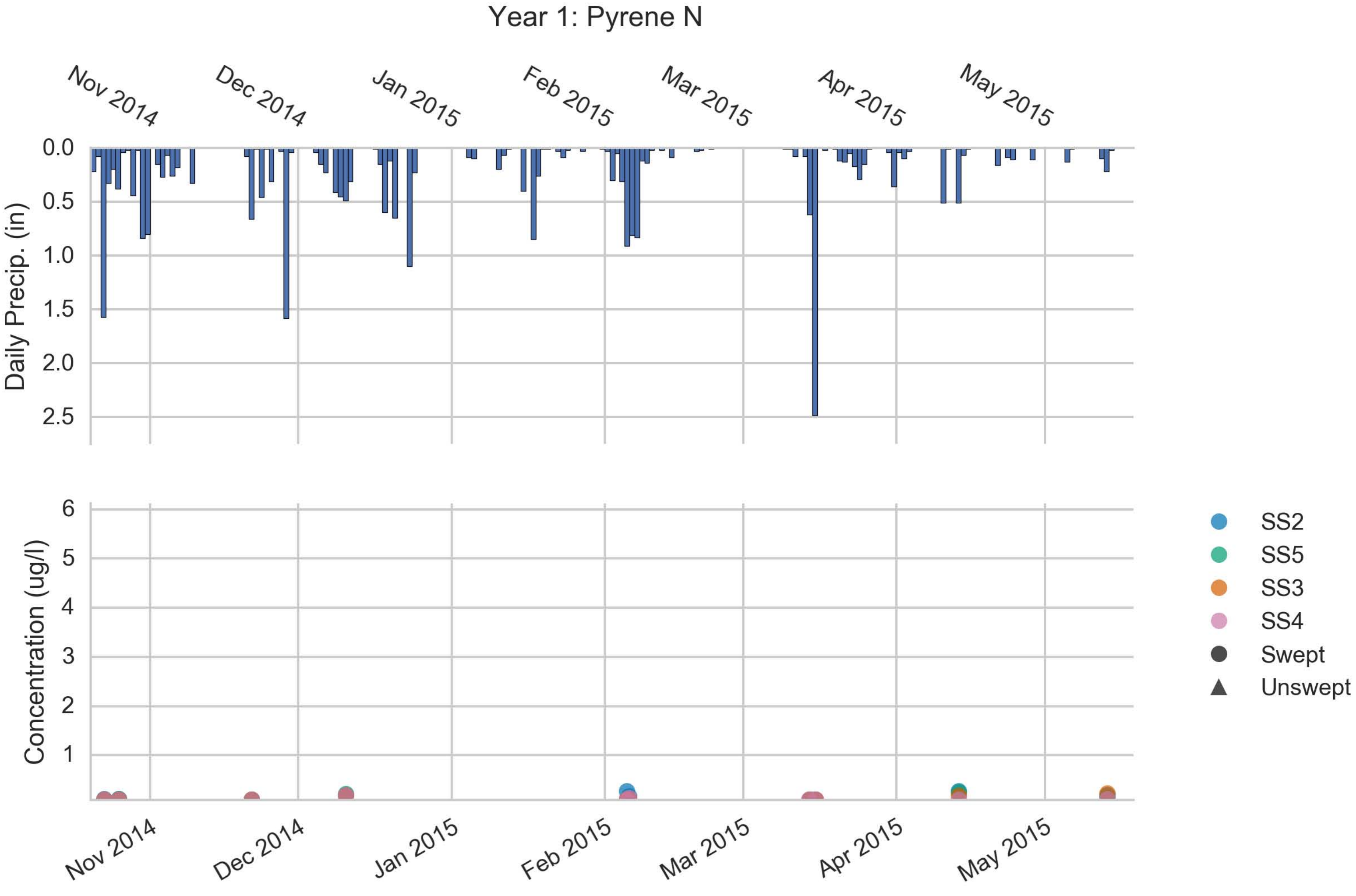


Year 1: Nitrate + Nitrite N
Daily Precip. (in)
Concentration (mg/l)
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
SS2
SS5
SS3
SS4
Swept
Unswept

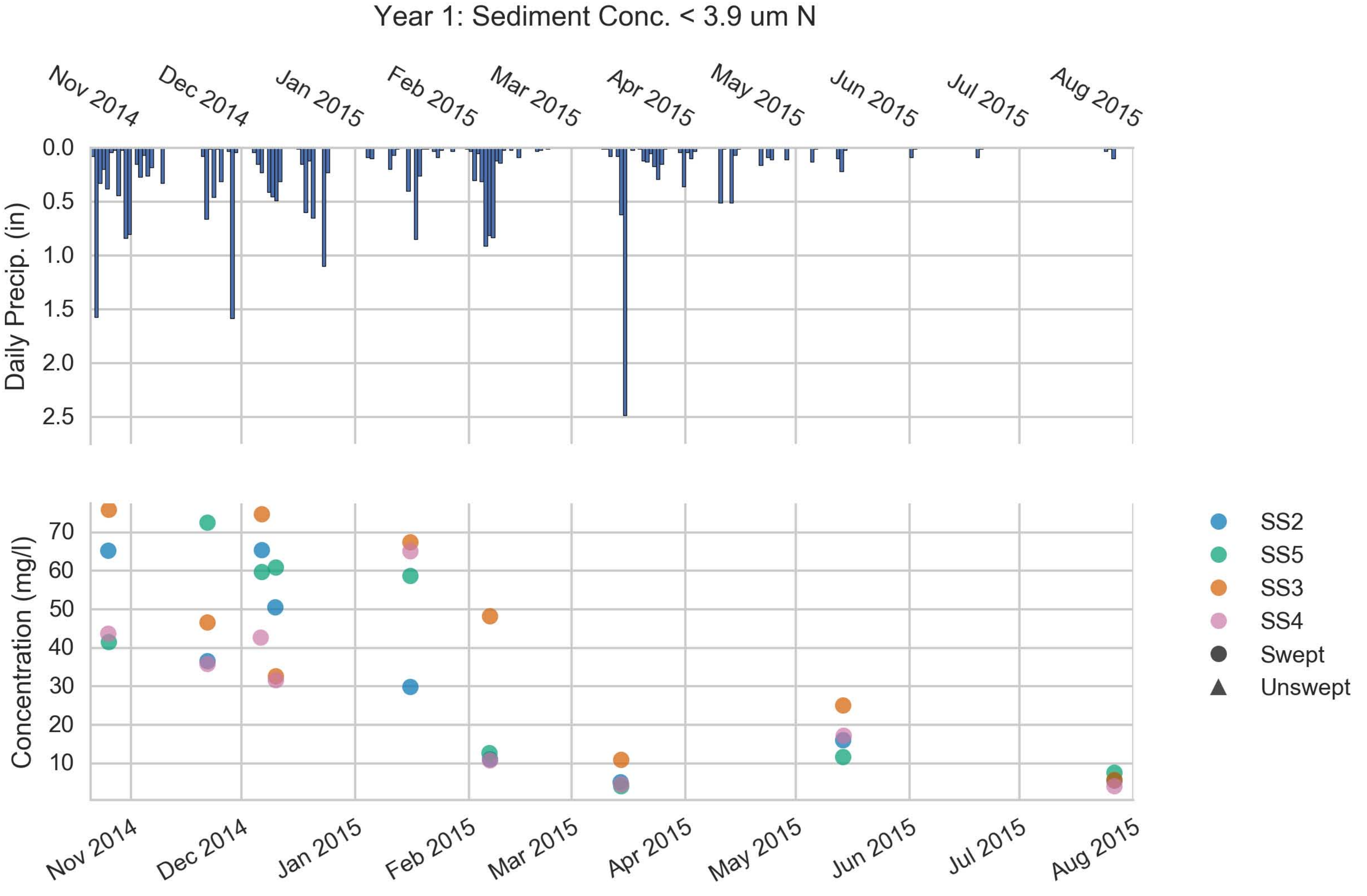

Year 1: Nitrogen, Total Kjeldahl N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
2
4
6
8
SS2
SS5
SS3
SS4
Swept
Unswept

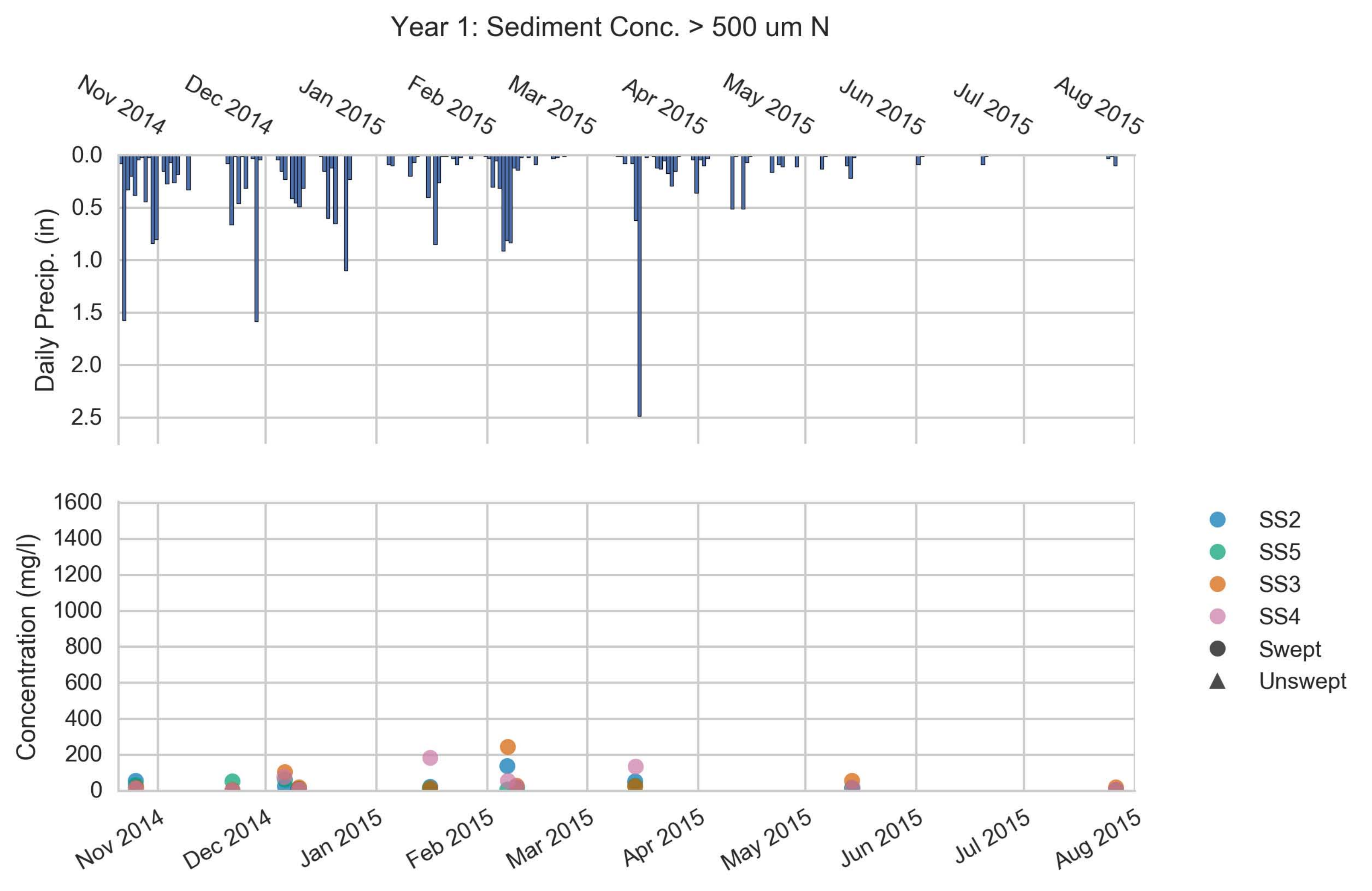


Year 1: Phosphorus, Total N
Daily Precip. (in)
Concentration (mg/l)
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
SS2
SS5
SS3
SS4
Swept
Unswept

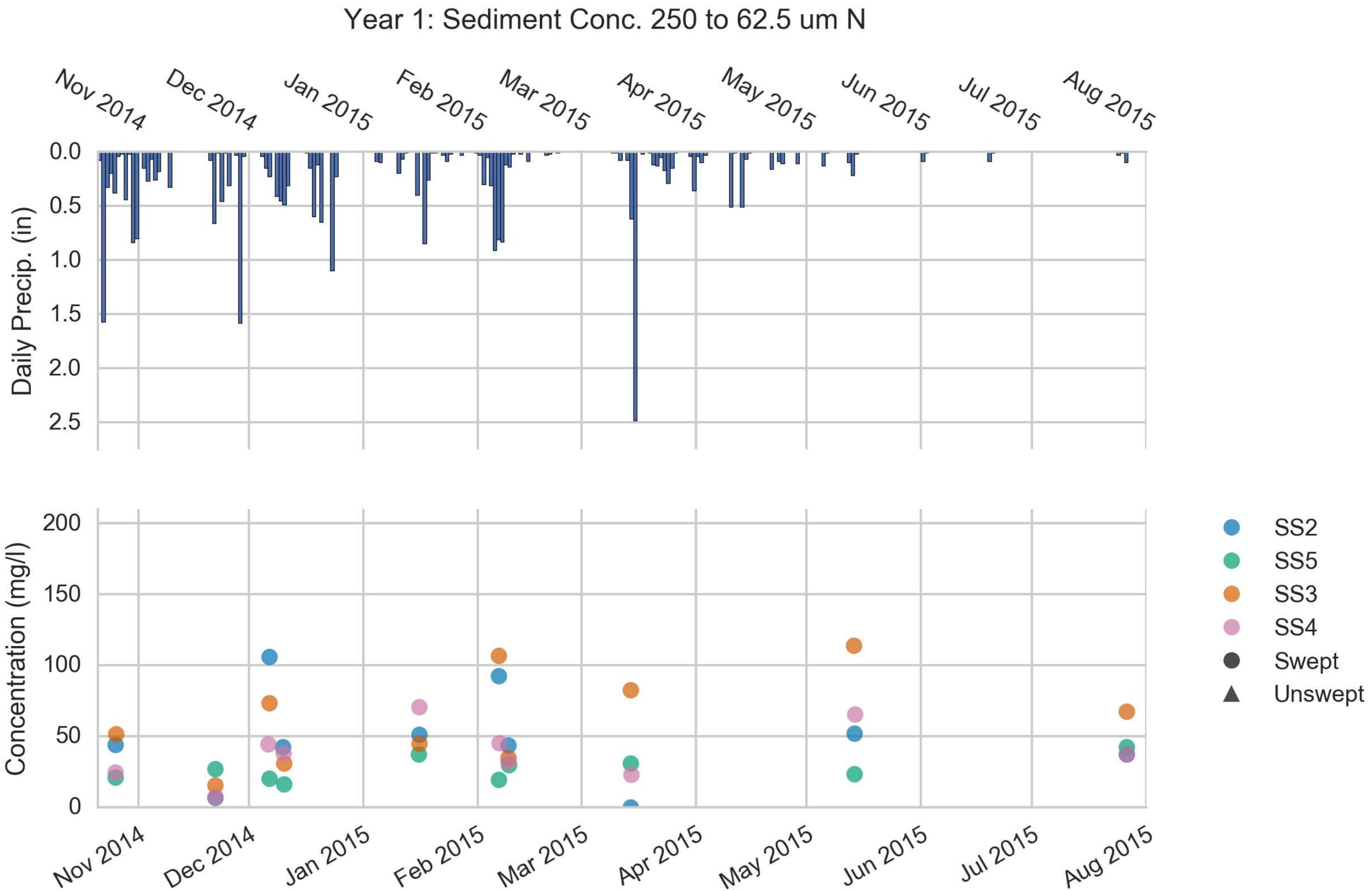


Year 1: Pyrene N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
6
5
4
3
2
1
SS2
SS5
SS3
SS4
Swept
Unswept

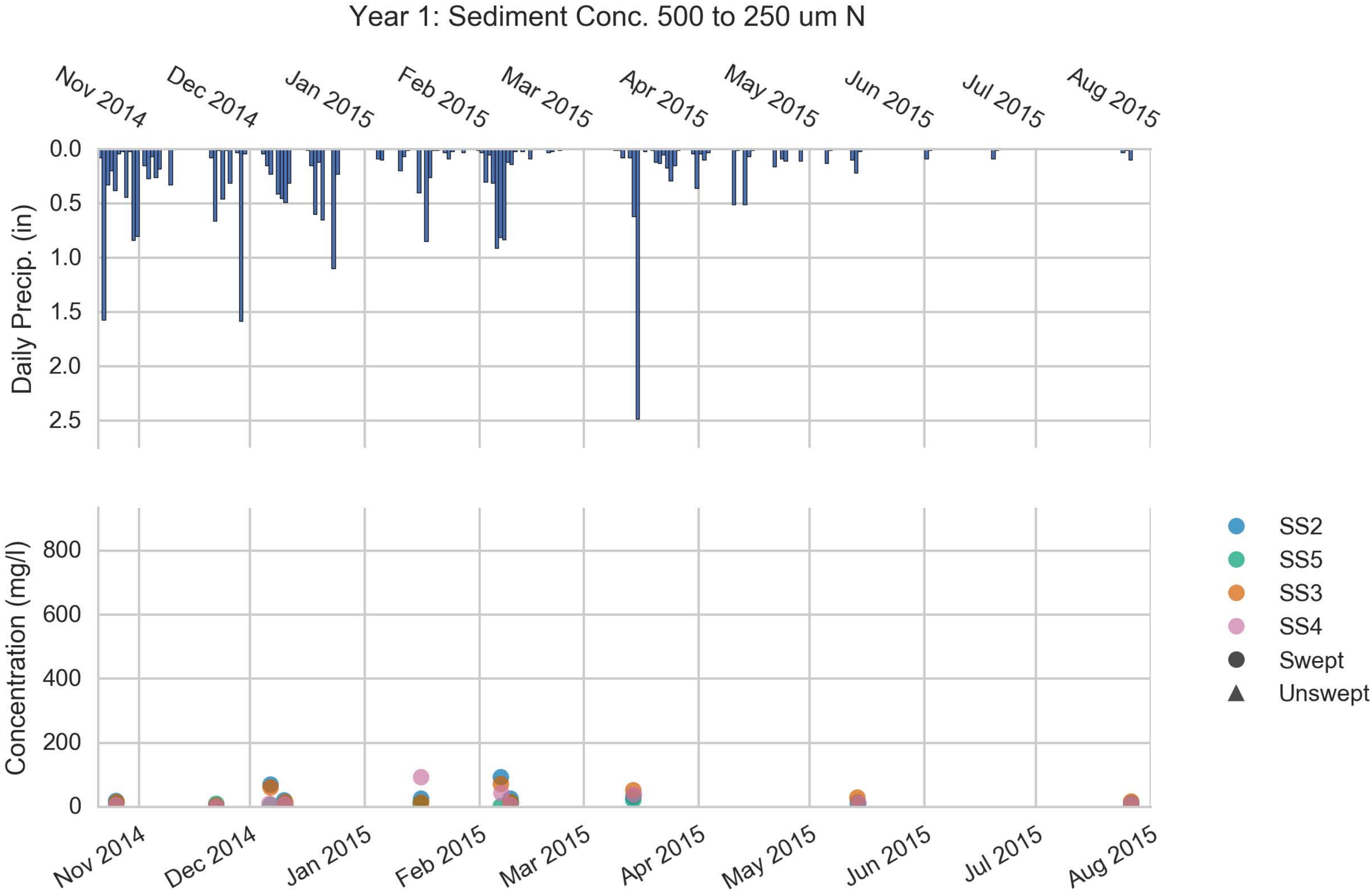

Year 1: Sediment Conc. < 3.9 um N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
70
60
50
40
30
20
10
SS2
SS5
SS3
SS4
Swept
Unswept

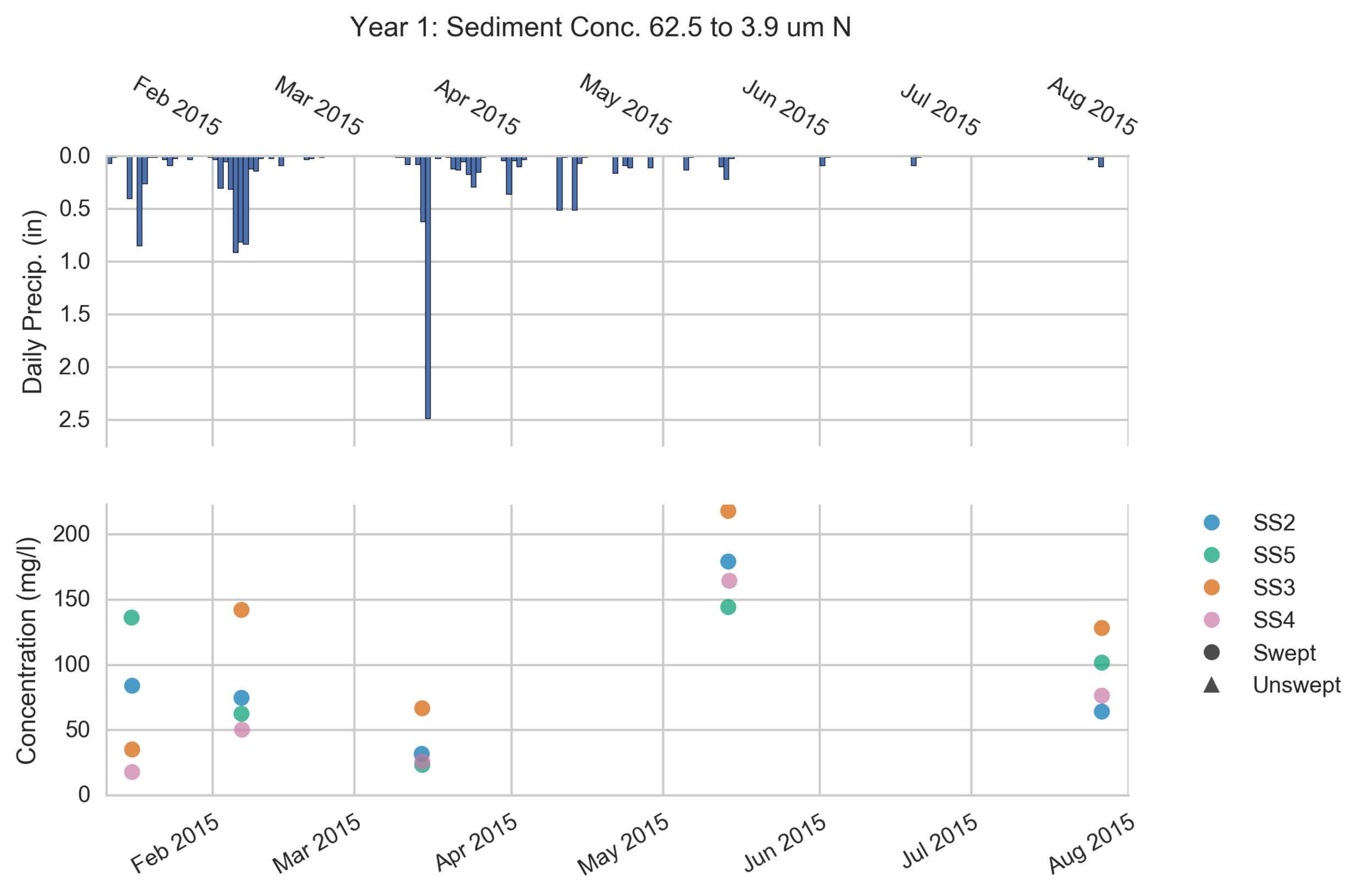


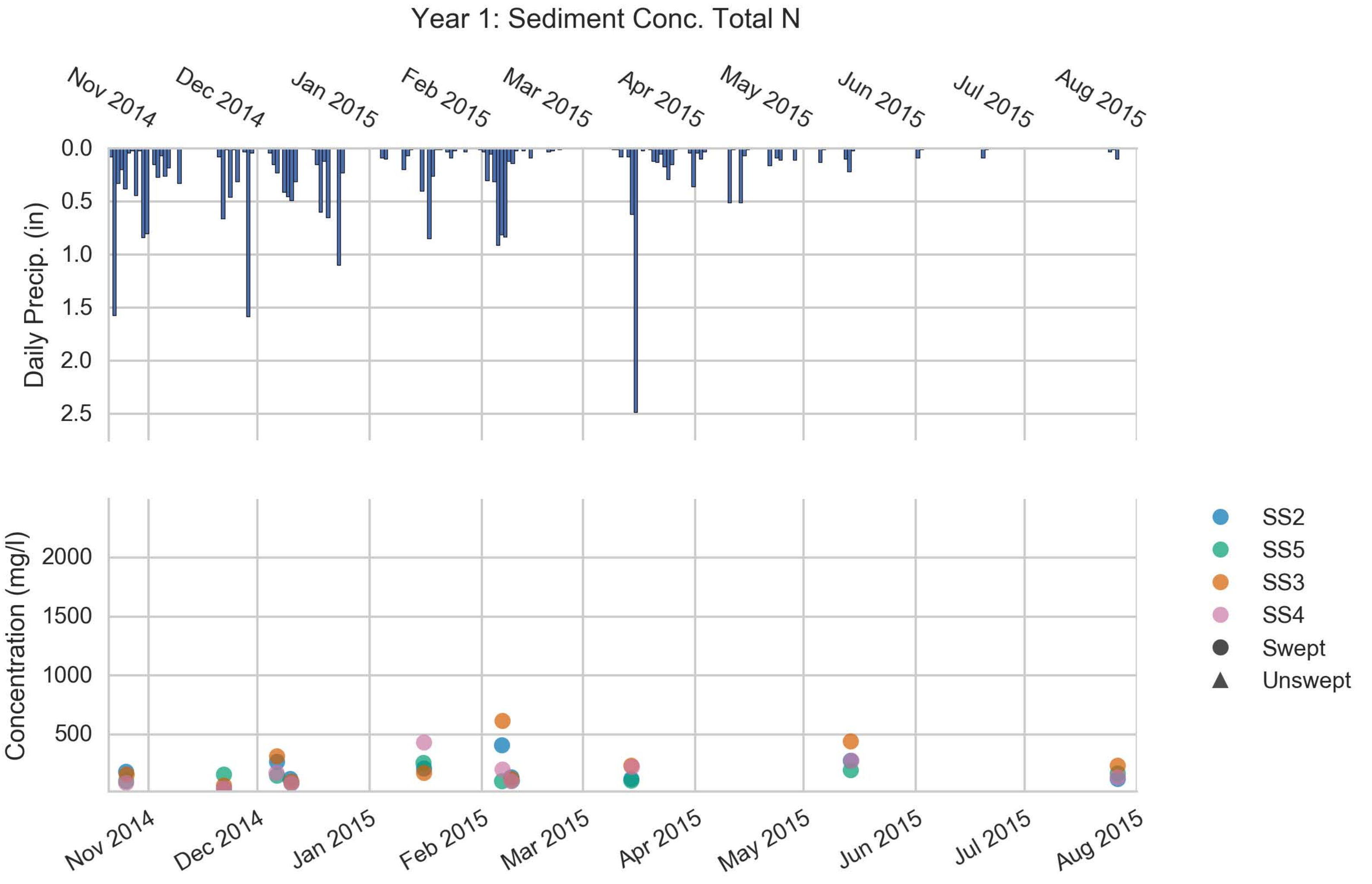
Year 1: Sediment Conc. > 500 um N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
1600
1400
1200
1000
800
600
400
200
0
SS2
SS5
SS3
SS4
Swept
Unswept



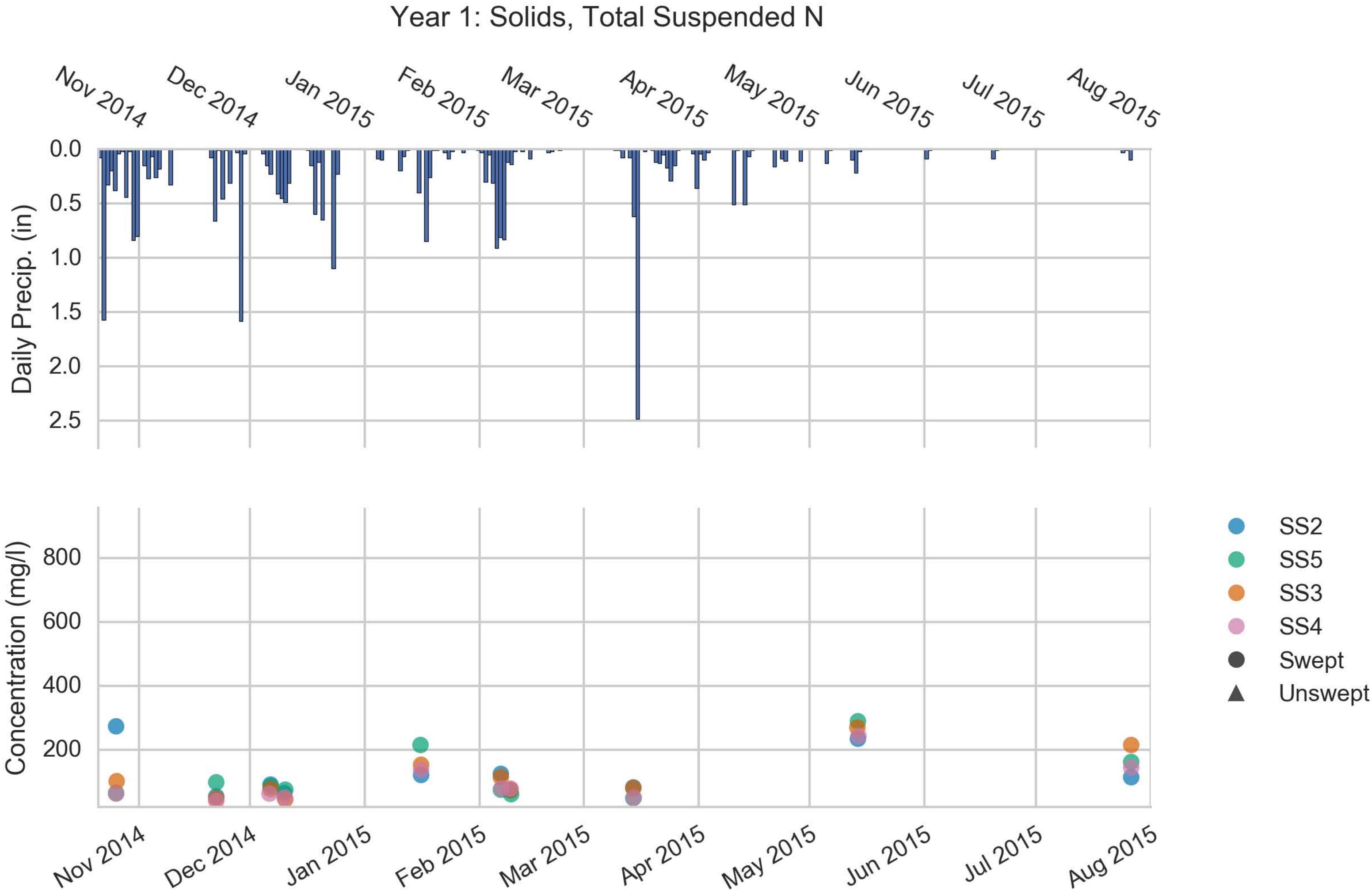
Year 1: Sediment Conc. 250 to 62.5 um N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
200
150
100
50
0
SS2
SS5
SS3
SS4
Swept
Unswept

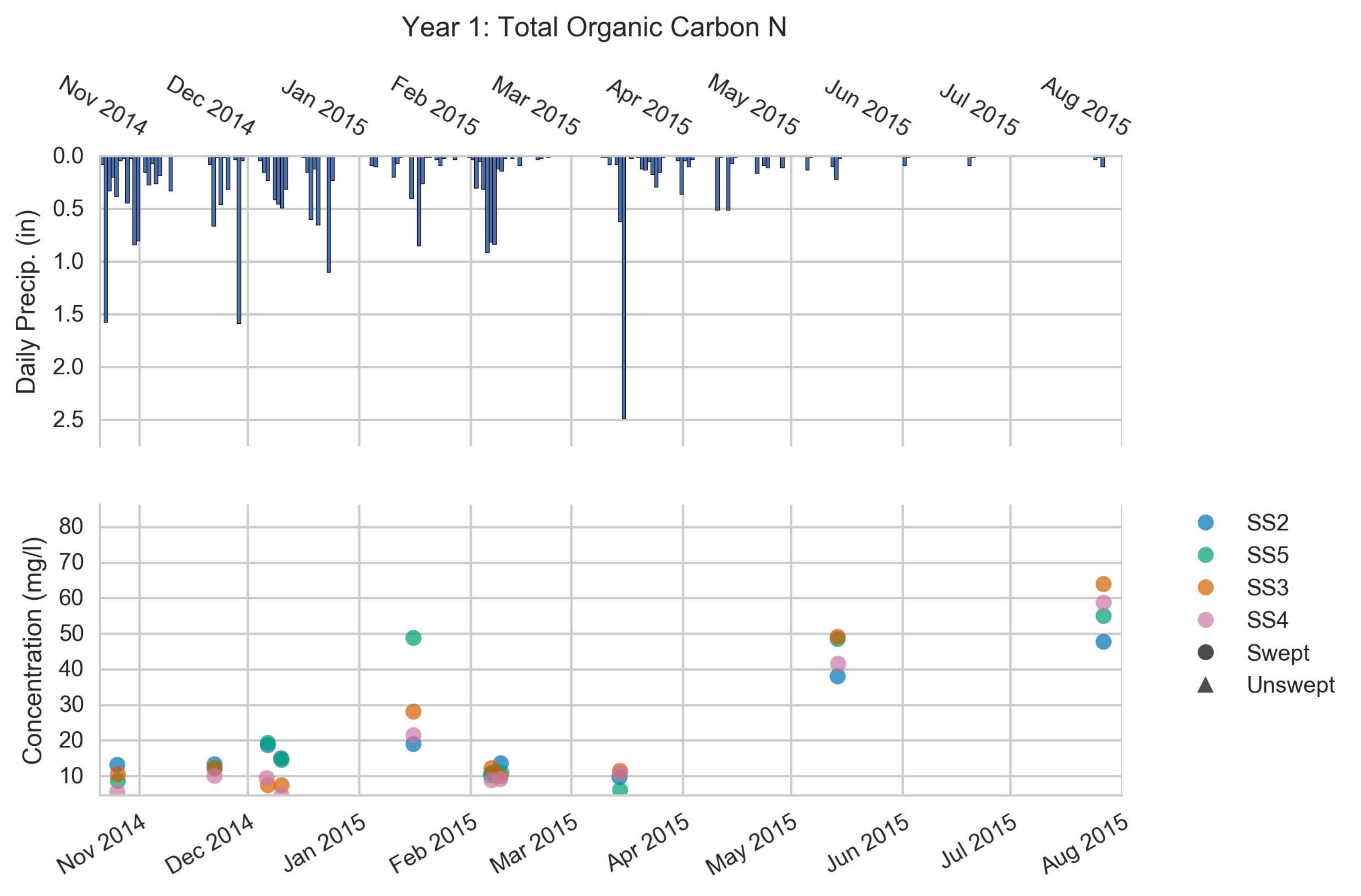

Year 1: Sediment Conc. 500 to 250 um N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
800
600
400
200
0
SS2
SS5
SS3
SS4
Swept
Unswept

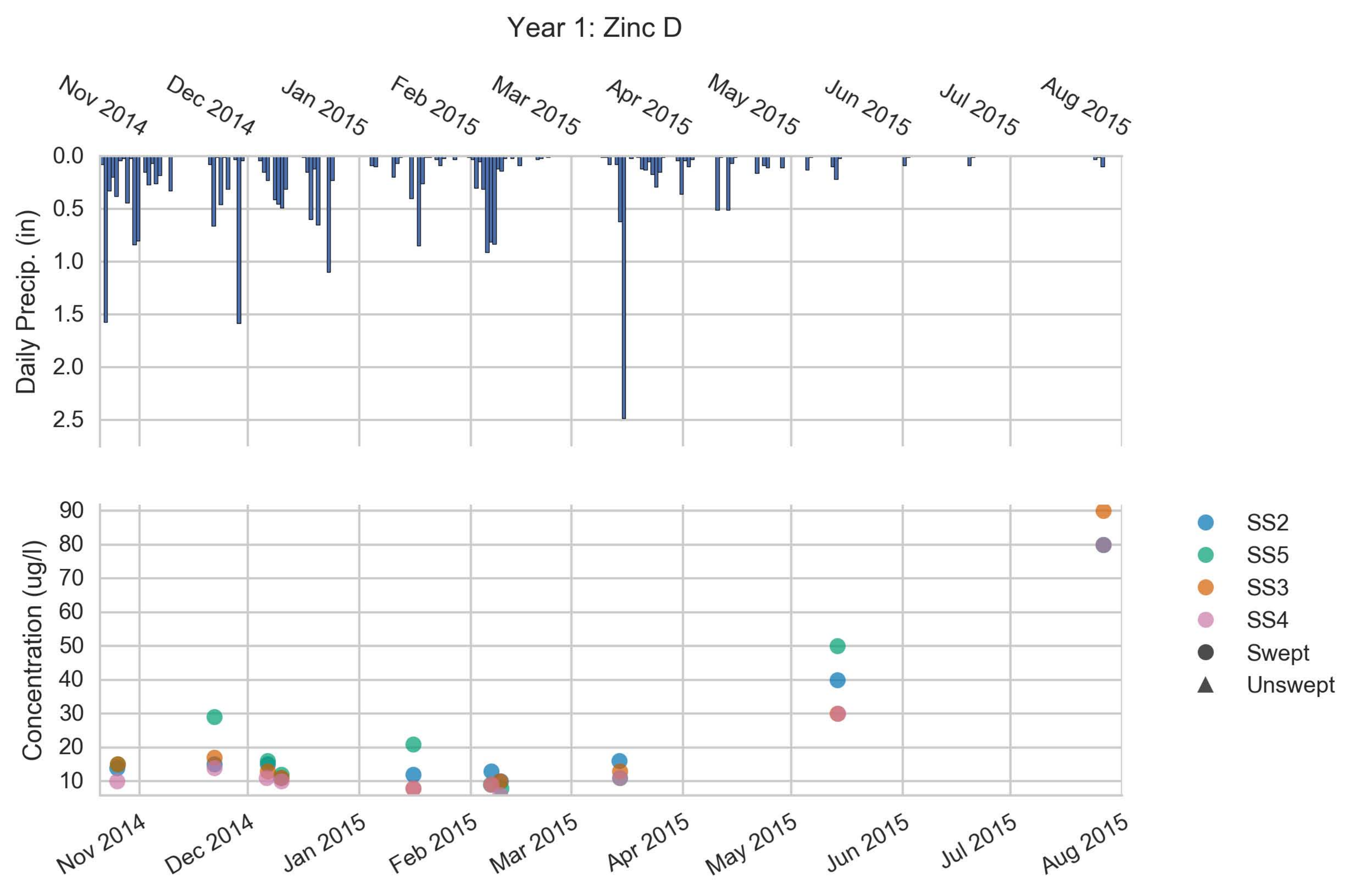

Year 1: Sediment Conc. 62.5 to 3.9 um N
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
0
50
100
150
200
SS2
SS5
SS3
SS4
Swept
Unswept



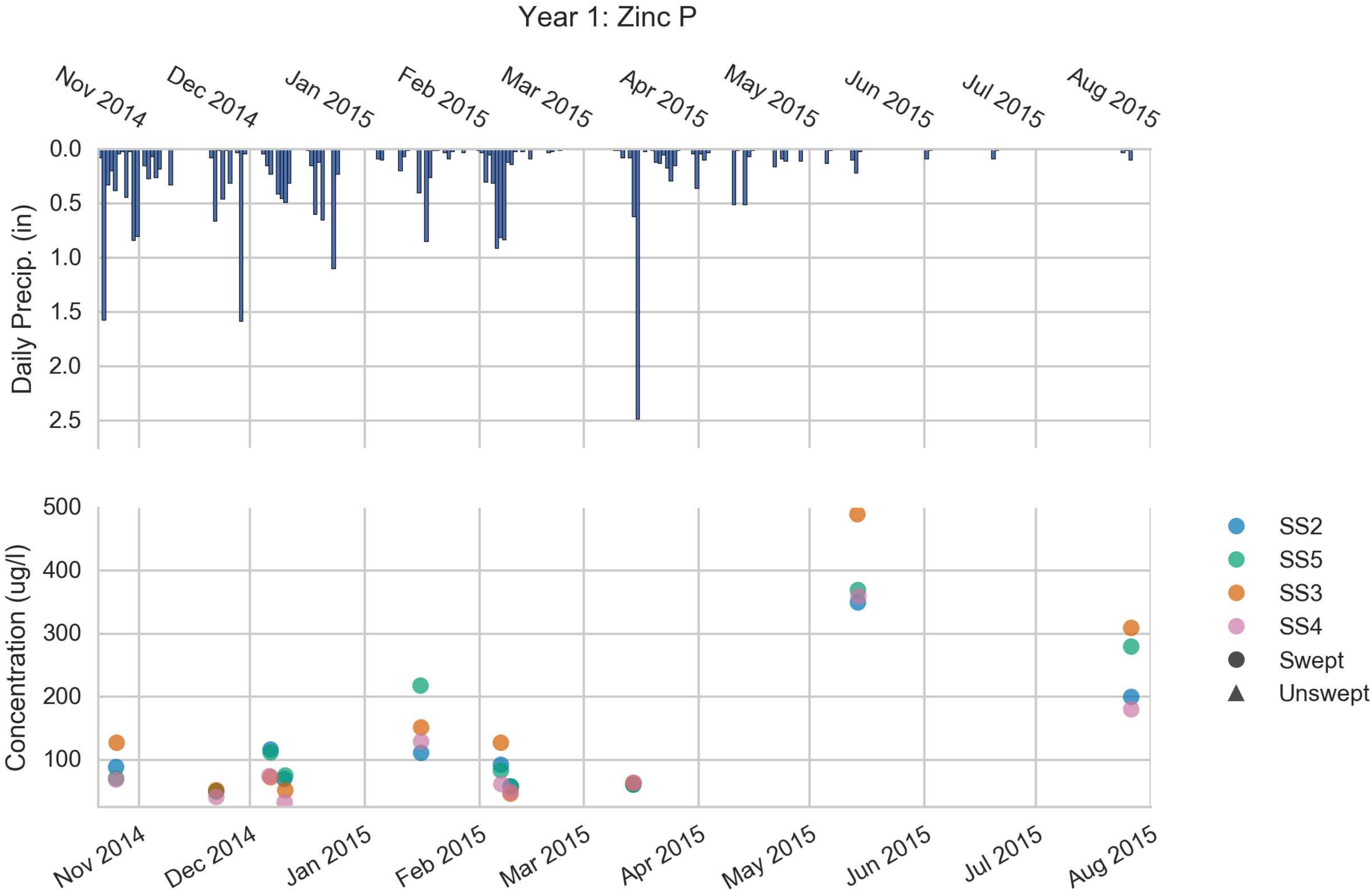
Year 1: Sediment Conc. Total N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
2000
1500
1000
500
SS2
SS5
SS3
SS4
Swept
Unswept

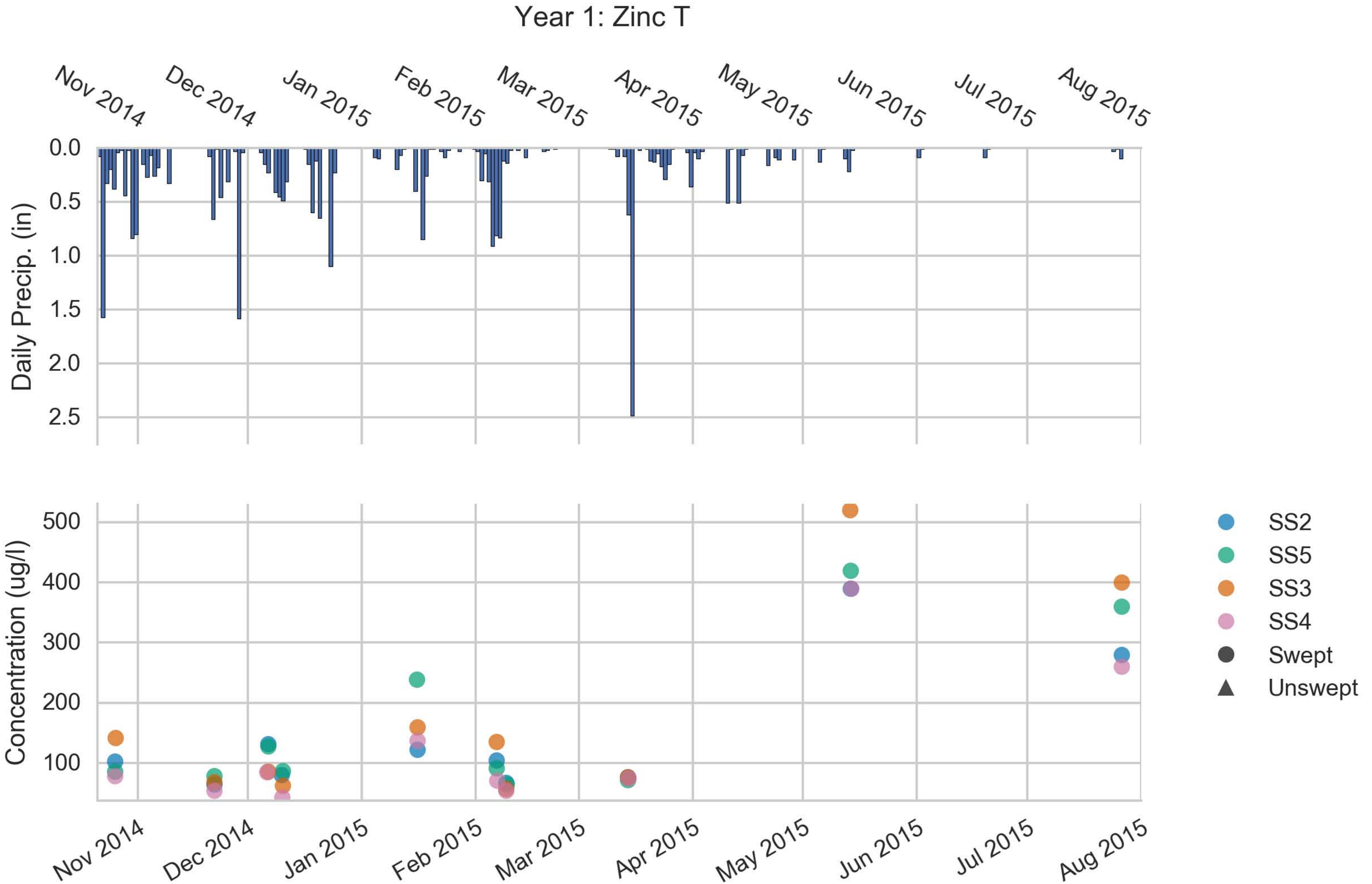

Year 1: Solids, Total Suspended N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
800
600
400
200
SS2
SS5
SS3
SS4
Swept
Unswept

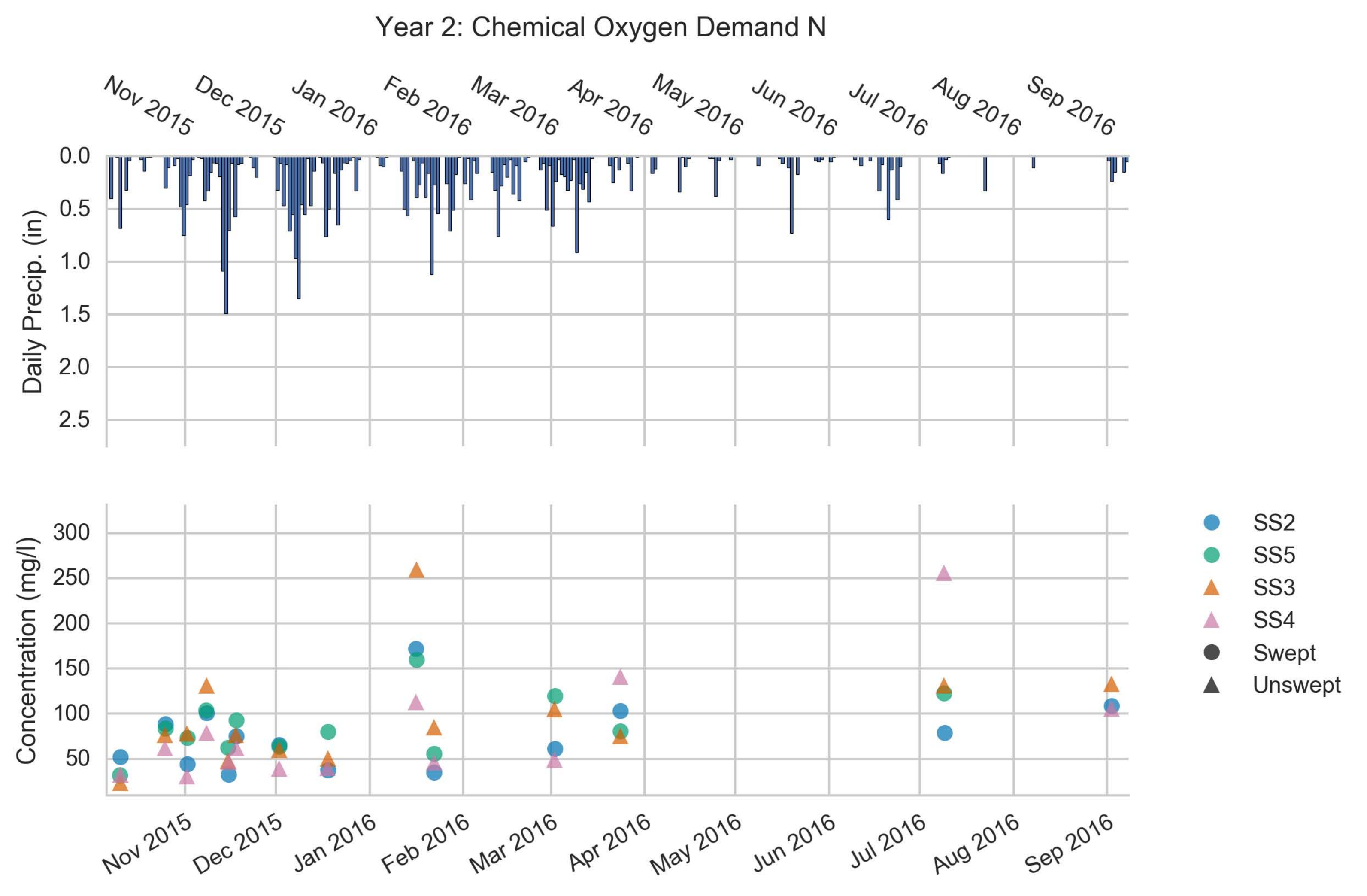

Year 1: Total Organic Carbon N
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
80
70
60
50
40
30
20
10
SS2
SS5
SS3
SS4
Swept
Unswept

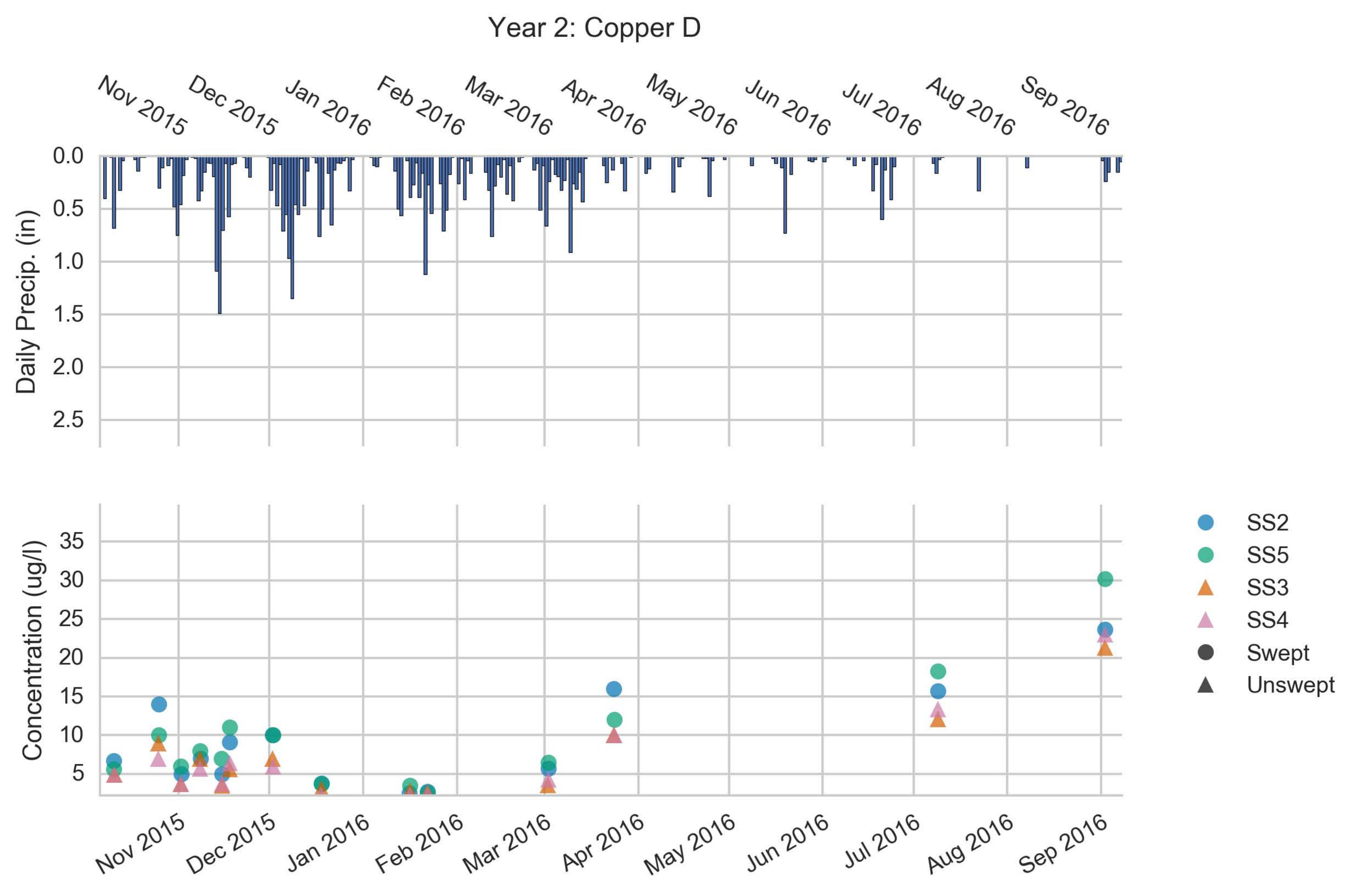


Year 1: Zinc D
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
90
80
70
60
50
40
30
20
10
SS2
SS5
SS3
SS4
Swept
Unswept

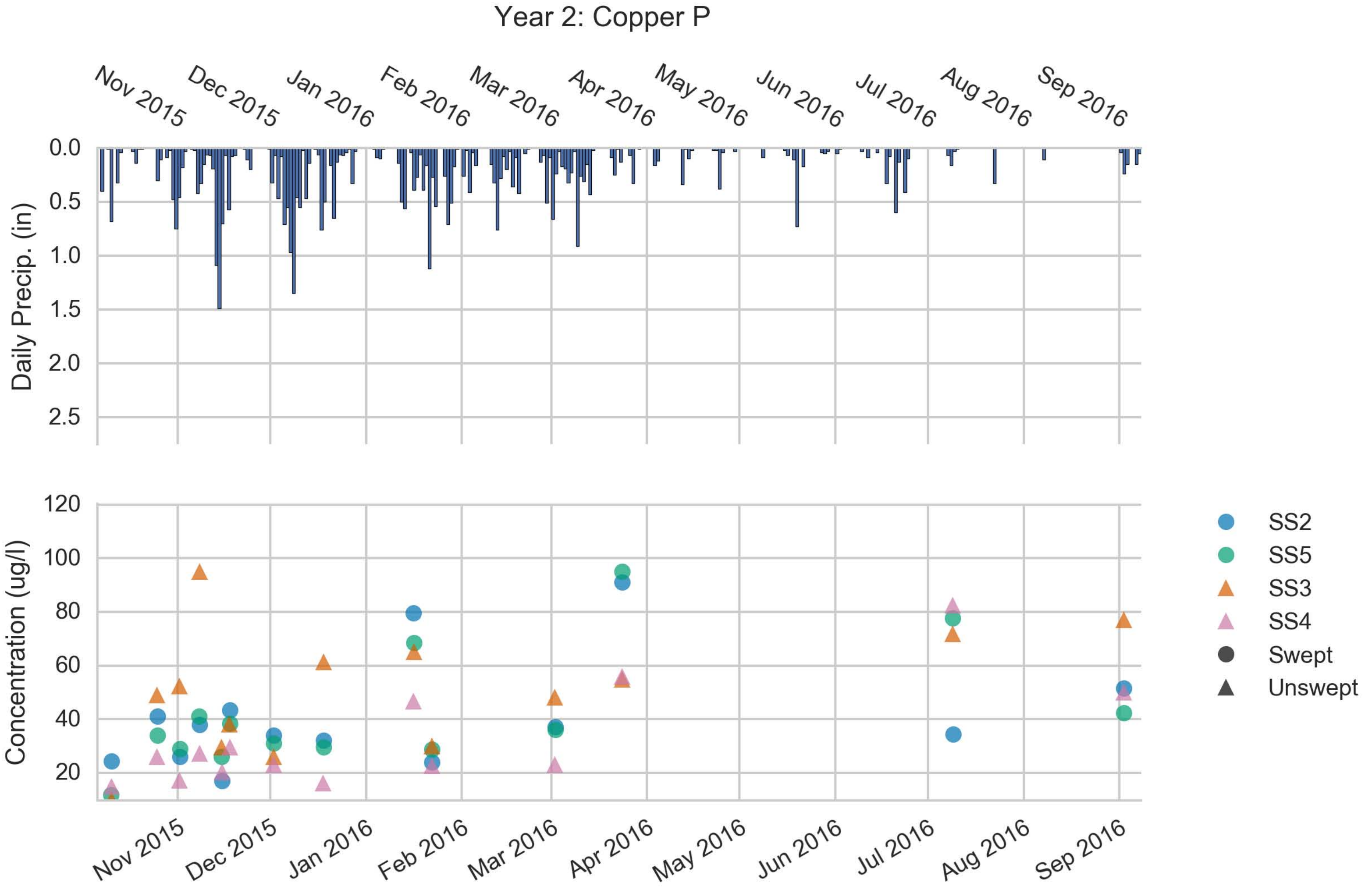

Year 1: Zinc P
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
500
400
300
200
100
SS2
SS5
SS3
SS4
Swept
Unswept


Year 1: Zinc T
Nov 2014
Dec 2014
Jan 2015
Feb 2015
Mar 2015
Apr 2015
May 2015
Jun 2015
Jul 2015
Aug 2015
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
500
400
300
200
100
SS2
SS5
SS3
SS4
Swept
Unswept

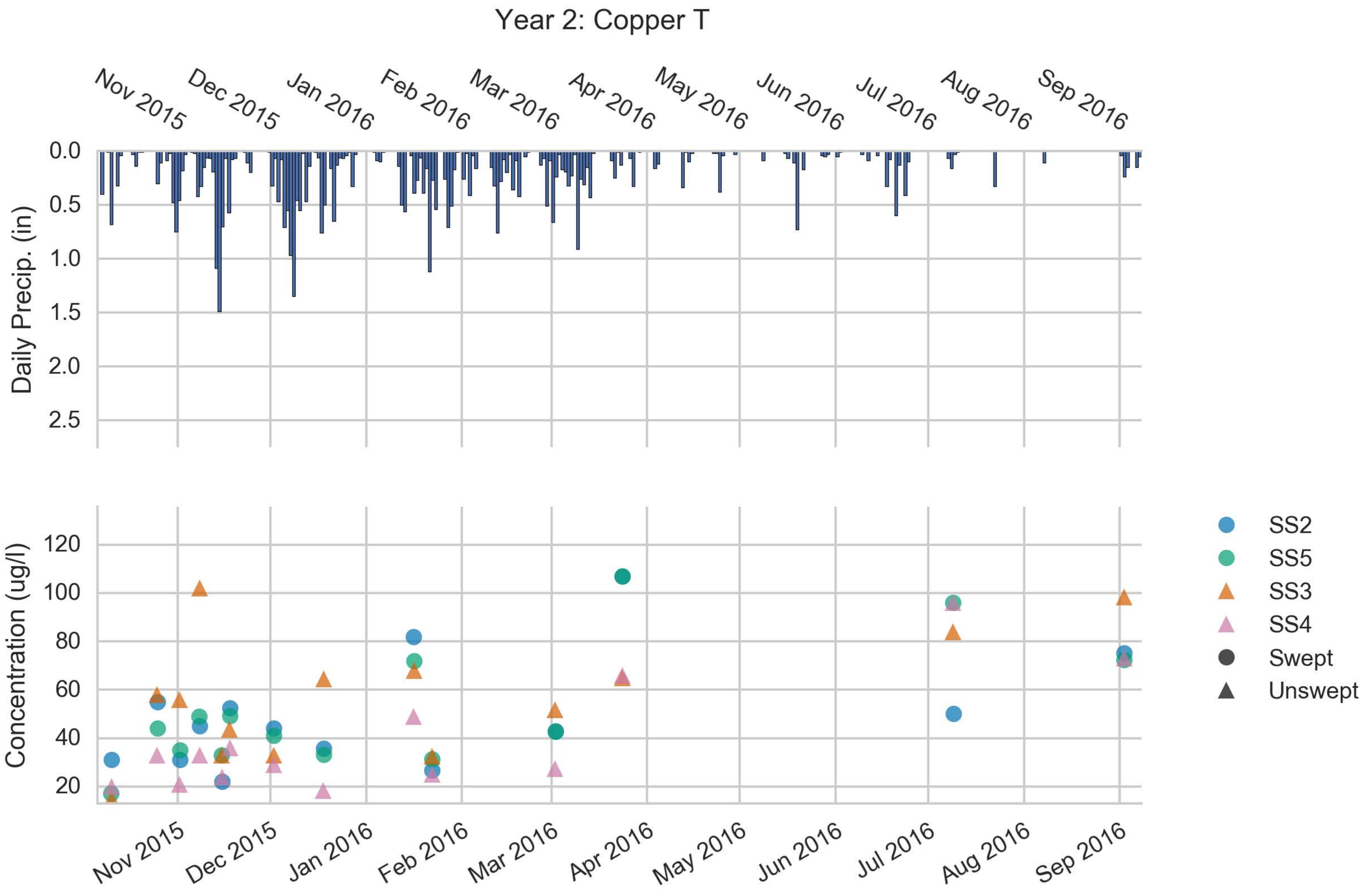

Year 2: Chemical Oxygen Demand N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
300
250
200
150
100
50
SS2
SS5
SS3
SS4
Swept
Unswept



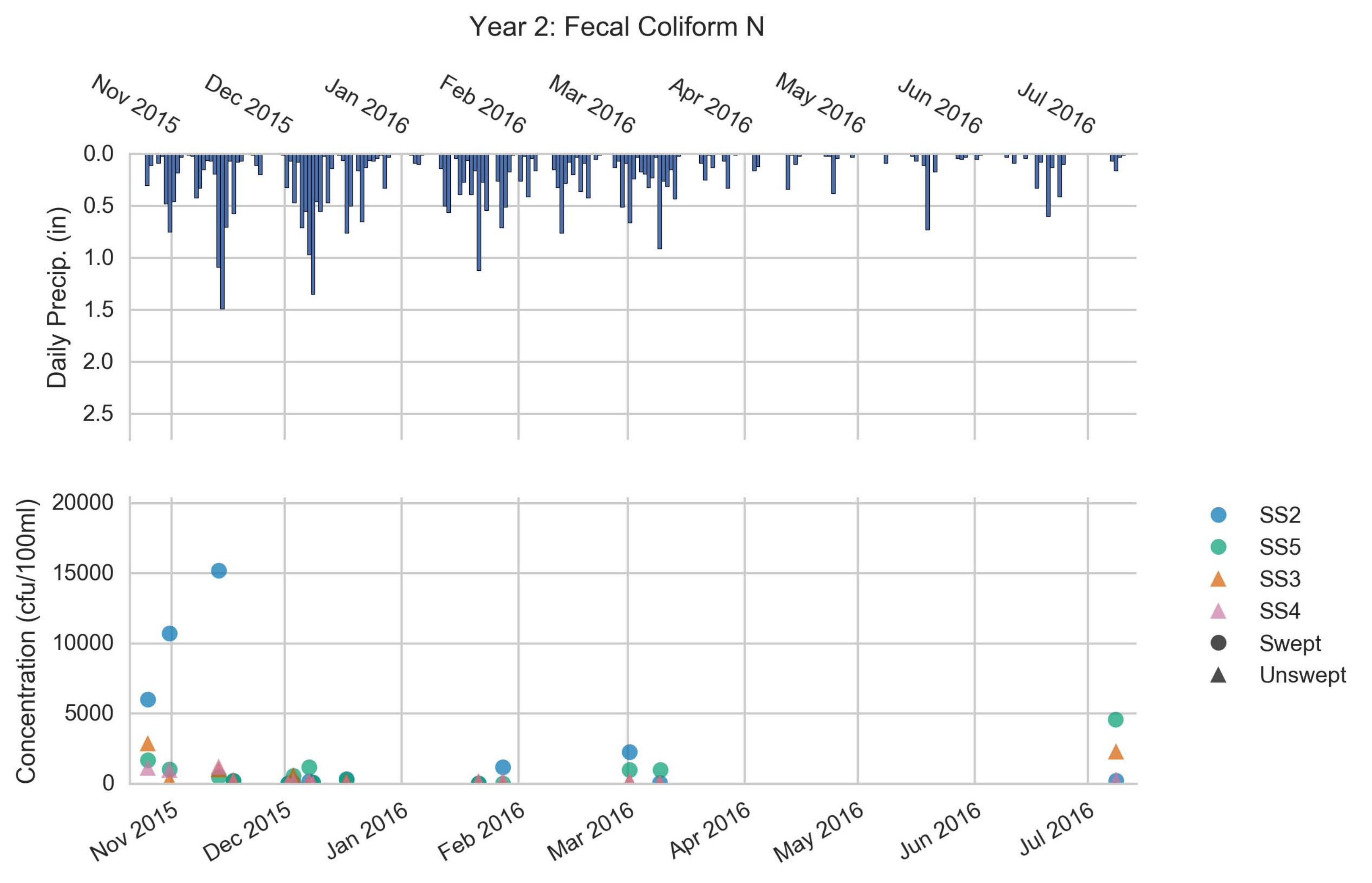
Year 2: Copper D
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
35
30
25
20
15
10
5
SS2
SS5
SS3
SS4
Swept
Unswept



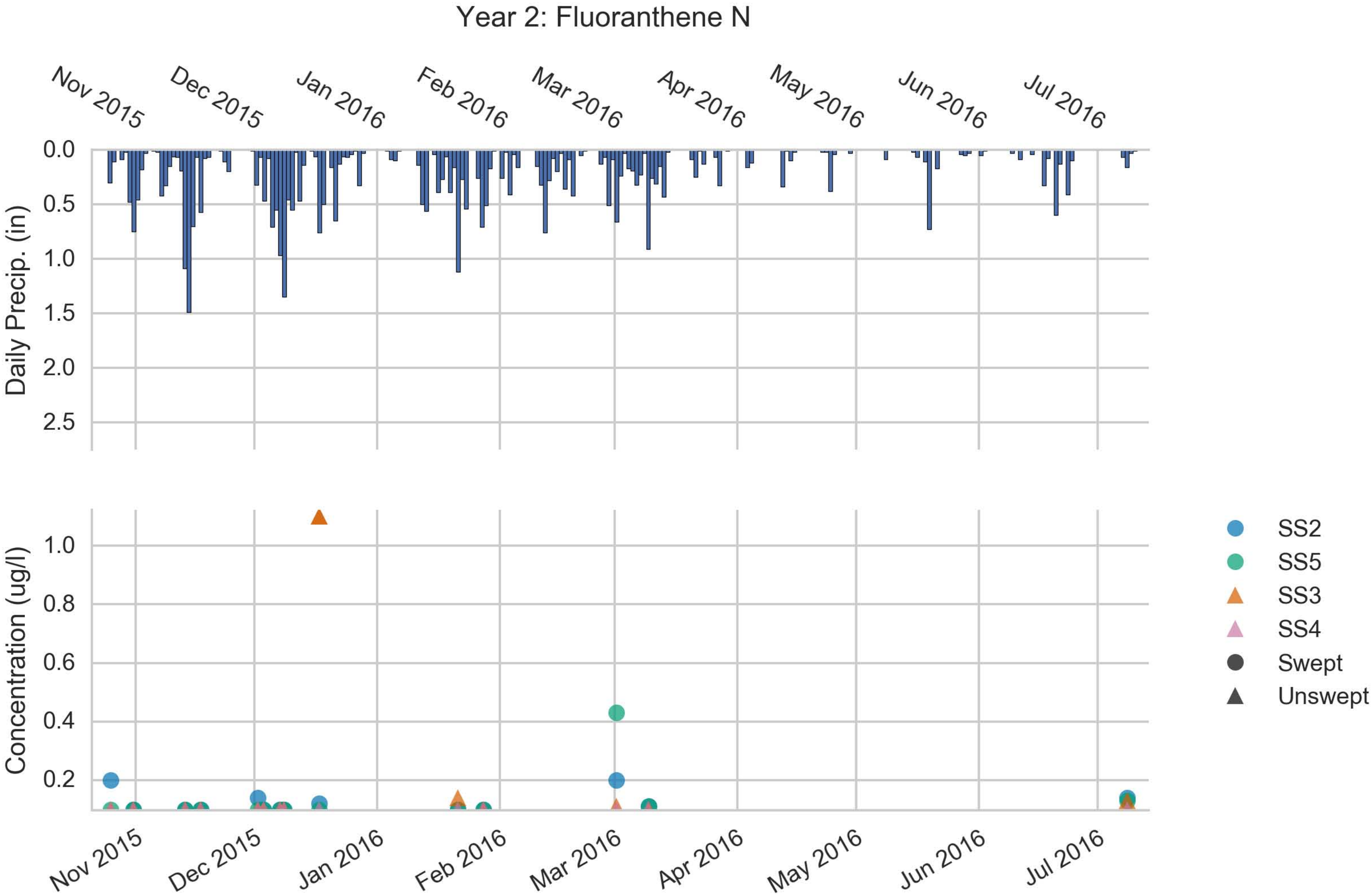
Year 2: Copper P
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
120
100
80
60
40
20
SS2
SS5
SS3
SS4
Swept
Unswept



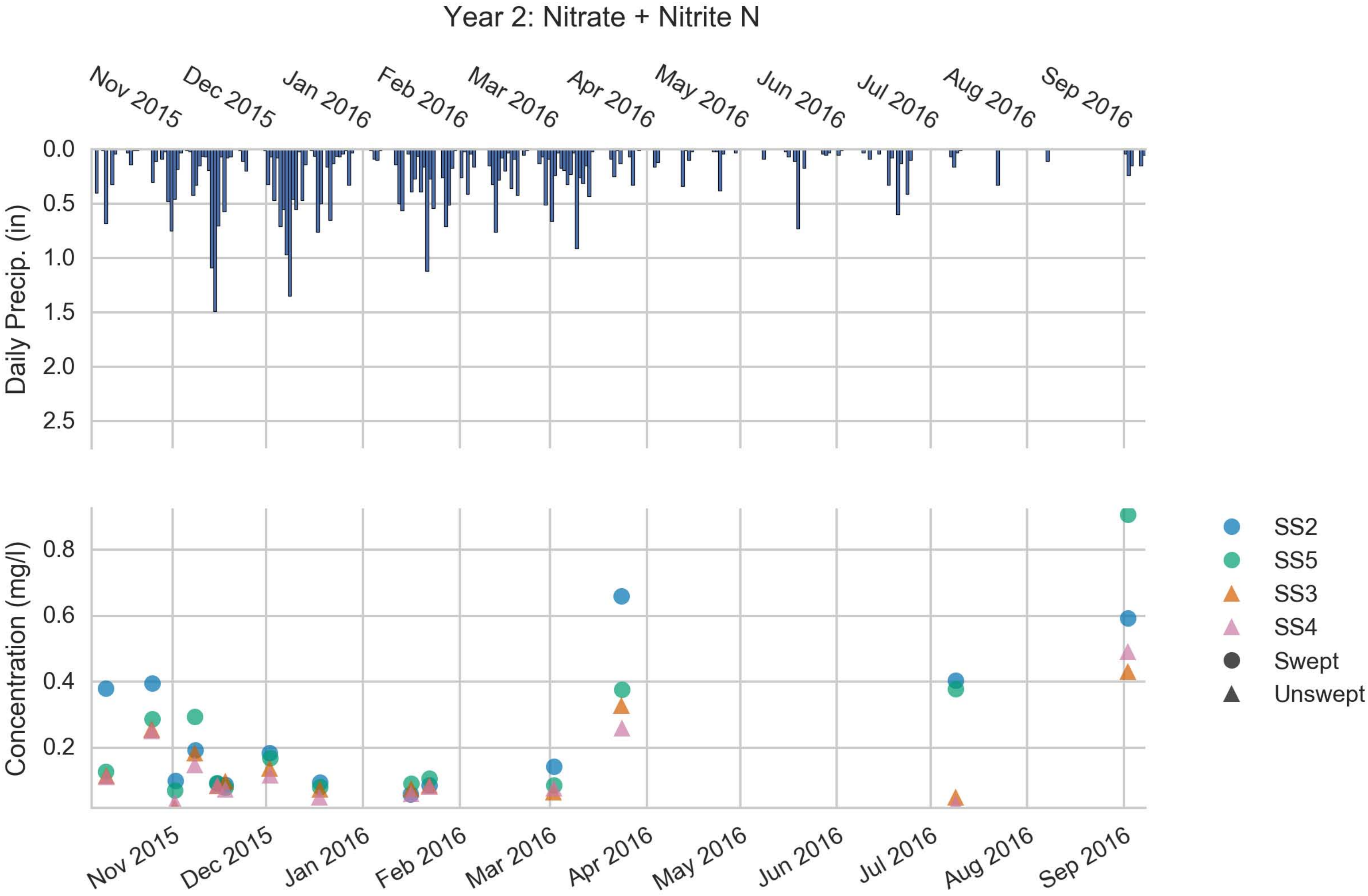
Year 2: Copper T
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
20
40
60
80
100
120
SS2
SS5
SS3
SS4
Swept
Unswept



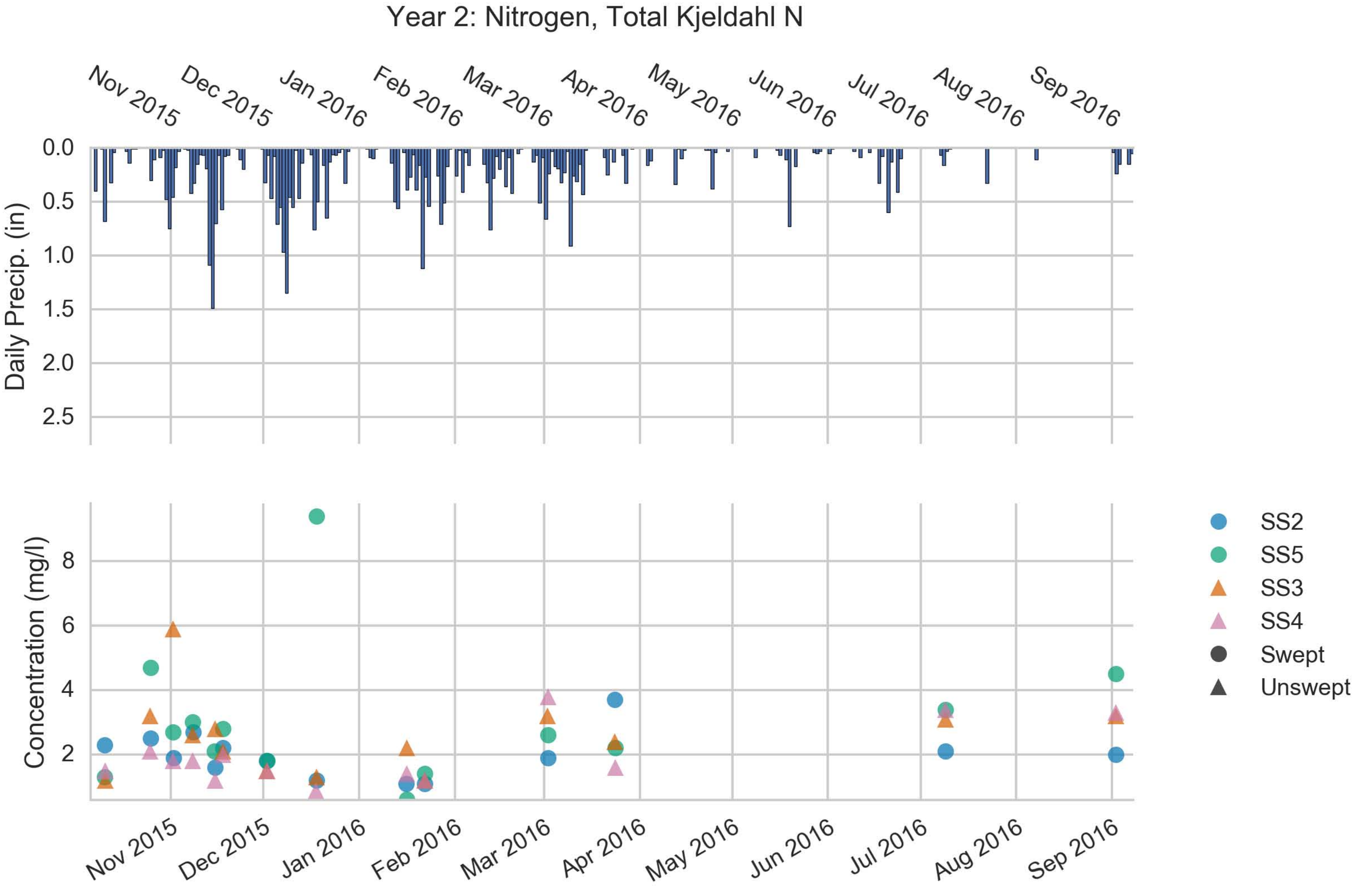
Year 2: Fecal Coliform N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (cfu/100ml)
20000
15000
10000
5000
0
SS2
SS5
SS3
SS4
Swept
Unswept



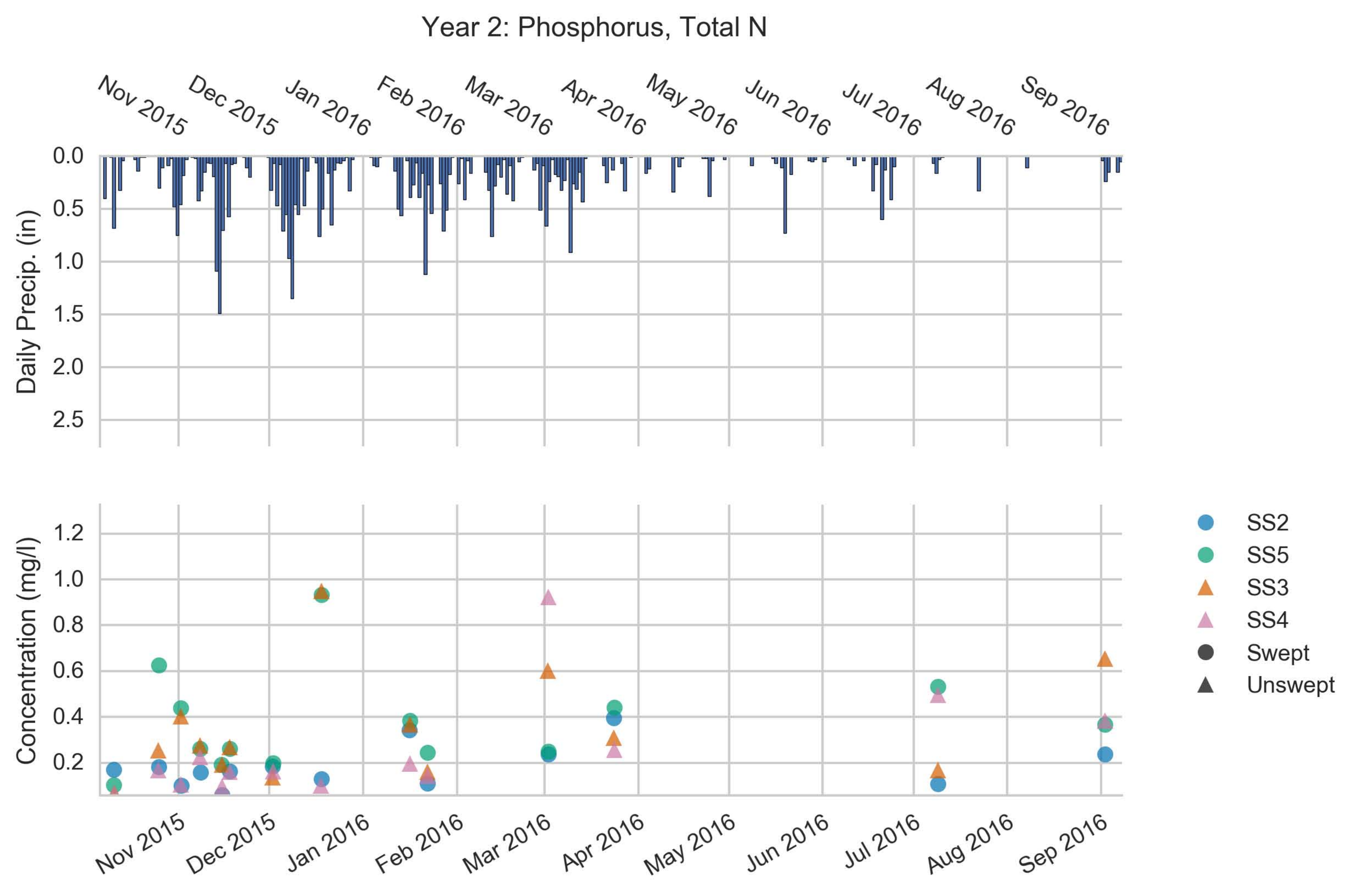
Year 2: Fluoranthene N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
1.0
0.8
0.6
0.4
0.2
SS2
SS5
SS3
SS4
Swept
Unswept



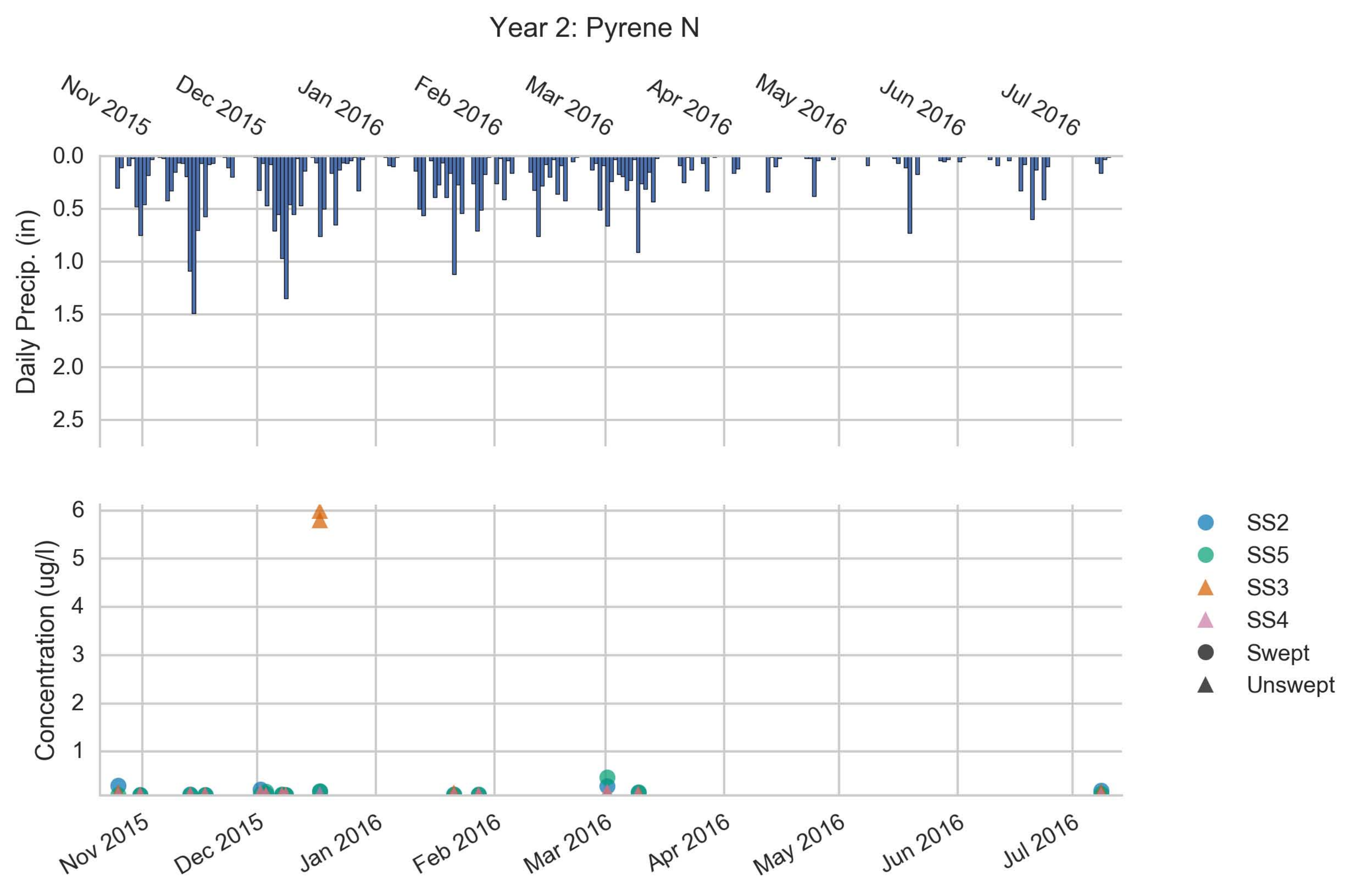
Year 2: Nitrate + Nitrite N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
0.2
0.4
0.6
0.8
SS2
SS5
SS3
SS4
Swept
Unswept

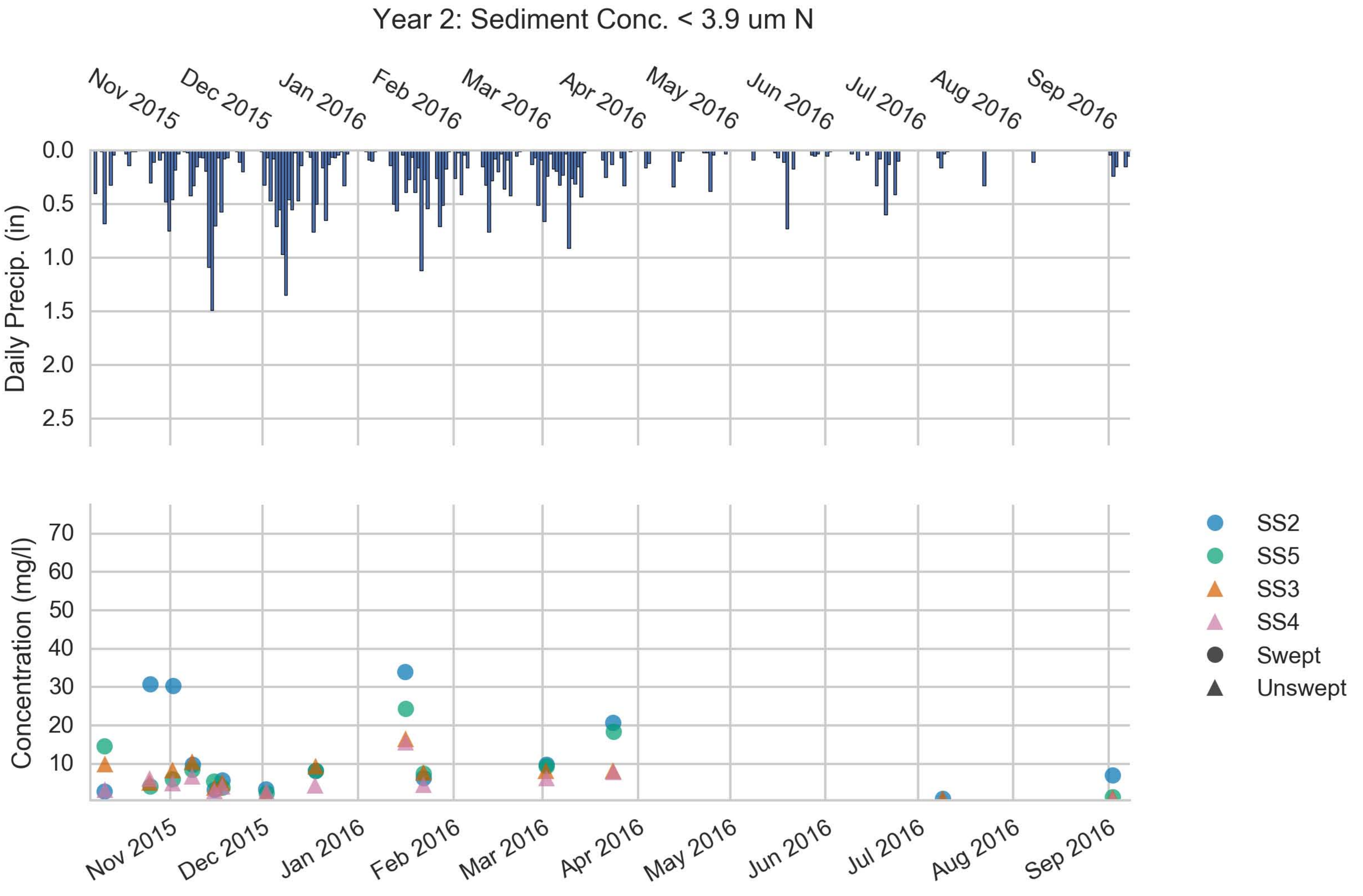


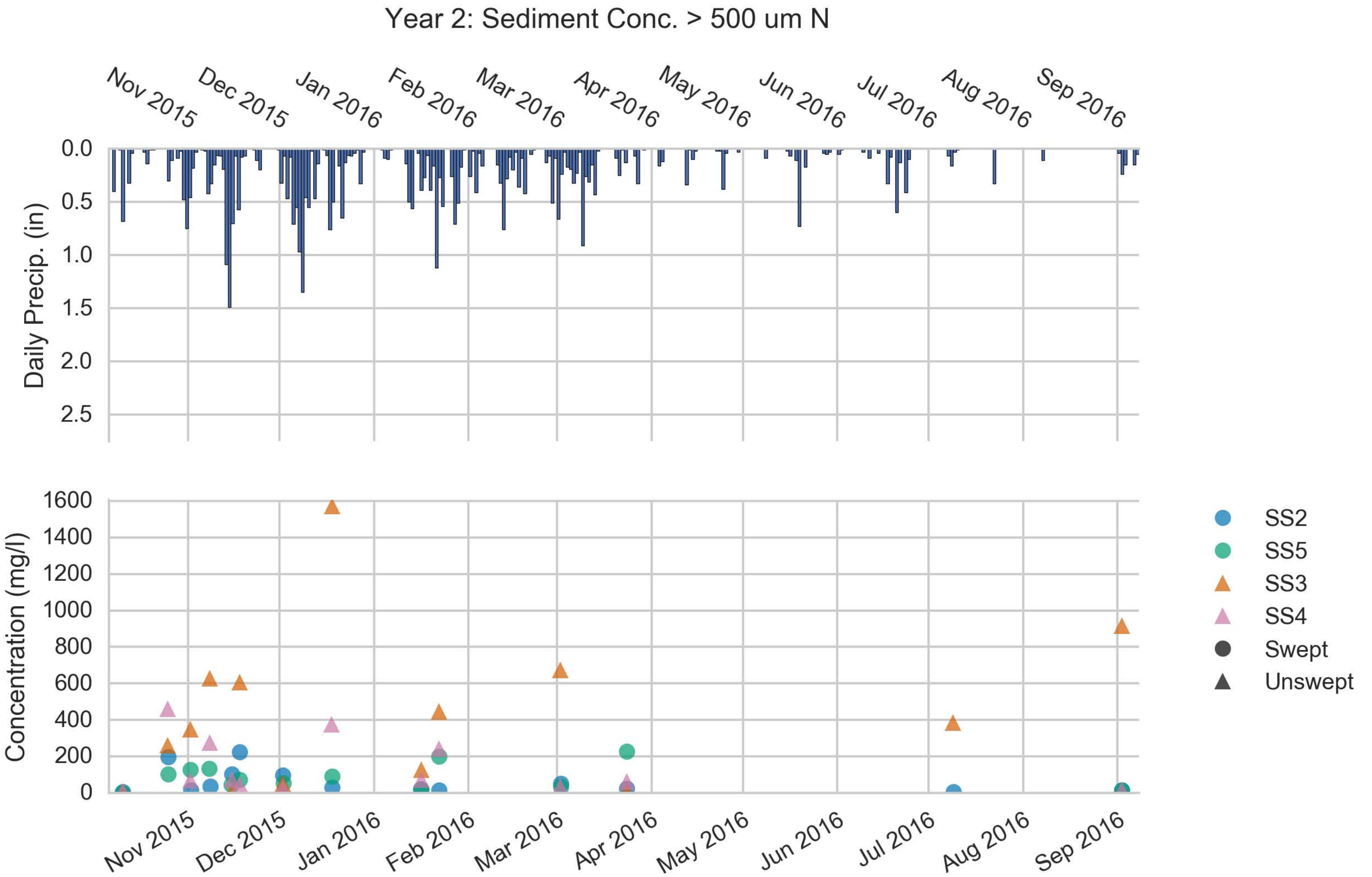
Year 2: Nitrogen, Total Kjeldahl N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
8
6
4
2
SS2
SS5
SS3
SS4
Swept
Unswept



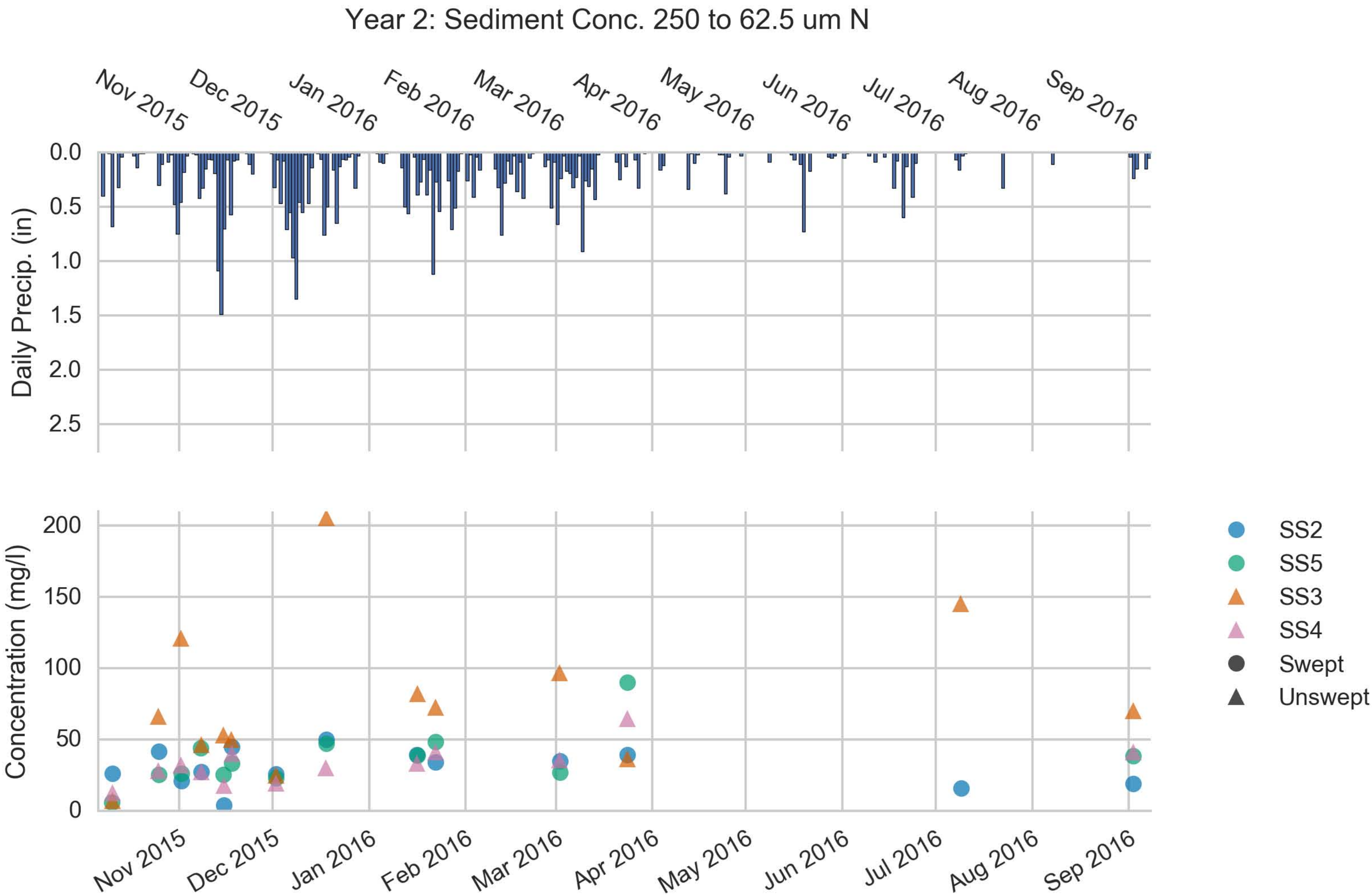
Year 2: Phosphorus, Total N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
1.2
1.0
0.8
0.6
0.4
0.2
SS2
SS5
SS3
SS4
Swept
Unswept

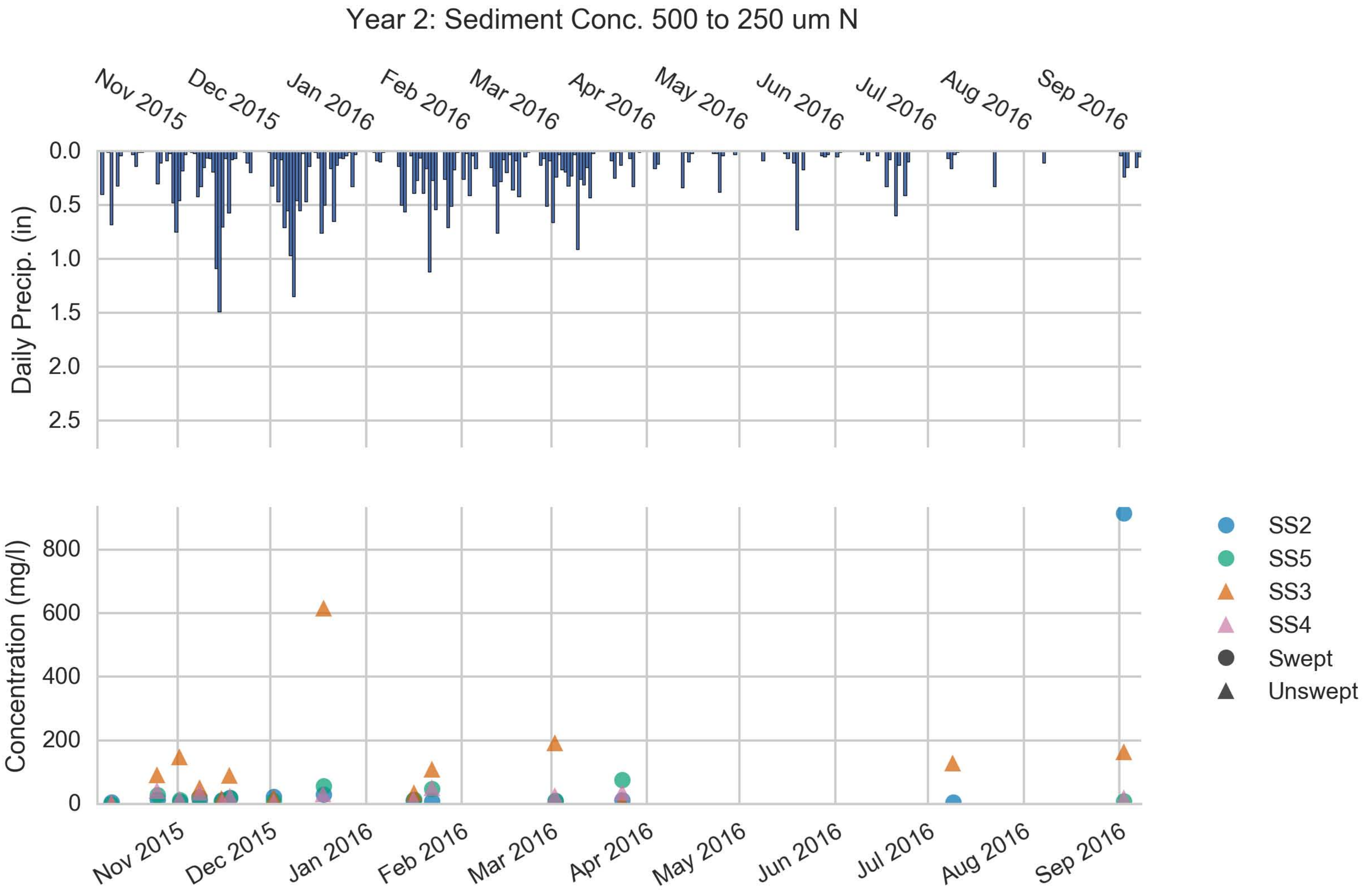

Year 2: Pyrene N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
6
5
4
3
2
1
SS2
SS5
SS3
SS4
Swept
Unswept


Year 2: Sediment Conc. < 3.9 um N
Daily Precip. (in)
Concentration (mg/l)
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
SS2
SS5
SS3
SS4
Swept
Unswept

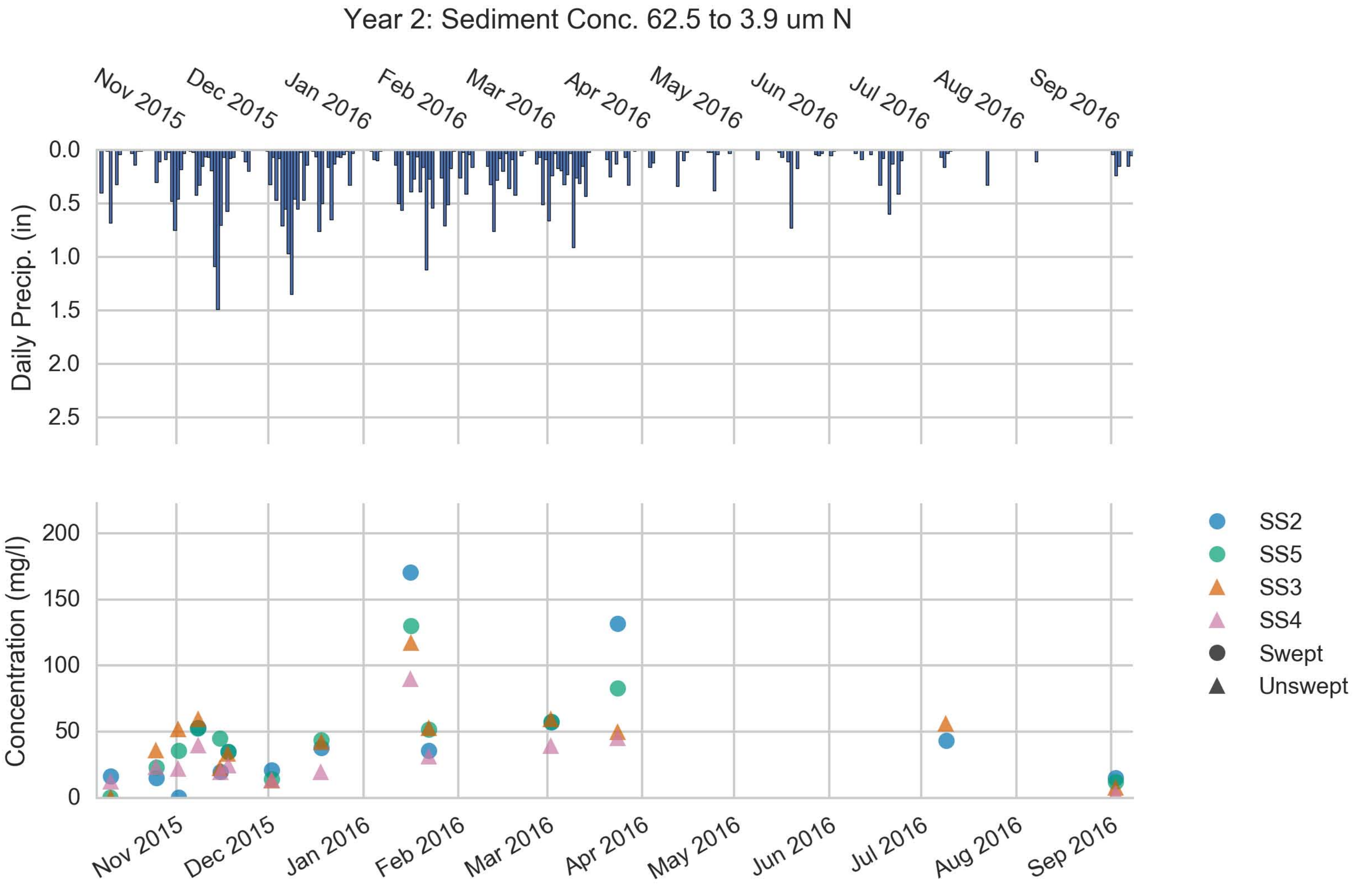


Year 2: Sediment Conc. > 500 um N
Daily Precip. (in)
Concentration (mg/l)
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
0.0
0.5
1.0
1.5
2.0
2.5
0
200
400
600
800
1000
1200
1400
1600
SS2
SS5
SS3
SS4
Swept
Unswept

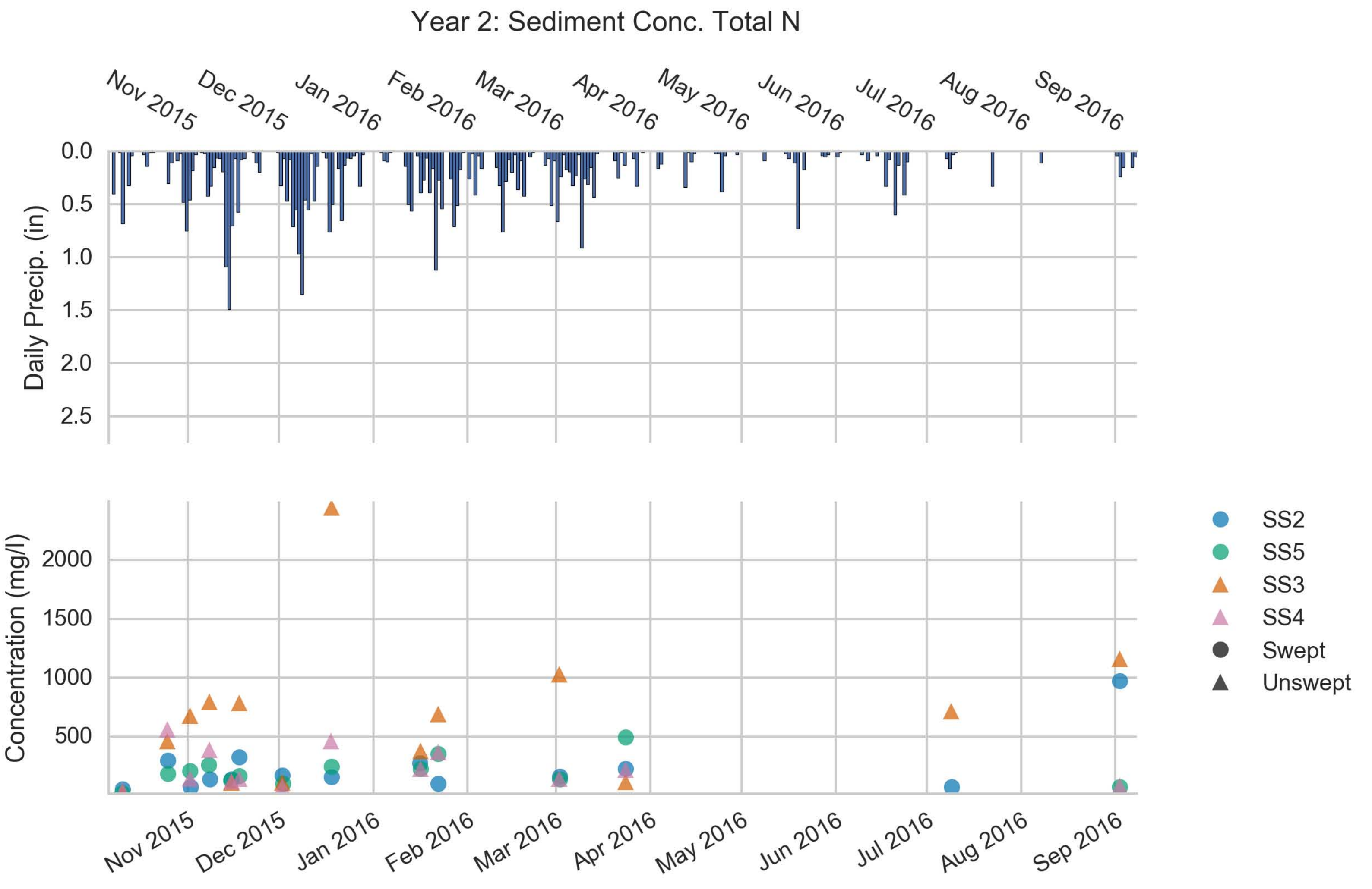

Year 2: Sediment Conc. 250 to 62.5 um N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
0
50
100
150
200
SS2
SS5
SS3
SS4
Swept
Unswept

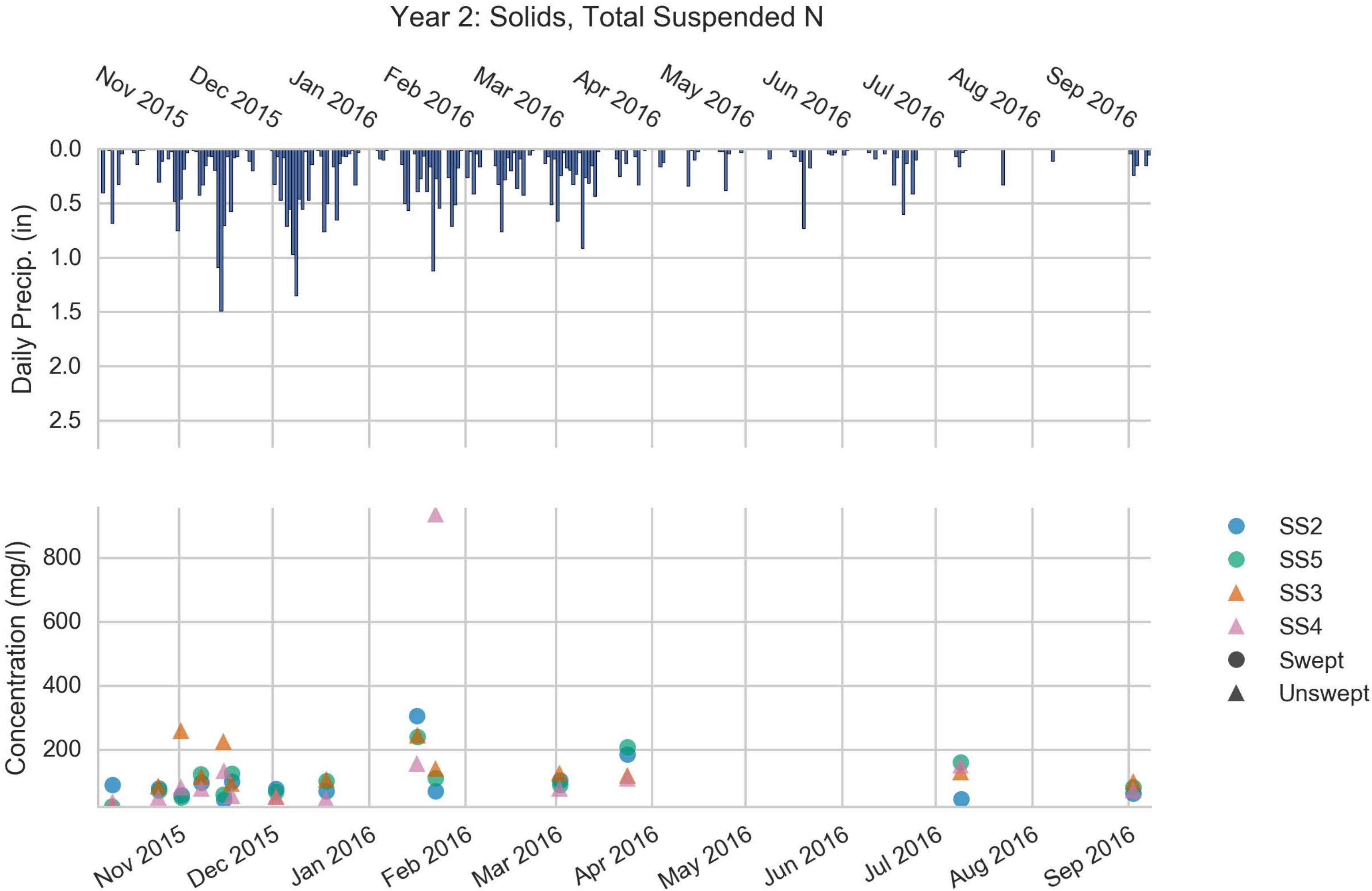


Year 2: Sediment Conc. 500 to 250 um N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
800
600
400
200
0
SS2
SS5
SS3
SS4
Swept
Unswept

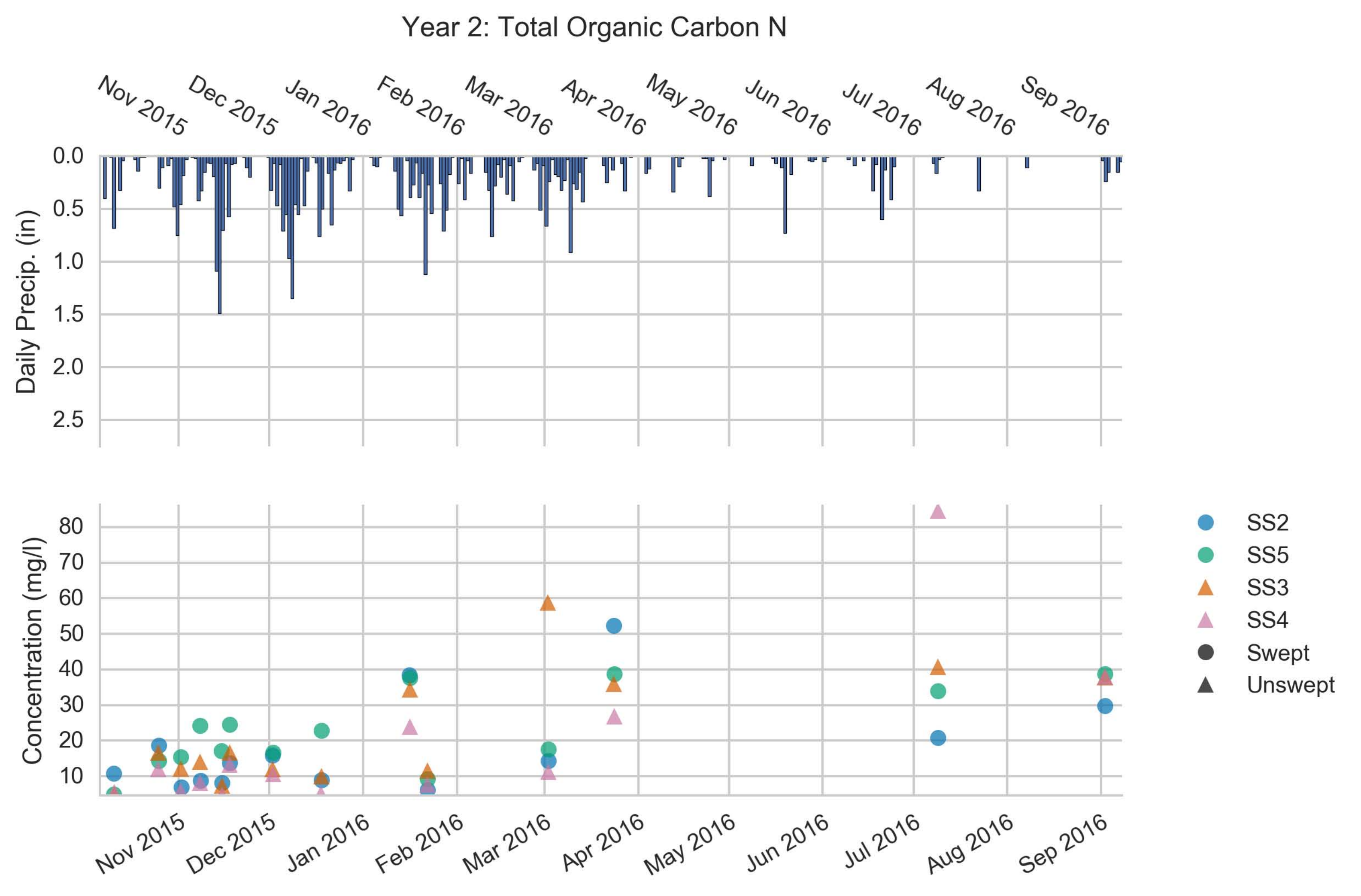


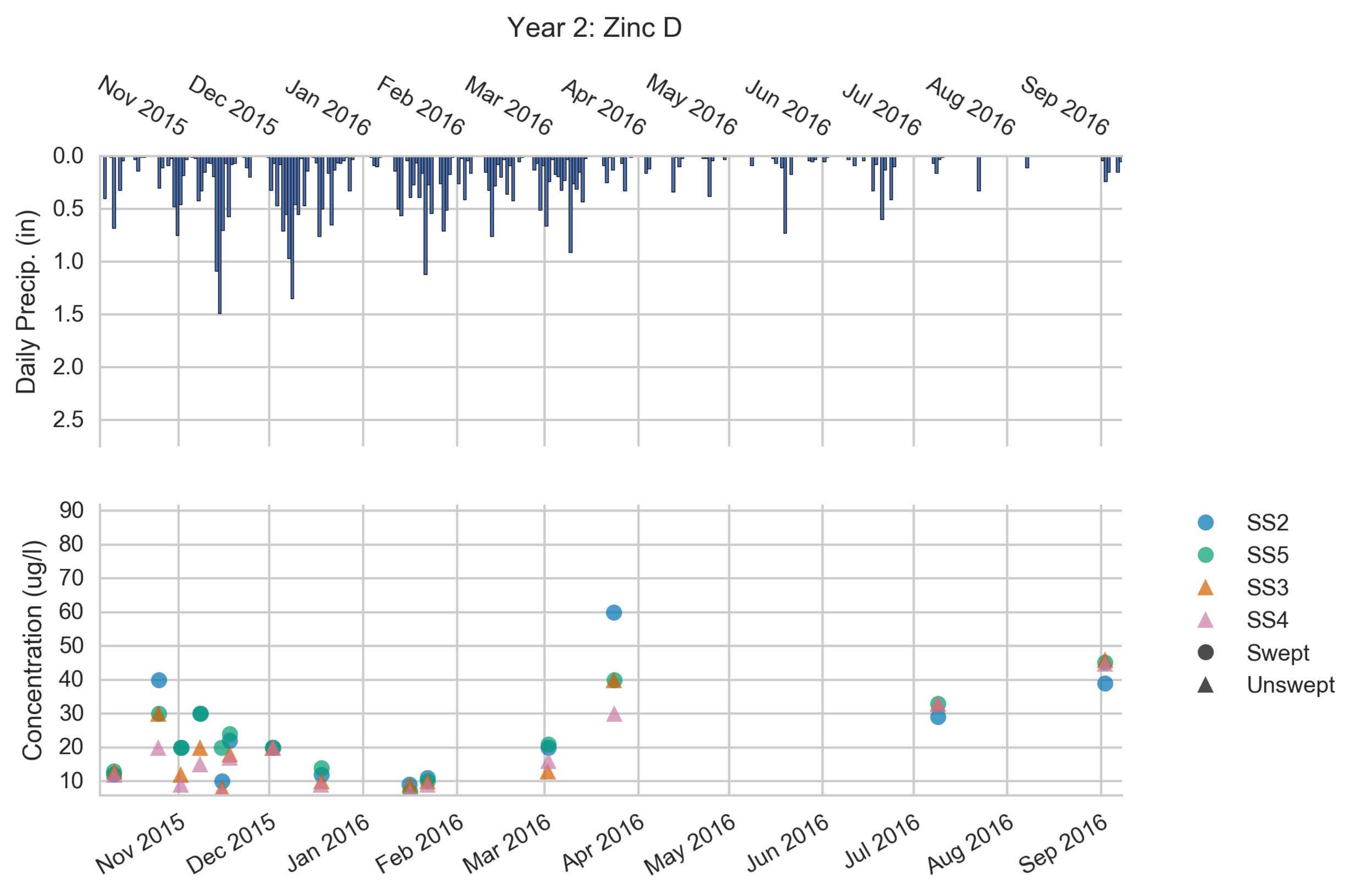
Year 2: Sediment Conc. 62.5 to 3.9 um N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
0
50
100
150
200
SS2
SS5
SS3
SS4
Swept
Unswept


Year 2: Sediment Conc. Total N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
500
1000
1500
2000
SS2
SS5
SS3
SS4
Swept
Unswept

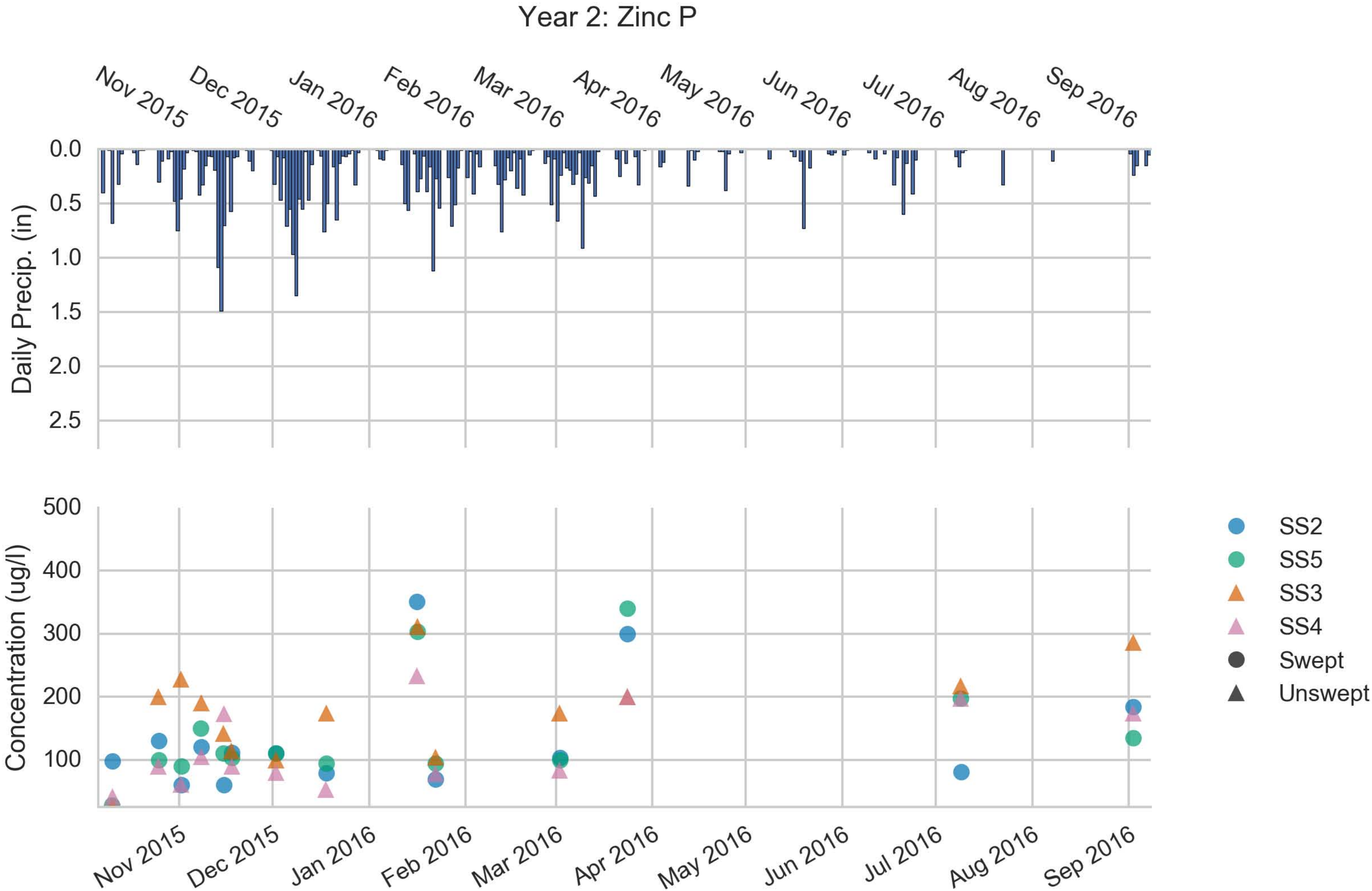


Year 2: Solids, Total Suspended N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
800
600
400
200
SS2
SS5
SS3
SS4
Swept
Unswept

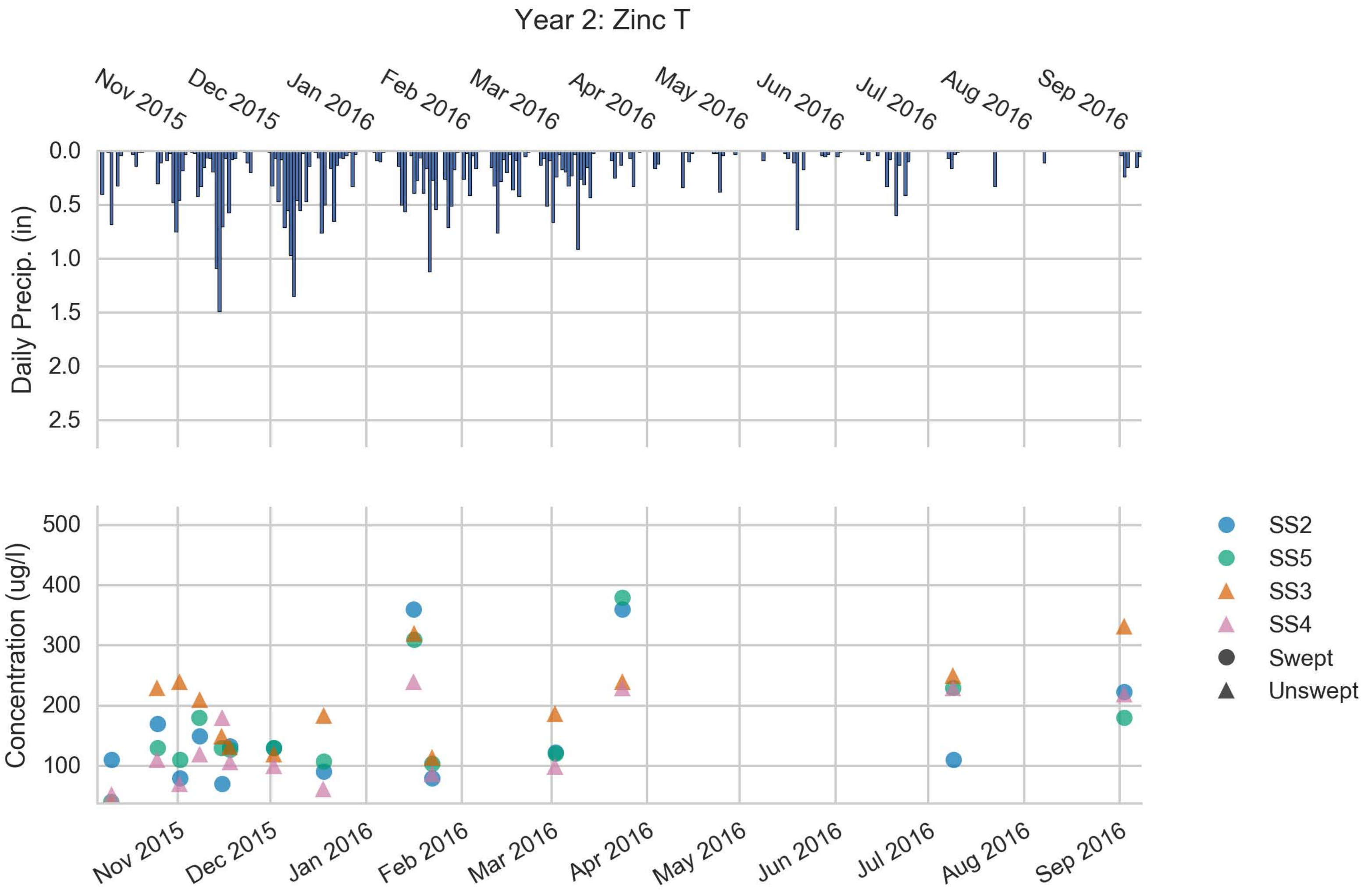

Year 2: Total Organic Carbon N
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (mg/l)
80
70
60
50
40
30
20
10
SS2
SS5
SS3
SS4
Swept
Unswept



Year 2: Zinc D
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
90
80
70
60
50
40
30
20
10
SS2
SS5
SS3
SS4
Swept
Unswept



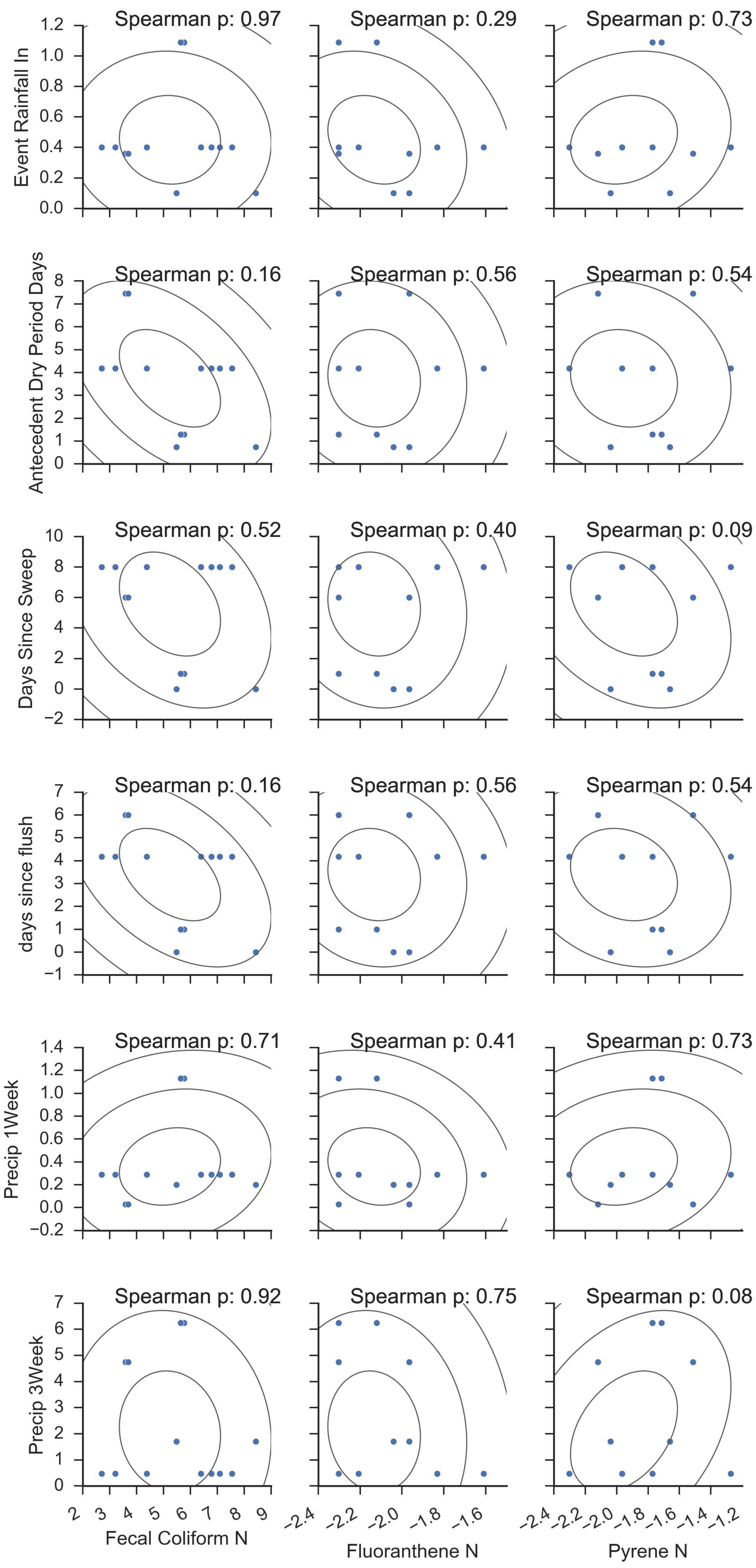
Year 2: Zinc P
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
500
400
300
200
100
SS2
SS5
SS3
SS4
Swept
Unswept



Year 2: Zinc T
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Daily Precip. (in)
0.0
0.5
1.0
1.5
2.0
2.5
Concentration (ug/l)
500
400
300
200
100
SS2
SS5
SS3
SS4
Swept
Unswept

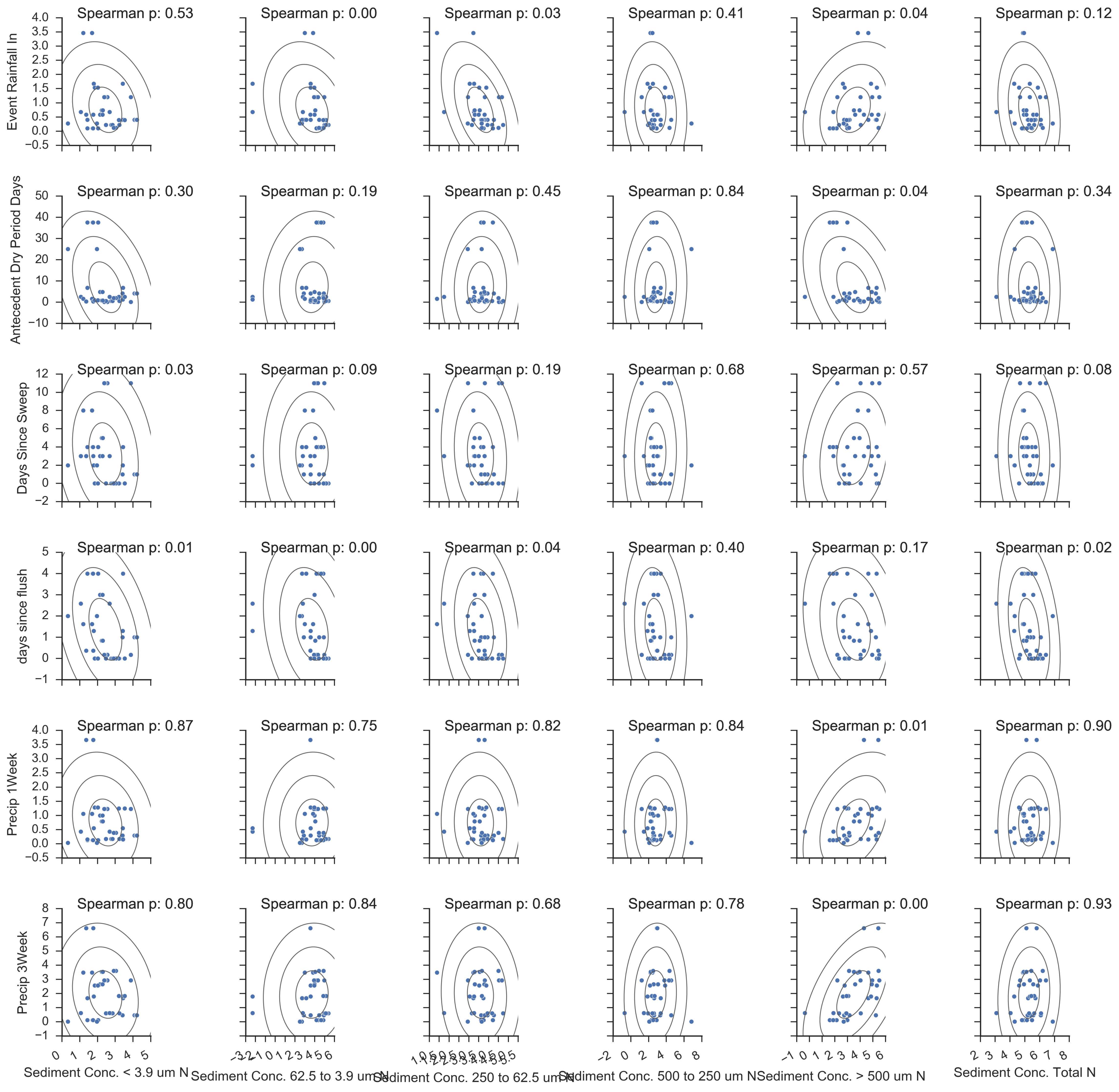
Attachment 1b

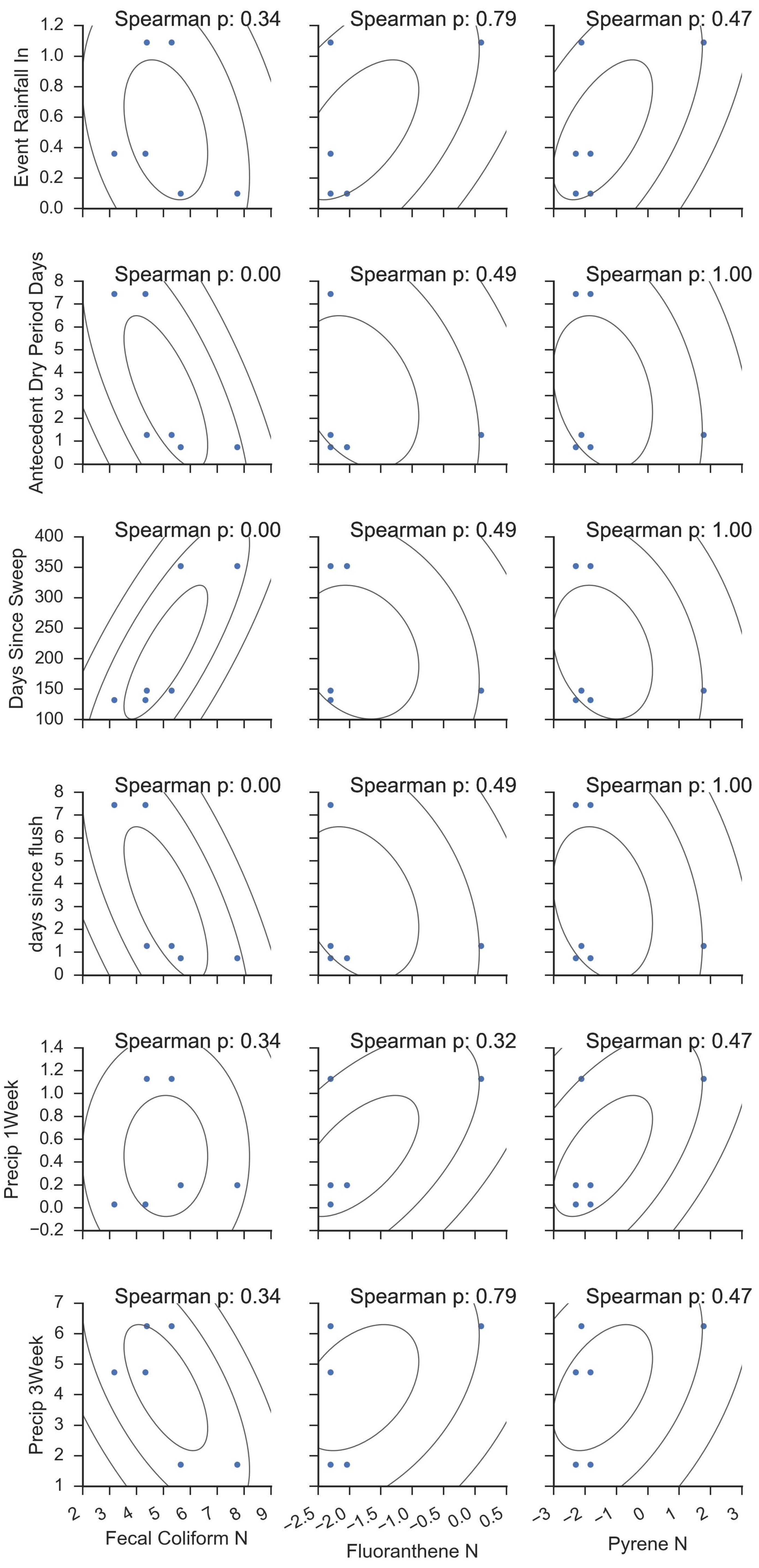
Consolidated Scatter Plots



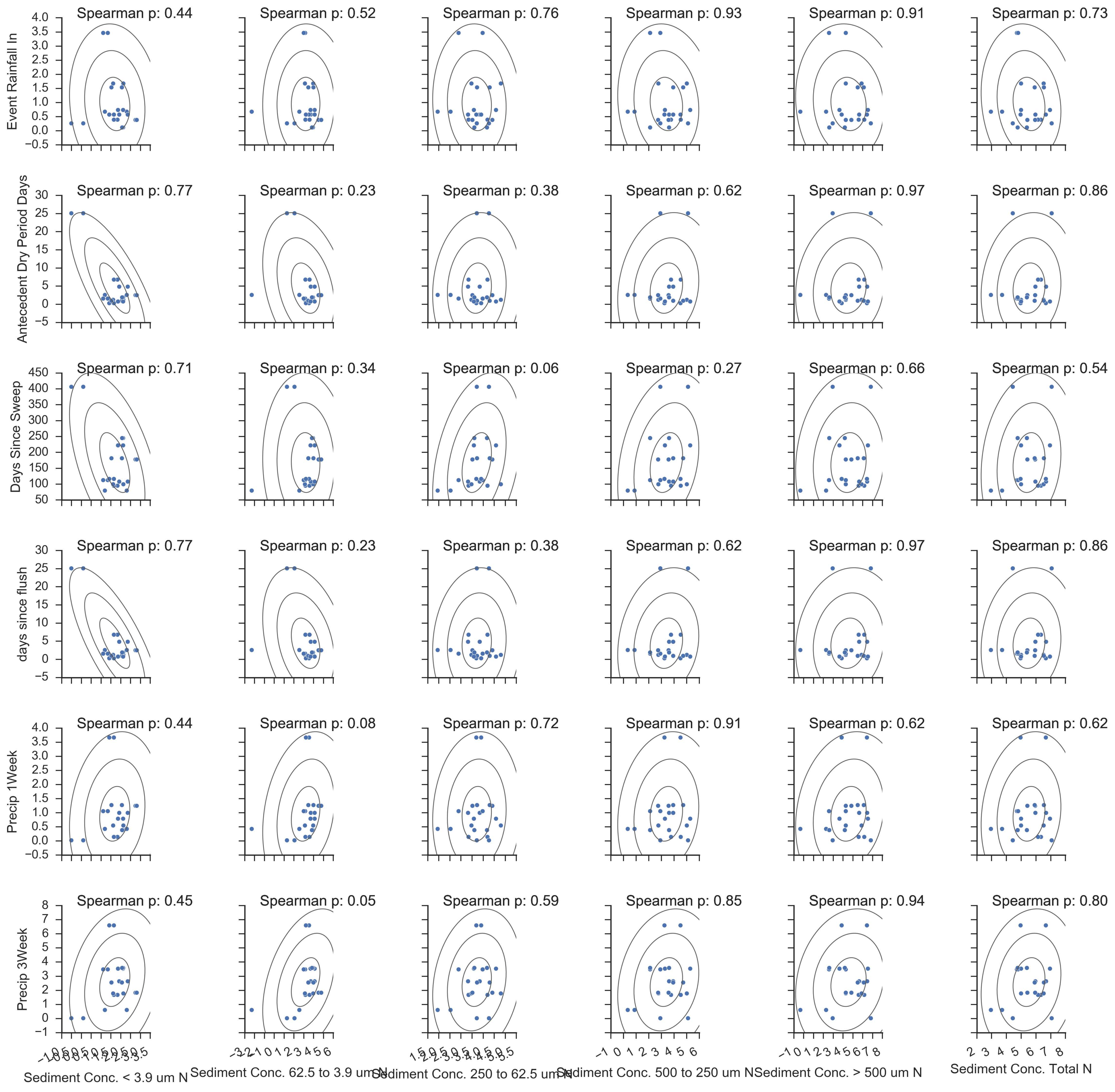
Spearman p: 0.97
Spearman p: 0.29
Spearman p: 0.73
Event Rainfall In
Spearman p: 0.16
Spearman p: 0.56
Spearman p: 0.54
Antecedent Dry Period Days
Spearman p: 0.52
Spearman p: 0.40
Spearman p: 0.09
Days Since Sweep
Spearman p: 0.16
Spearman p: 0.56
Spearman p: 0.54
days since flush
Spearman p: 0.71
Spearman p: 0.41
Spearman p: 0.73
Precip 1Week
Spearman p: 0.92
Spearman p: 0.75
Spearman p: 0.08
Precip 3Week
Fecal Coliform N
Fluoranthene N
Pyrene N


Event Rainfall In
Antecedent Dry Period Days
Days Since Sweep
days since flush
Precip 1Week
Precip 3Week
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.19
Spearman p: 0.01
Spearman p: 0.00
Spearman p: 0.03
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.01
Spearman p: 0.01
Spearman p: 0.41
Spearman p: 0.01
Spearman p: 0.01
Spearman p: 0.00
Spearman p: 0.01
Spearman p: 0.18
Spearman p: 0.02
Spearman p: 0.05
Spearman p: 0.01
Spearman p: 0.00
Spearman p: 0.03
Spearman p: 0.03
Spearman p: 0.01
Spearman p: 0.37
Spearman p: 0.03
Spearman p: 0.23
Spearman p: 0.56
Spearman p: 0.04
Spearman p: 0.02
Spearman p: 0.02
Spearman p: 0.87
Spearman p: 0.02
Spearman p: 0.60
Spearman p: 0.45
Spearman p: 0.01
Spearman p: 0.18
Spearman p: 0.97
Spearman p: 0.00
Spearman p: 0.03
Spearman p: 0.19
Spearman p: 0.26
Spearman p: 0.20
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.01
Spearman p: 0.01
Spearman p: 0.60
Spearman p: 0.02
Spearman p: 0.06
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.16
Spearman p: 0.02
Spearman p: 0.03
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.01
Spearman p: 0.01
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.02
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Total Organic Carbon N
Nitrate + Nitrite N
Copper T
Zinc T
Solids, Total Suspended N
Nitrogen, Total Kjeldahl N
Chemical Oxygen Demand N
Copper D
Zinc D
Phosphorus, Total N
Zinc P
Copper P


Spearman p: 0.53
Spearman p: 0.00
Spearman p: 0.03
Spearman p: 0.41
Spearman p: 0.04
Spearman p: 0.12
Event Rainfall In
Spearman p: 0.30
Spearman p: 0.19
Spearman p: 0.45
Spearman p: 0.84
Spearman p: 0.04
Spearman p: 0.34
Antecedent Dry Period Days
Spearman p: 0.03
Spearman p: 0.09
Spearman p: 0.19
Spearman p: 0.68
Spearman p: 0.57
Spearman p: 0.08
Days Since Sweep
Spearman p: 0.01
Spearman p: 0.00
Spearman p: 0.04
Spearman p: 0.40
Spearman p: 0.17
Spearman p: 0.02
days since flush
Spearman p: 0.87
Spearman p: 0.75
Spearman p: 0.82
Spearman p: 0.84
Spearman p: 0.01
Spearman p: 0.90
Precip 1Week
Spearman p: 0.80
Spearman p: 0.84
Spearman p: 0.68
Spearman p: 0.78
Spearman p: 0.00
Spearman p: 0.93
Precip 3Week
Sediment Conc. < 3.9 um N
Sediment Conc. 62.5 to 3.9 um N
Sediment Conc. 250 to 62.5 um N
Sediment Conc. 500 to 250 um N
Sediment Conc. > 500 um N
Sediment Conc. Total N

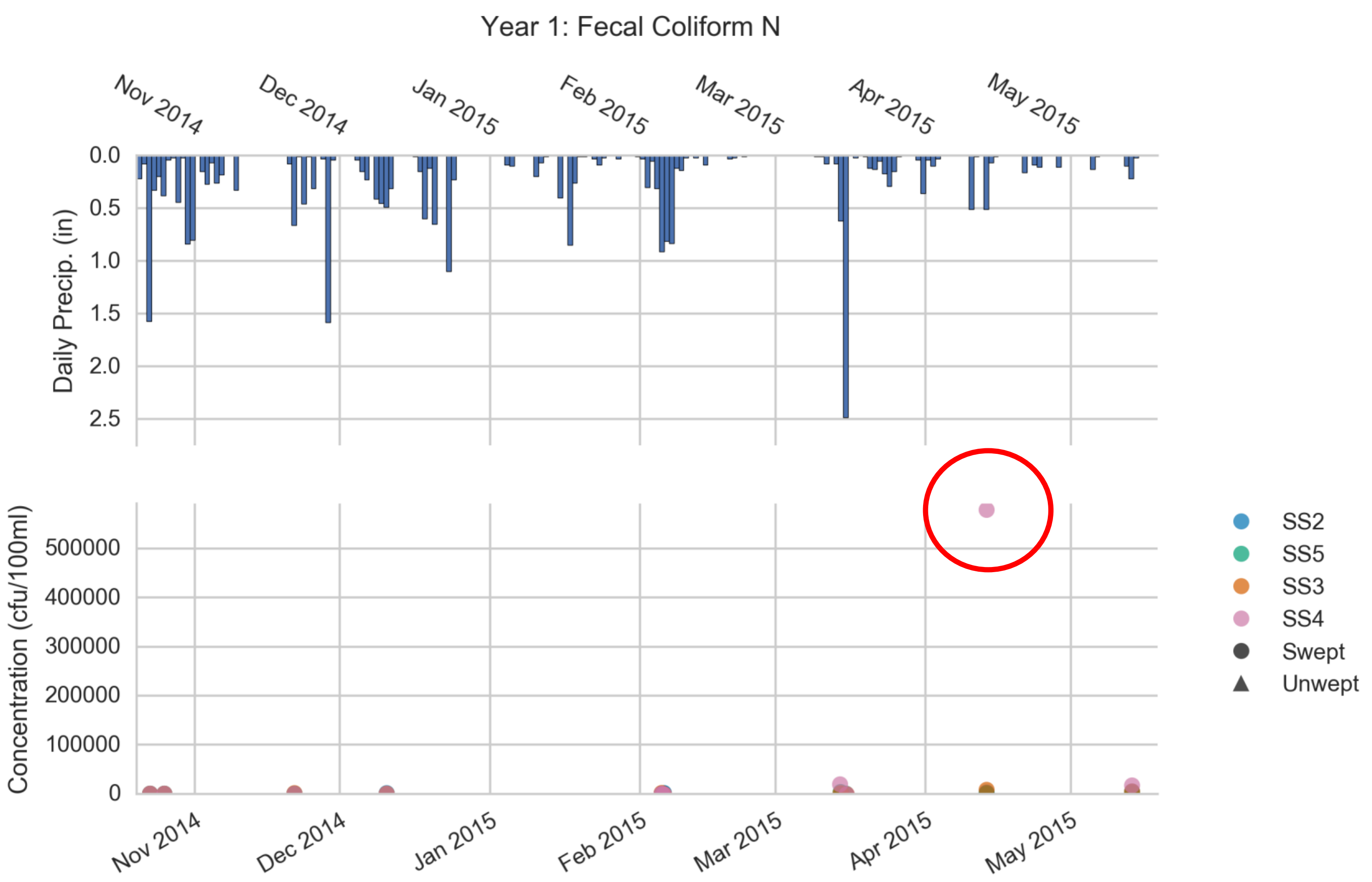

Spearman p: 0.34
Spearman p: 0.79
Spearman p: 0.47
Event Rainfall In
Spearman p: 0.00
Spearman p: 0.49
Spearman p: 1.00
Antecedent Dry Period Days
Spearman p: 0.00
Spearman p: 0.49
Spearman p: 1.00
Days Since Sweep
Spearman p: 0.00
Spearman p: 0.49
Spearman p: 1.00
days since flush
Spearman p: 0.34
Spearman p: 0.32
Spearman p: 0.47
Precip 1Week
Spearman p: 0.34
Spearman p: 0.79
Spearman p: 0.47
Precip 3Week
Fecal Coliform N
Fluoranthene N
Pyrene N

Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.01
Spearman p: 0.28
Spearman p: 0.44
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.07
Spearman p: 0.01
Spearman p: 0.00
Event Rainfall In
Spearman p: 0.46
Spearman p: 0.00
Spearman p: 0.11
Spearman p: 0.15
Spearman p: 0.15
Spearman p: 0.58
Spearman p: 0.23
Spearman p: 0.01
Spearman p: 0.06
Spearman p: 0.82
Spearman p: 0.18
Spearman p: 0.26
Antecedent Dry Period Days
Spearman p: 0.00
Spearman p: 0.39
Spearman p: 0.02
Spearman p: 0.03
Spearman p: 0.14
Spearman p: 0.30
Spearman p: 0.01
Spearman p: 0.55
Spearman p: 0.17
Spearman p: 0.00
Spearman p: 0.05
Spearman p: 0.02
Days Since Sweep
Spearman p: 0.46
Spearman p: 0.00
Spearman p: 0.11
Spearman p: 0.15
Spearman p: 0.15
Spearman p: 0.58
Spearman p: 0.23
Spearman p: 0.01
Spearman p: 0.06
Spearman p: 0.82
Spearman p: 0.18
Spearman p: 0.26
days since flush
Spearman p: 0.27
Spearman p: 0.00
Spearman p: 0.23
Spearman p: 0.33
Spearman p: 0.05
Spearman p: 0.06
Spearman p: 0.80
Spearman p: 0.00
Spearman p: 0.00
Spearman p: 0.26
Spearman p: 0.46
Spearman p: 0.41
Precip 1Week
Spearman p: 0.72
Spearman p: 0.32
Spearman p: 0.90
Spearman p: 0.95
Spearman p: 0.29
Spearman p: 0.82
Spearman p: 0.83
Spearman p: 0.64
Spearman p: 0.82
Spearman p: 0.58
Spearman p: 0.99
Spearman p: 0.70
Precip 3Week
Total Organic Carbon N
Nitrate + Nitrite N
Copper T
Zinc T
Solids, Total Suspended N
Nitrogen, Total Kjeldahl N
Chemical Oxygen Demand N
Copper D
Zinc D
Phosphorus, Total N
Zinc P
Copper P

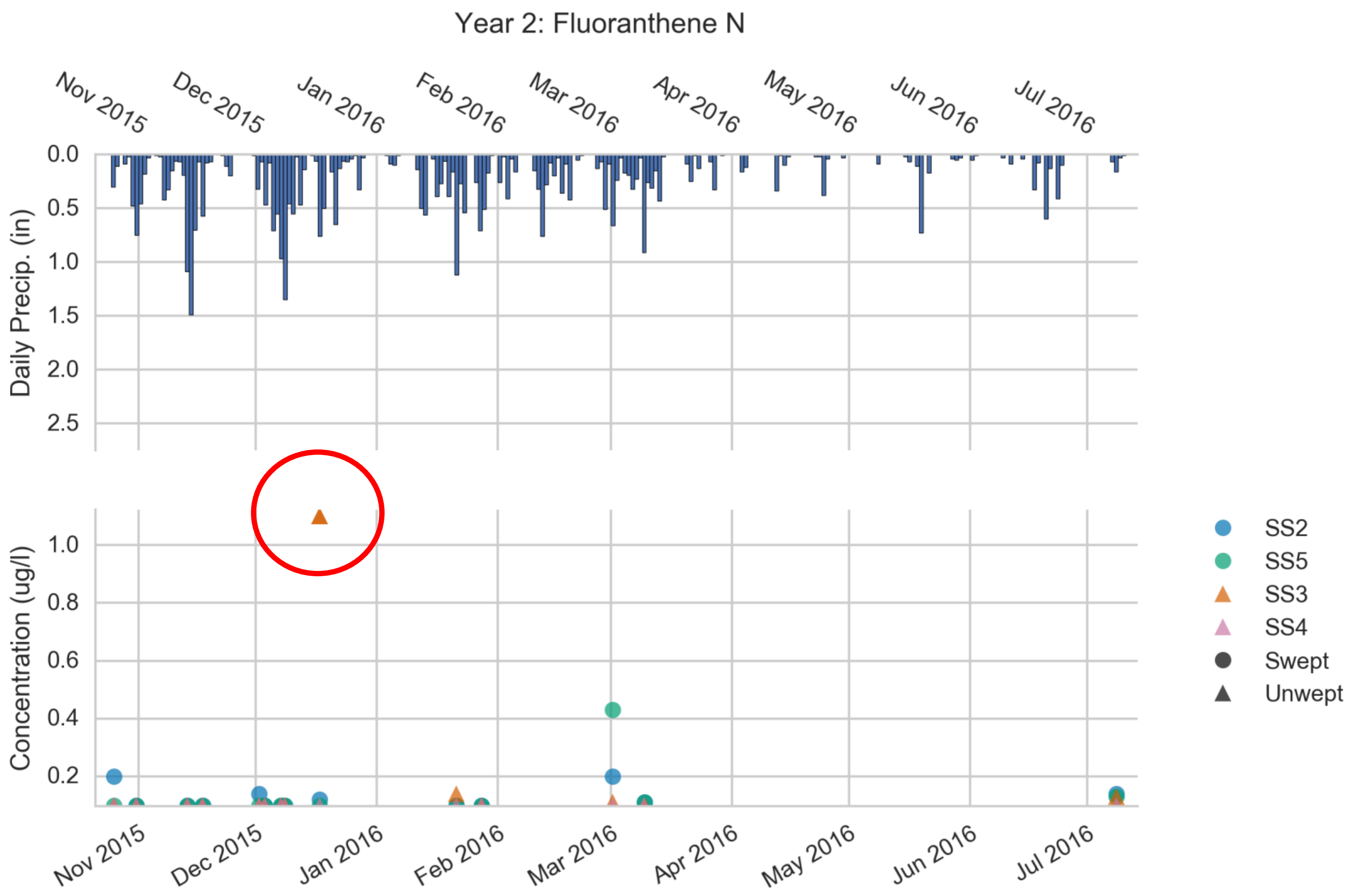

Spearman p: 0.44
Spearman p: 0.52
Spearman p: 0.76
Spearman p: 0.93
Spearman p: 0.91
Spearman p: 0.73
Event Rainfall In
Spearman p: 0.77
Spearman p: 0.23
Spearman p: 0.38
Spearman p: 0.62
Spearman p: 0.97
Spearman p: 0.86
Antecedent Dry Period Days
Spearman p: 0.71
Spearman p: 0.34
Spearman p: 0.06
Spearman p: 0.27
Spearman p: 0.66
Spearman p: 0.54
Days Since Sweep
Spearman p: 0.77
Spearman p: 0.23
Spearman p: 0.38
Spearman p: 0.62
Spearman p: 0.97
Spearman p: 0.86
days since flush
Spearman p: 0.44
Spearman p: 0.08
Spearman p: 0.72
Spearman p: 0.91
Spearman p: 0.62
Spearman p: 0.62
Precip 1Week
Spearman p: 0.45
Spearman p: 0.05
Spearman p: 0.59
Spearman p: 0.85
Spearman p: 0.94
Spearman p: 0.80
Precip 3Week
Sediment Conc. < 3.9 um N
Sediment Conc. 62.5 to 3.9 um N
Sediment Conc. 250 to 62.5 um N
Sediment Conc. 500 to 250 um N
Sediment Conc. > 500 um N
Sediment Conc. Total N

Attachment 2

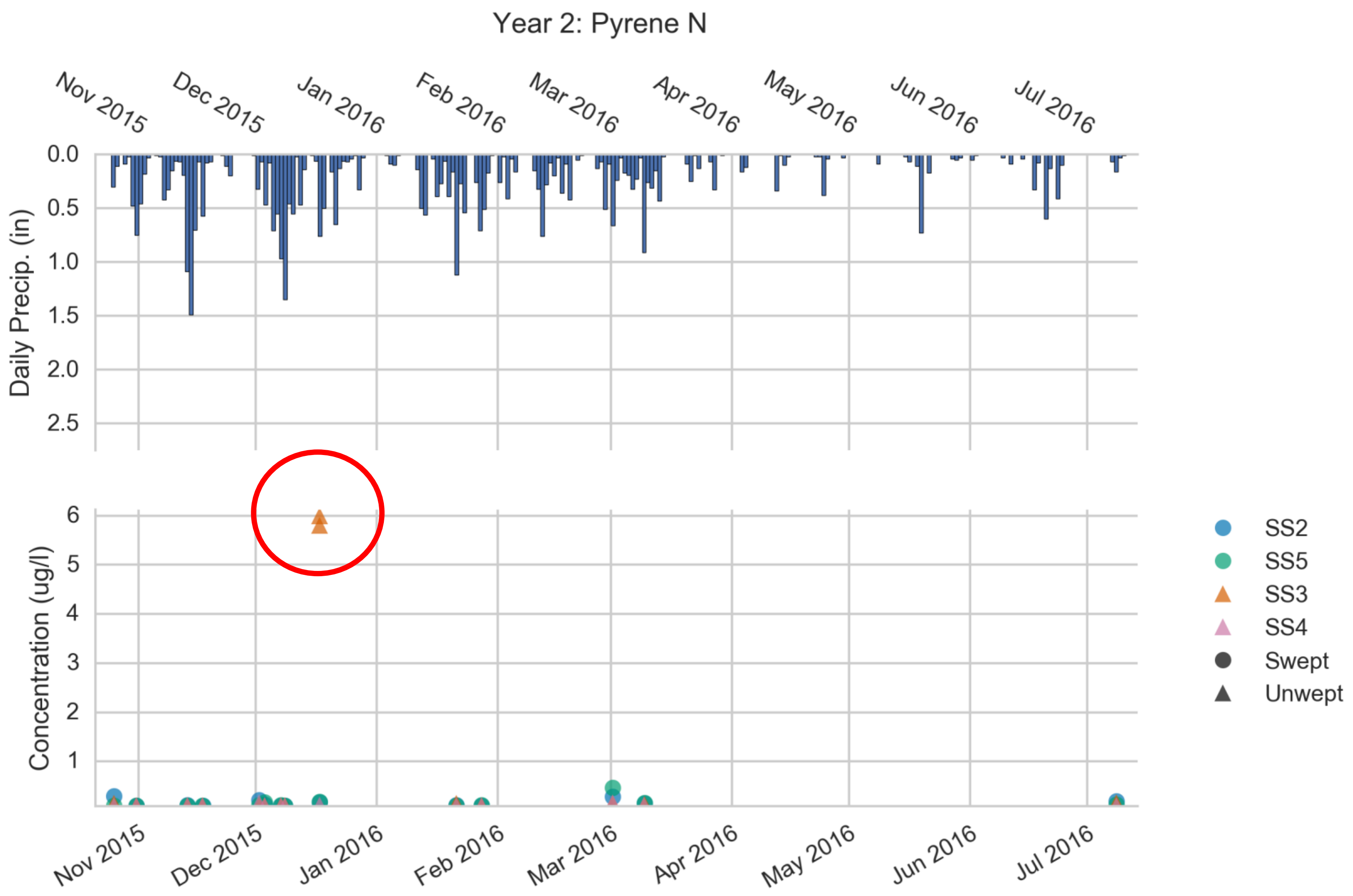
Outlier Evaluation



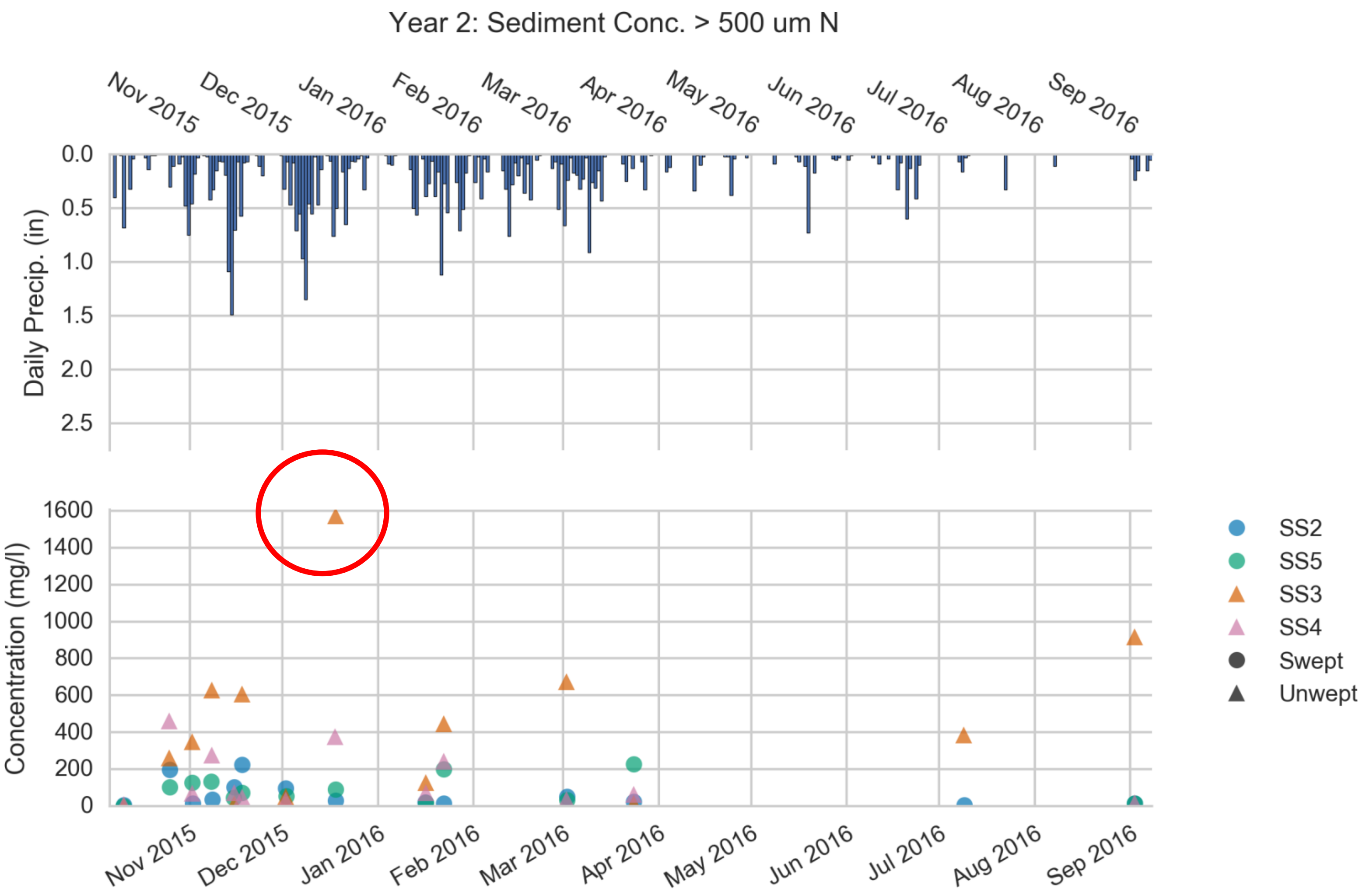
This was removed. The value of this point is 580,000. The next highest value is 20,000.



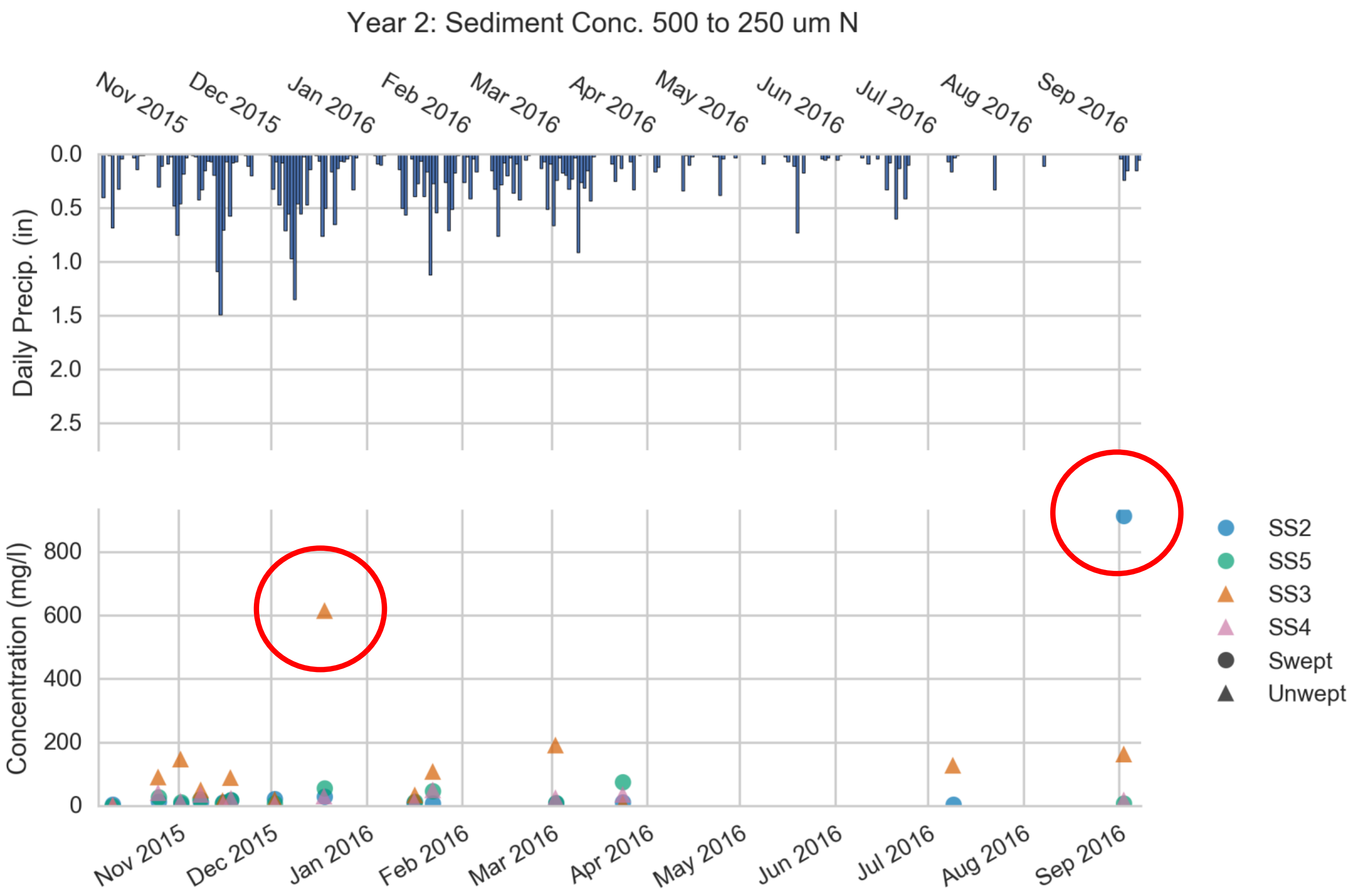
This point was evaluated but not removed. During the same event, this site also had elevated pyrene at both unswept sites.



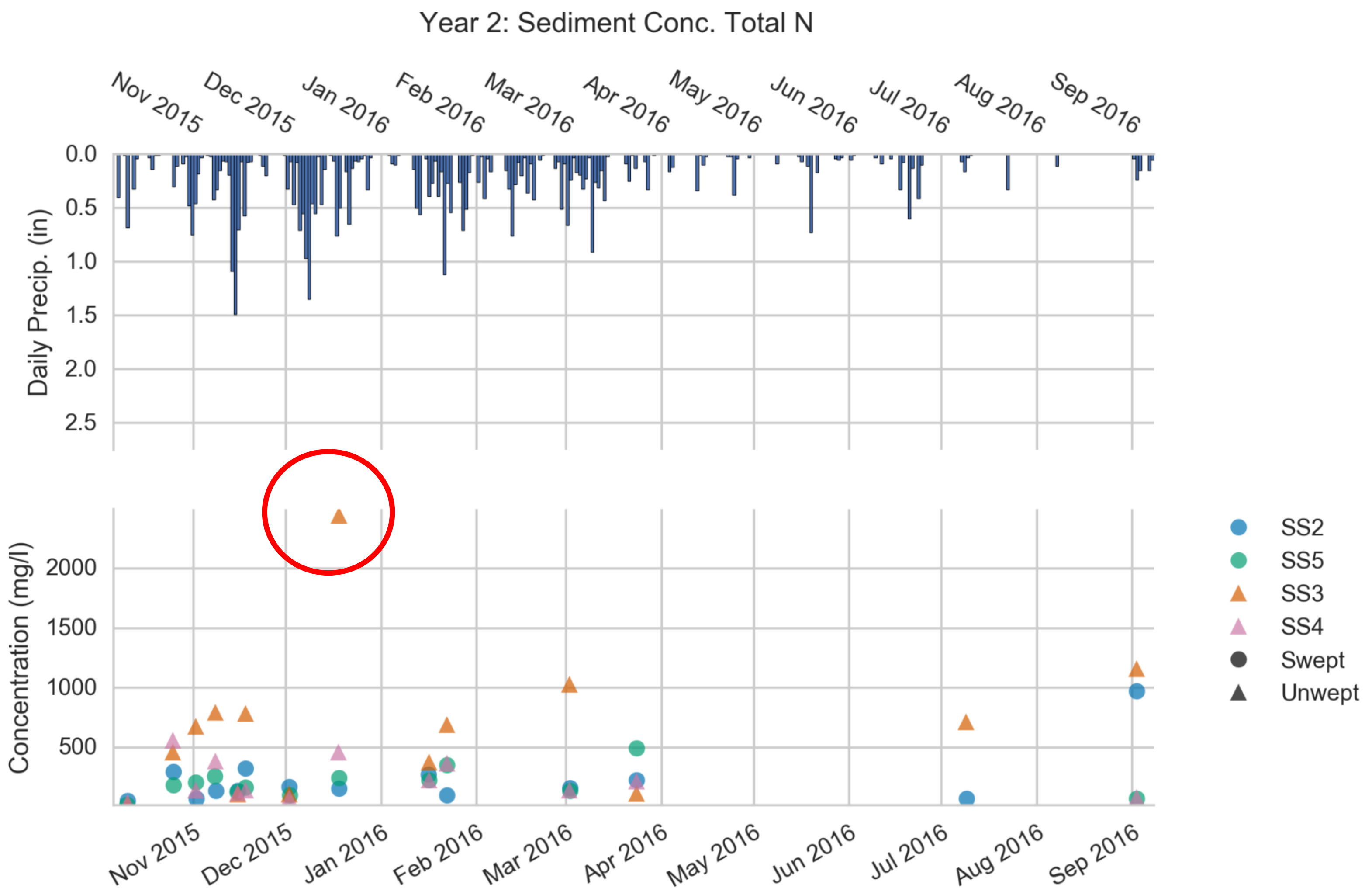
These points were evaluated but not removed. Elevated pyrene occurred at both unswept sites. Similarly, elevate fluoranthene was observed during the same event.



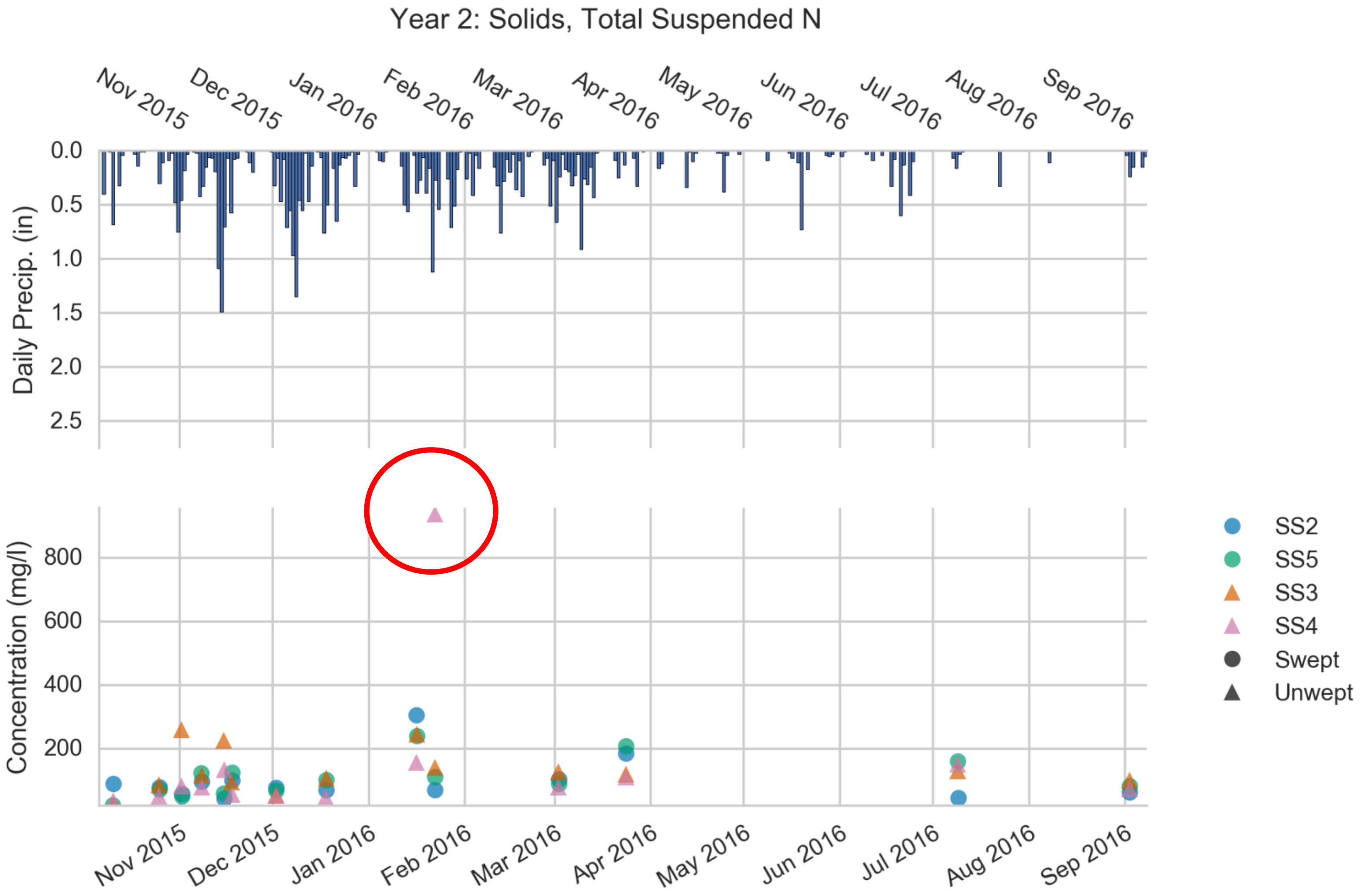
This point was evaluated but not removed. It is not more than two standard deviations away from the remainder of the data. Additionally, when inspecting the total sediment concentration, these points do not contribute to unreasonable variability.



These points were evaluated but not removed. When inspecting the total sediment concentration (next page), these points doe not contribute to unreasonable variability.



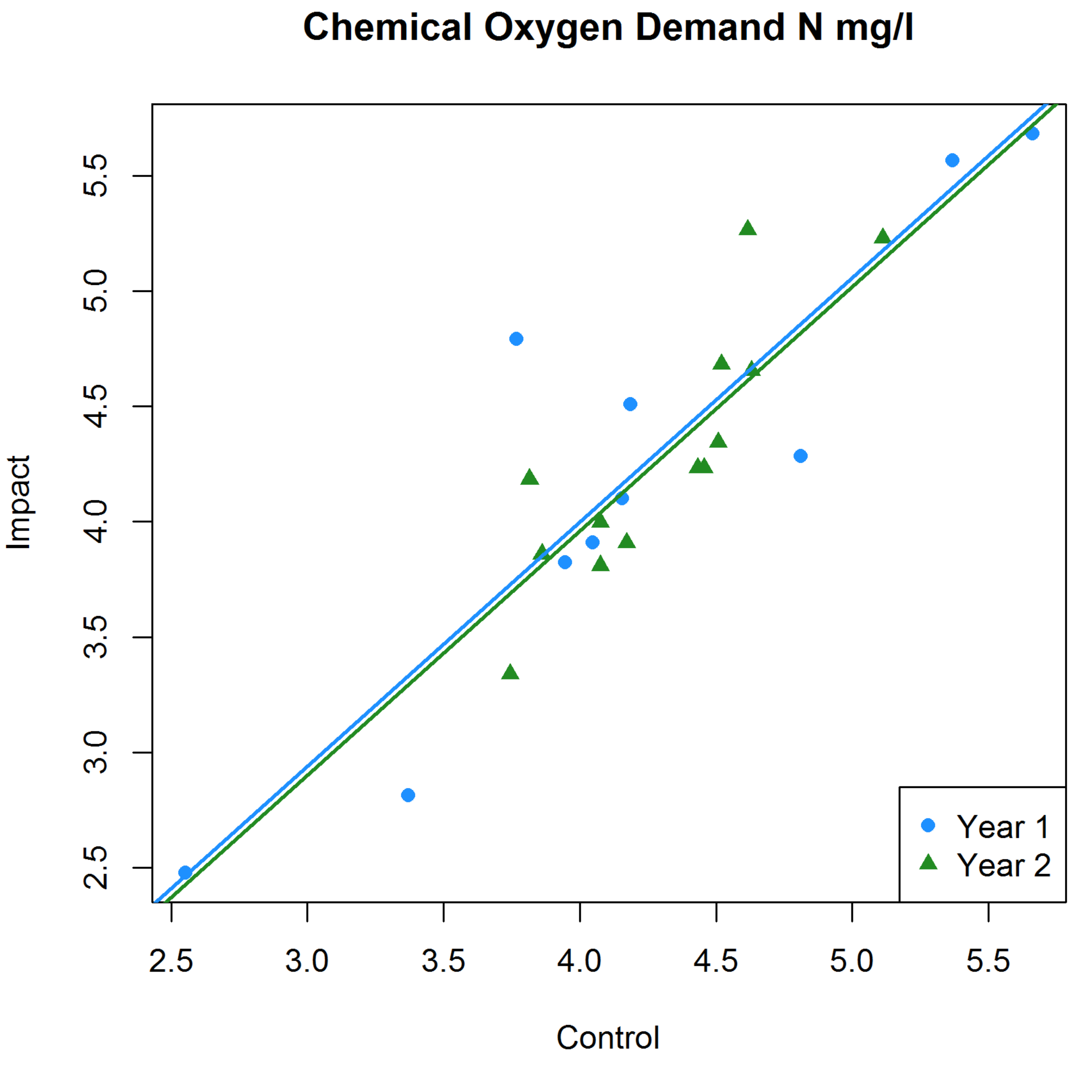
This point was evaluated but not removed. It is not more than two standard deviations away from the remainder of the data.



This point was evaluated but not removed. It is not more than two standard deviations away from the remainder of the data.

Attachment 3a

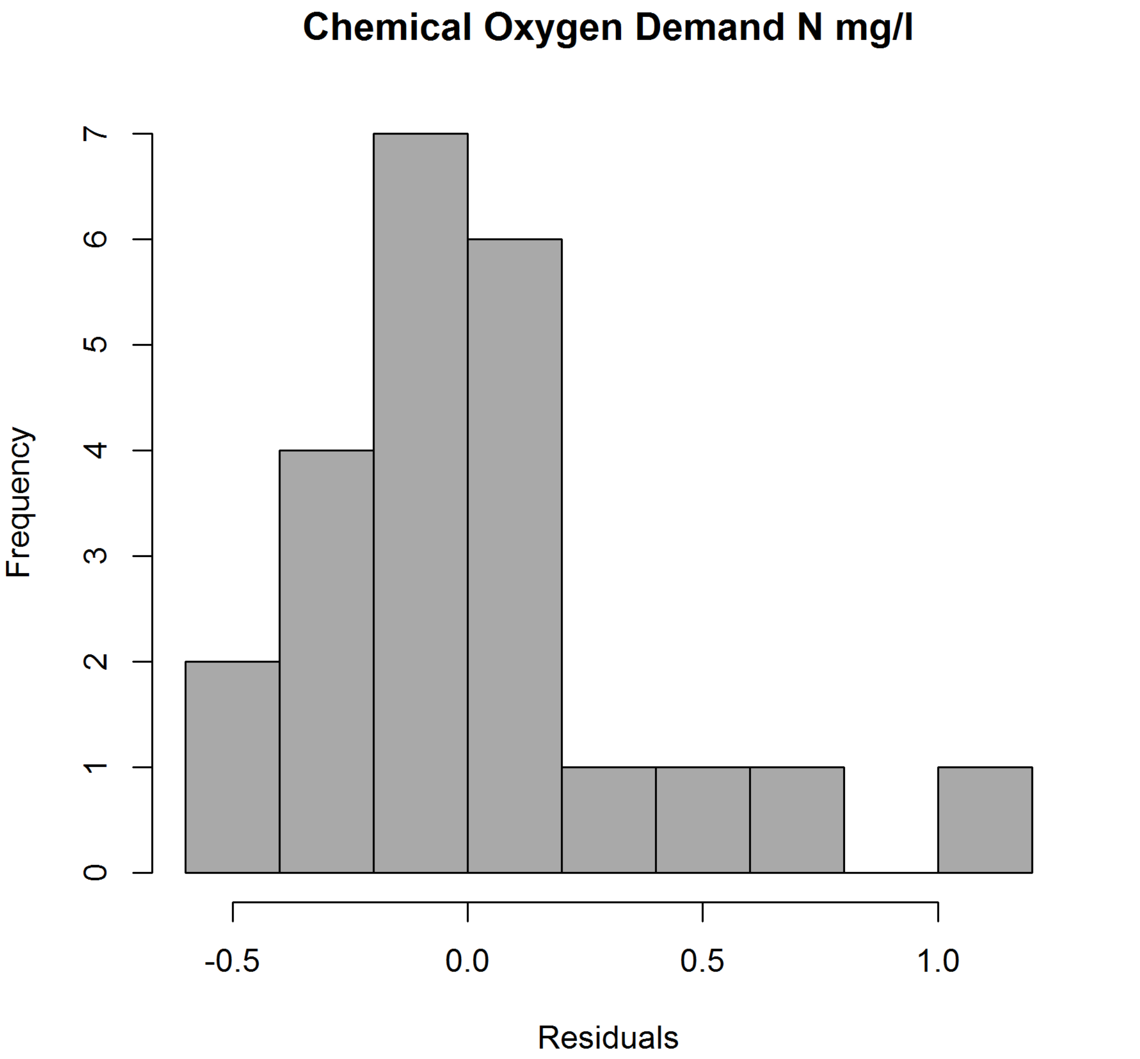
ANCOVA Pooled Impact



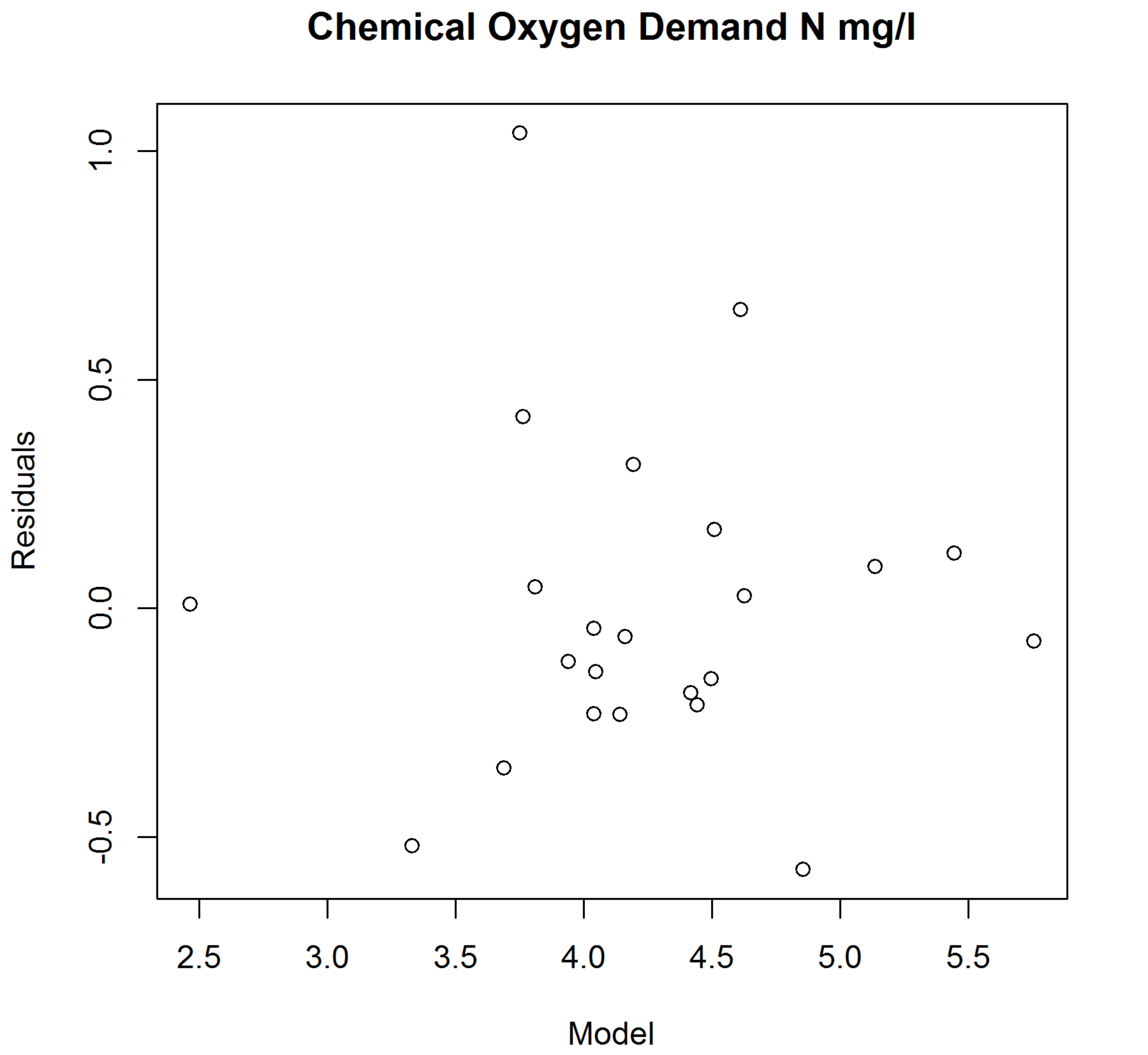
Chemical Oxygen Demand N mg/l
Impact
Control
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Year 1
Year 2

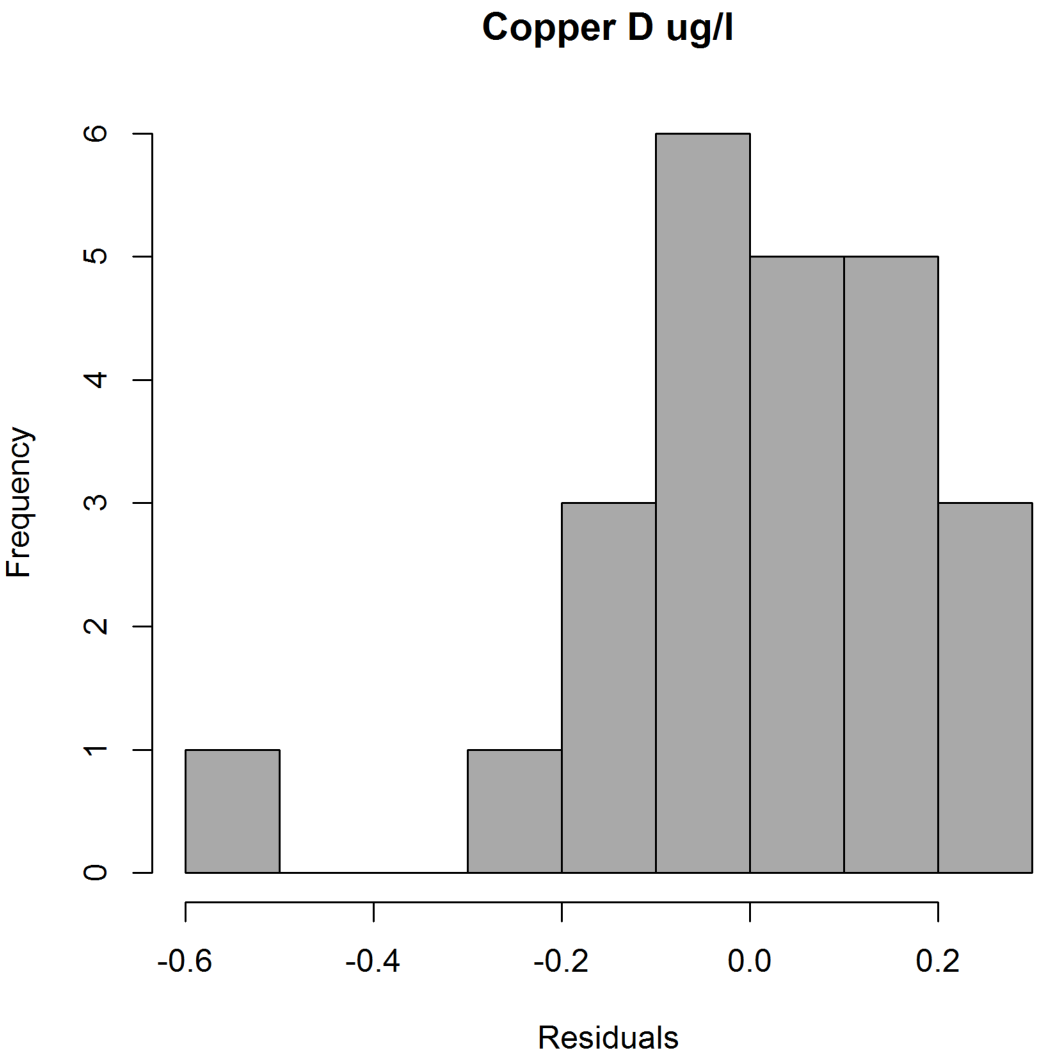
Attachment 3b

ANCOVA SS3 Impact

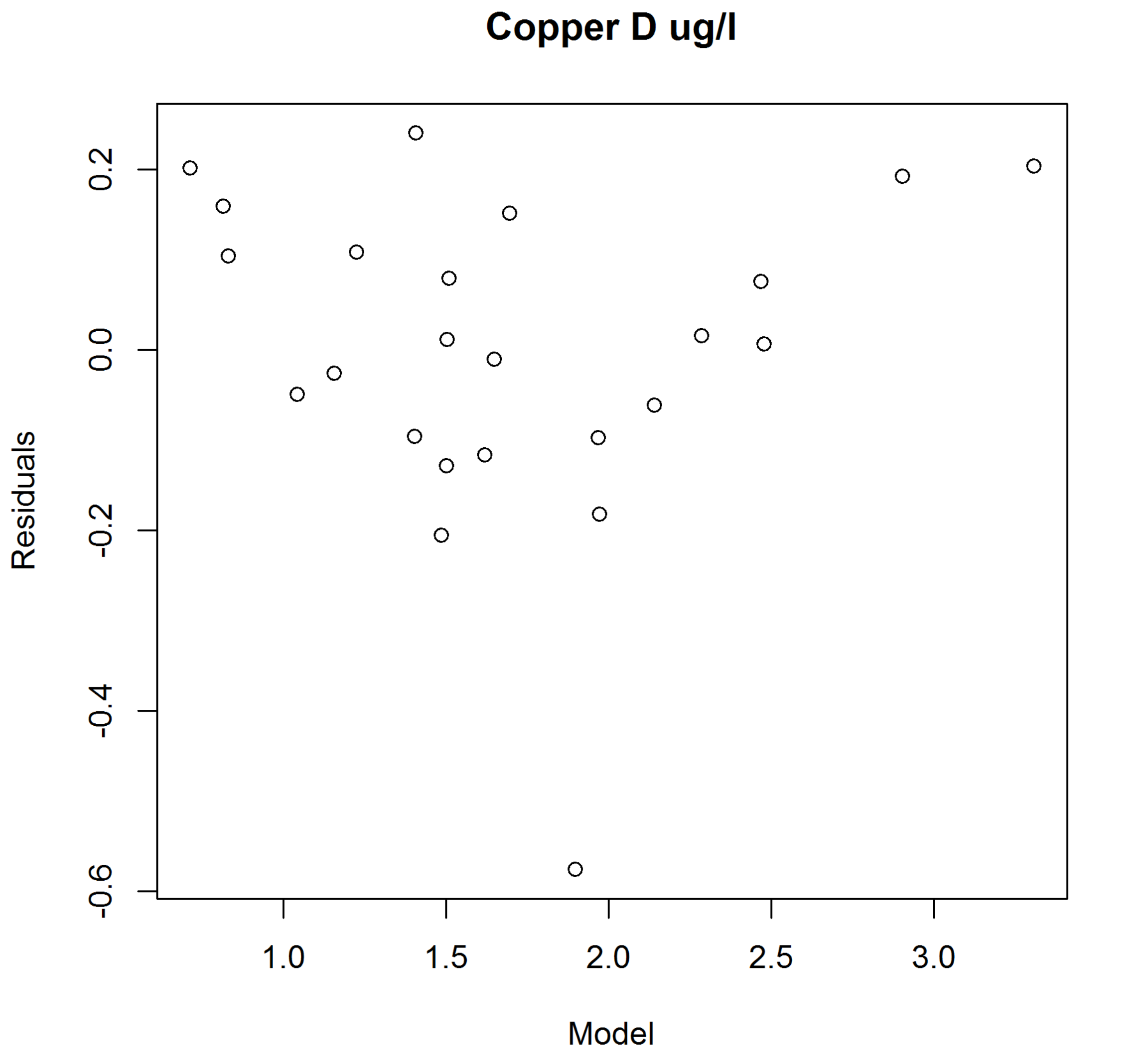


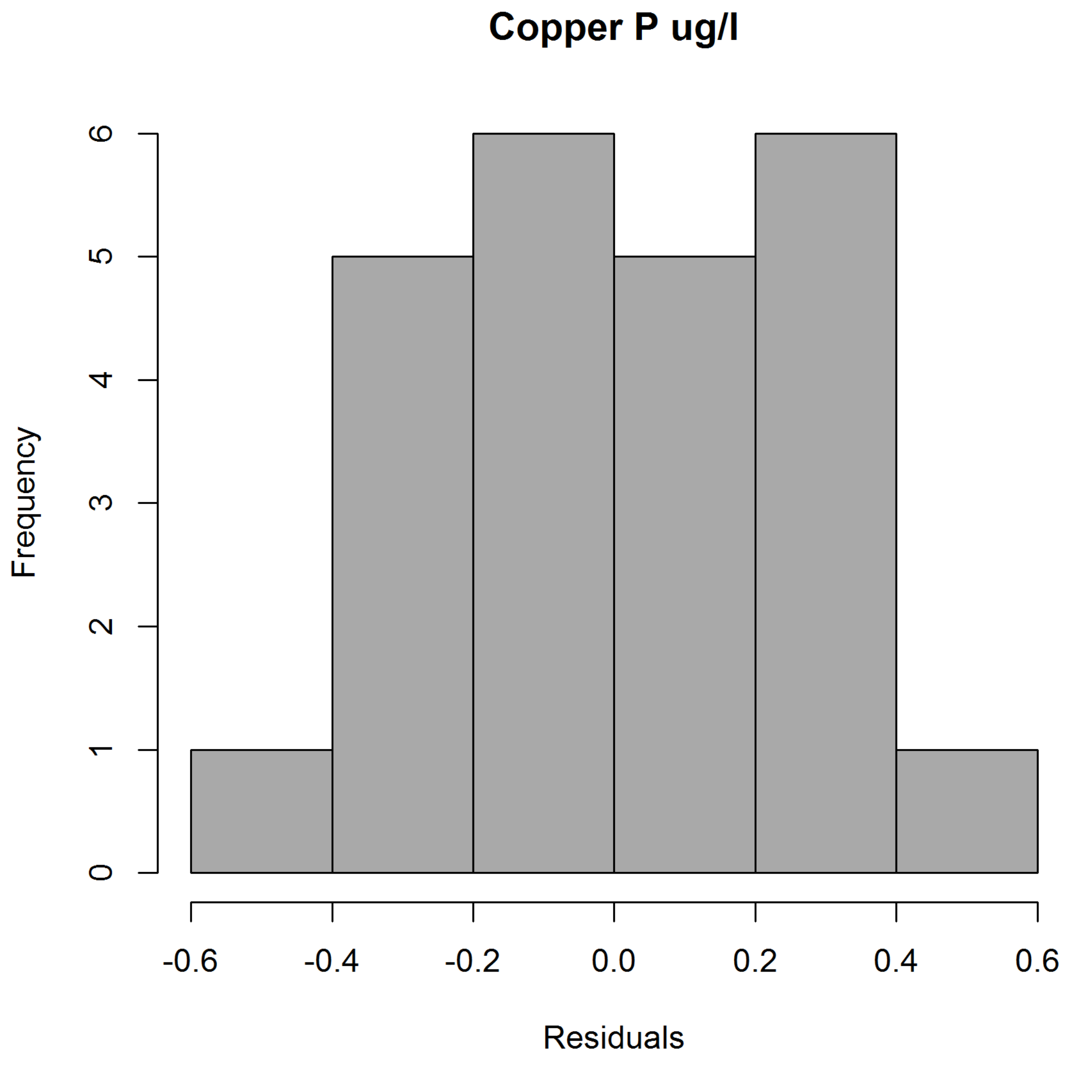
Chemical Oxygen Demand N mg/l
Frequency
0
1
2
3
4
5
6
7
-0.5
0.0
0.5
1.0
Residuals


Chemical Oxygen Demand N mg/l
Residuals
-0.5
0.0
0.5
1.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Model

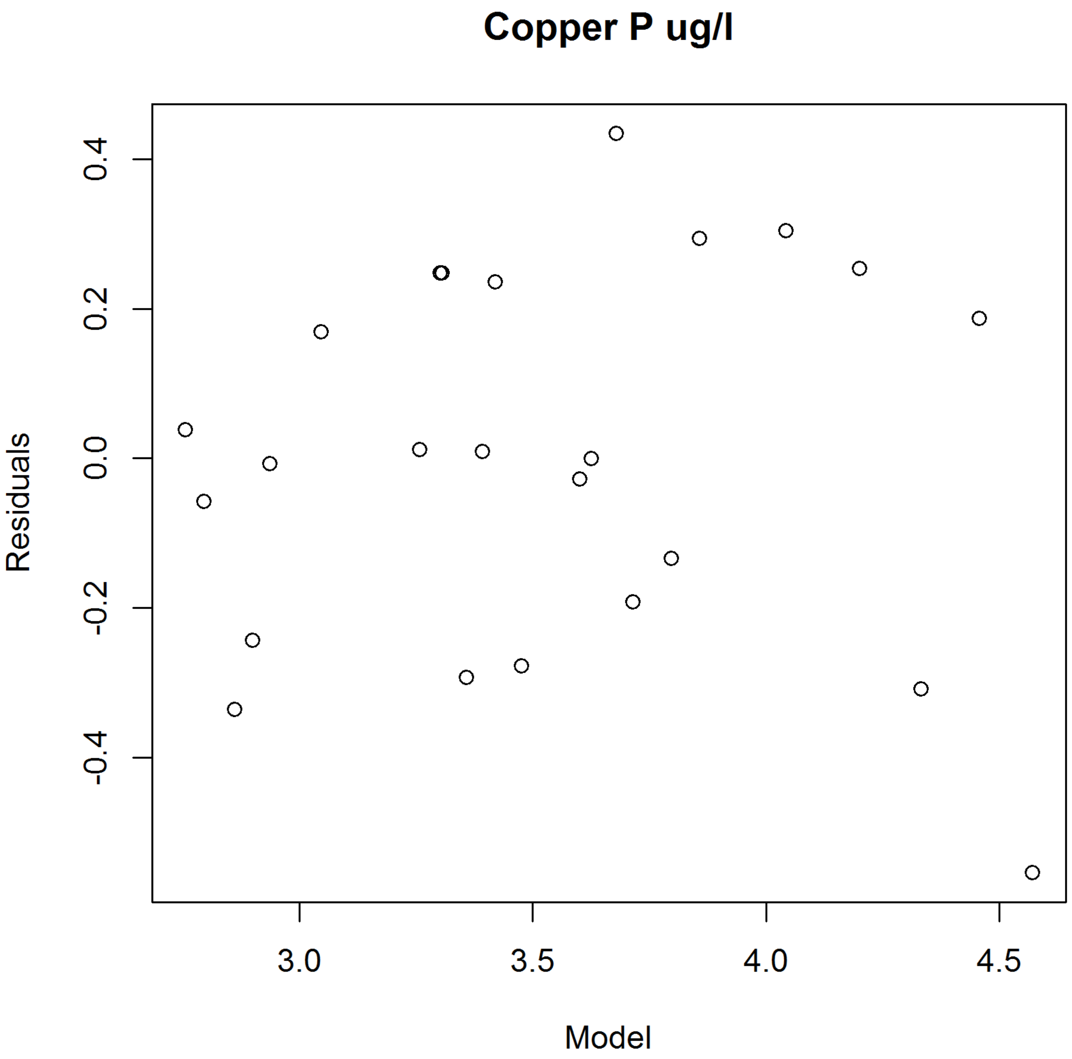


Copper D ug/l
Frequency
0
1
2
3
4
5
6
-0.6
-0.4
-0.2
0.0
0.2
Residuals

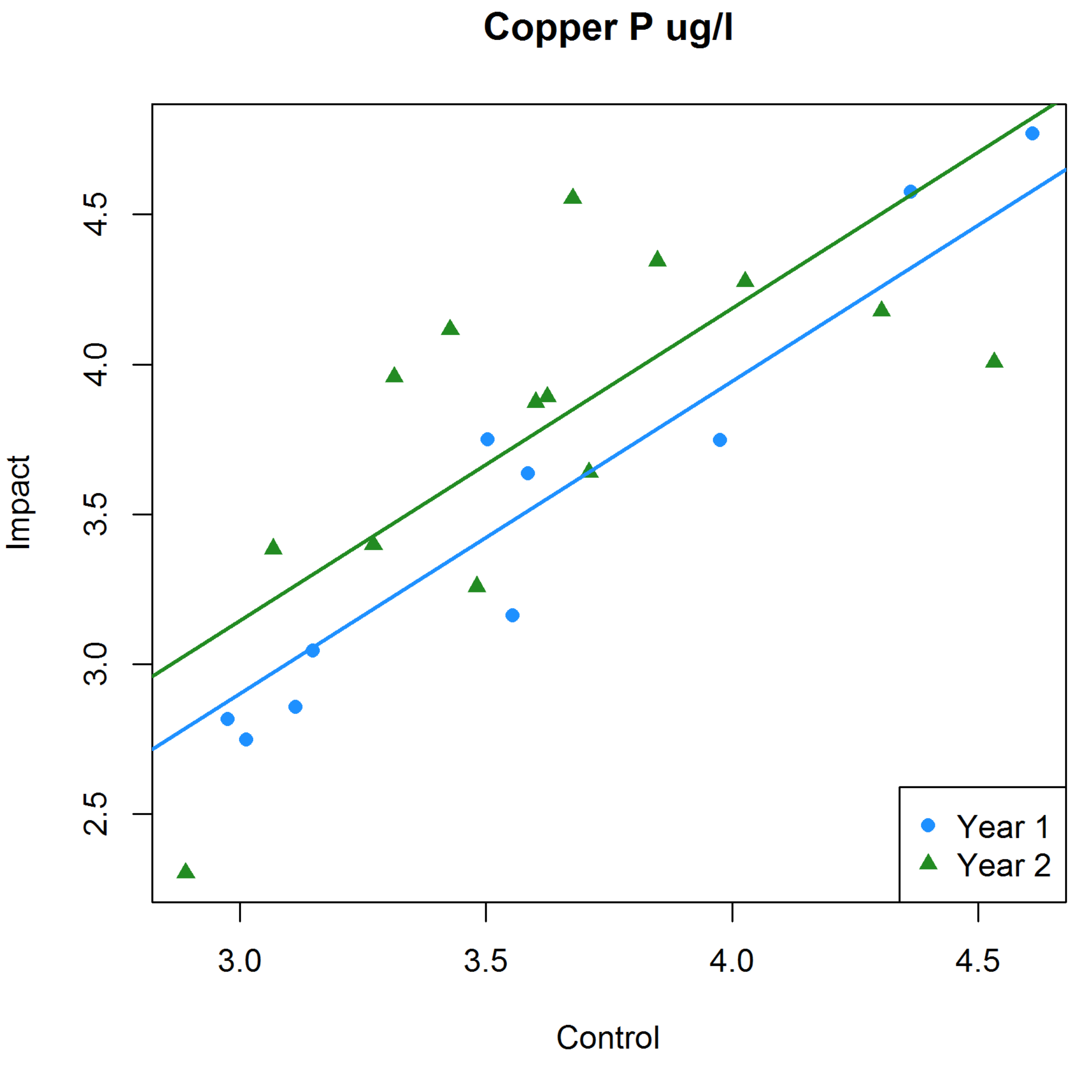

Copper D ug/l
Residuals
Model
0.2
0.0
-0.2
-0.4
-0.6
1.0
1.5
2.0
2.5
3.0



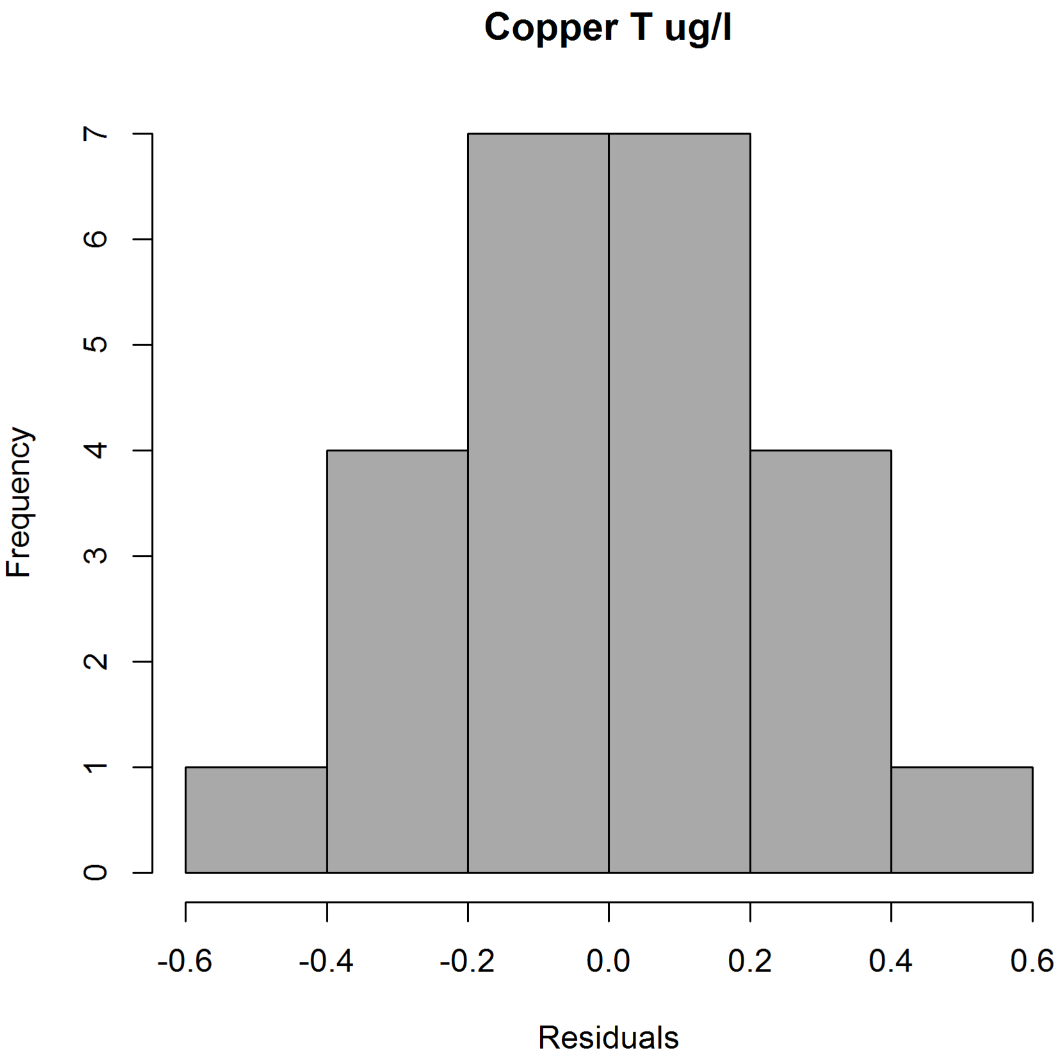
Copper P ug/l
Frequency
0
1
2
3
4
5
6
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
Residuals



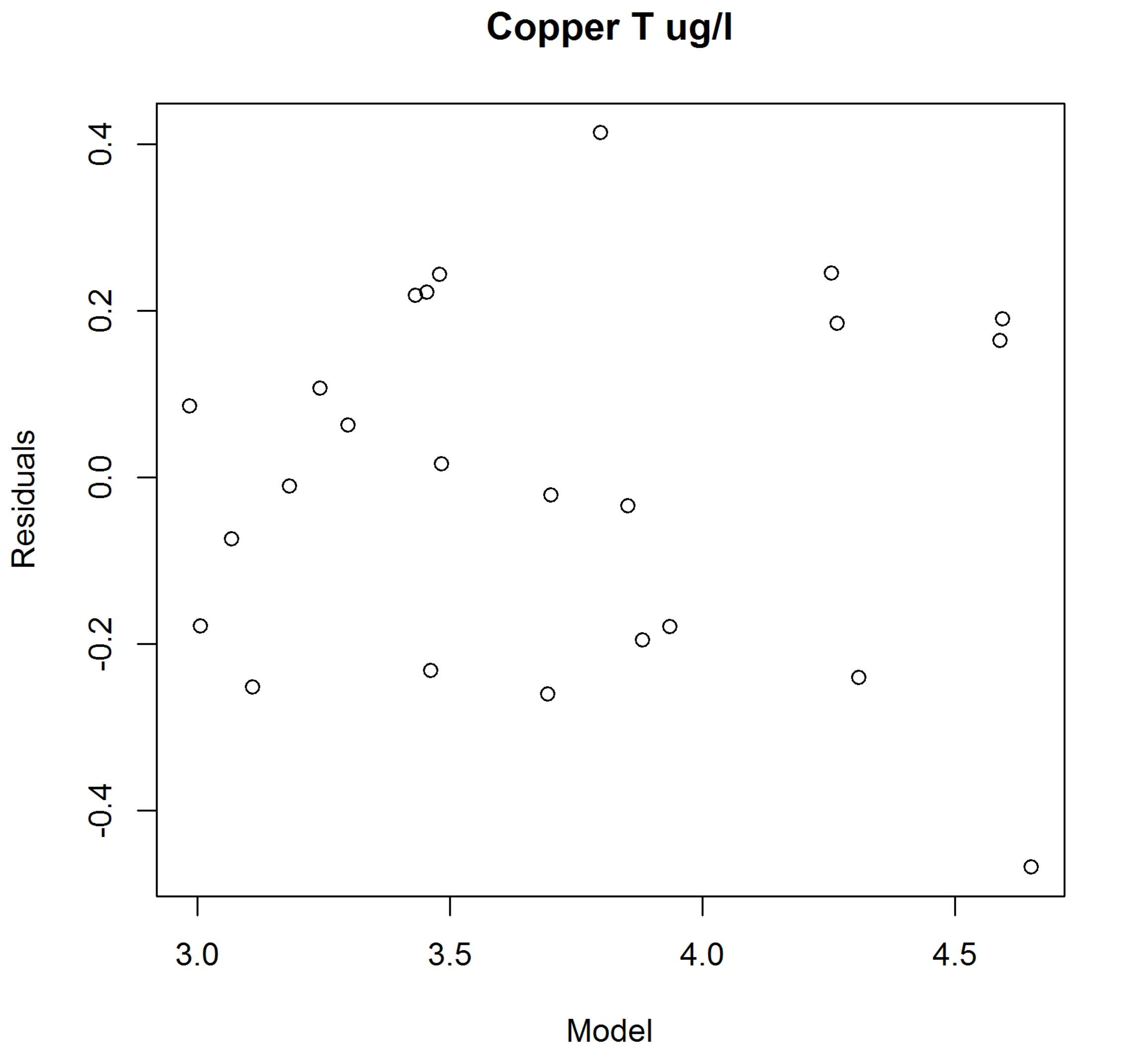
Copper P ug/l
Residuals
Model
0.4
0.2
0.0
-0.2
-0.4
3.0
3.5
4.0
4.5

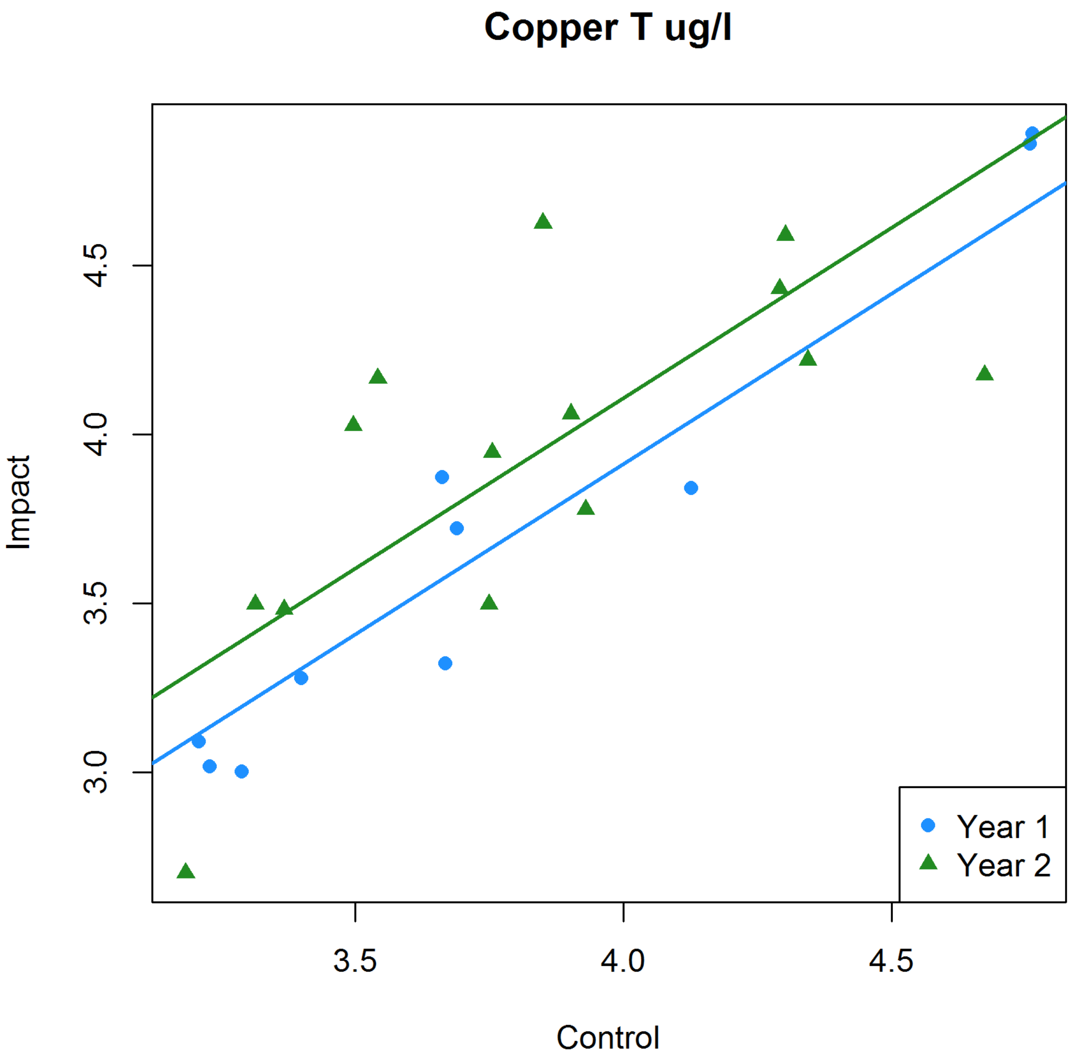


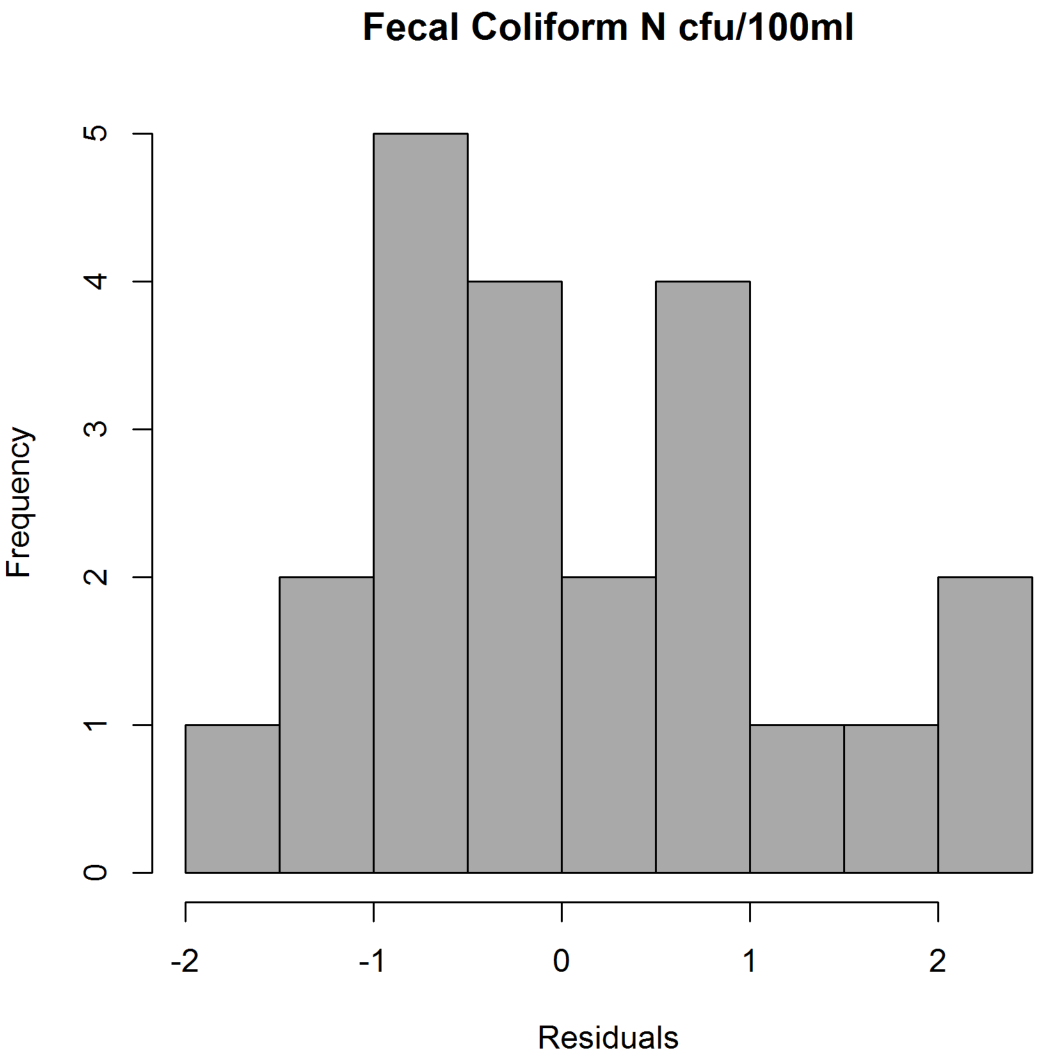
Copper P ug/l
Impact
Control
4.5
4.0
3.5
3.0
2.5
3.0
3.5
4.0
4.5
Year 1
Year 2



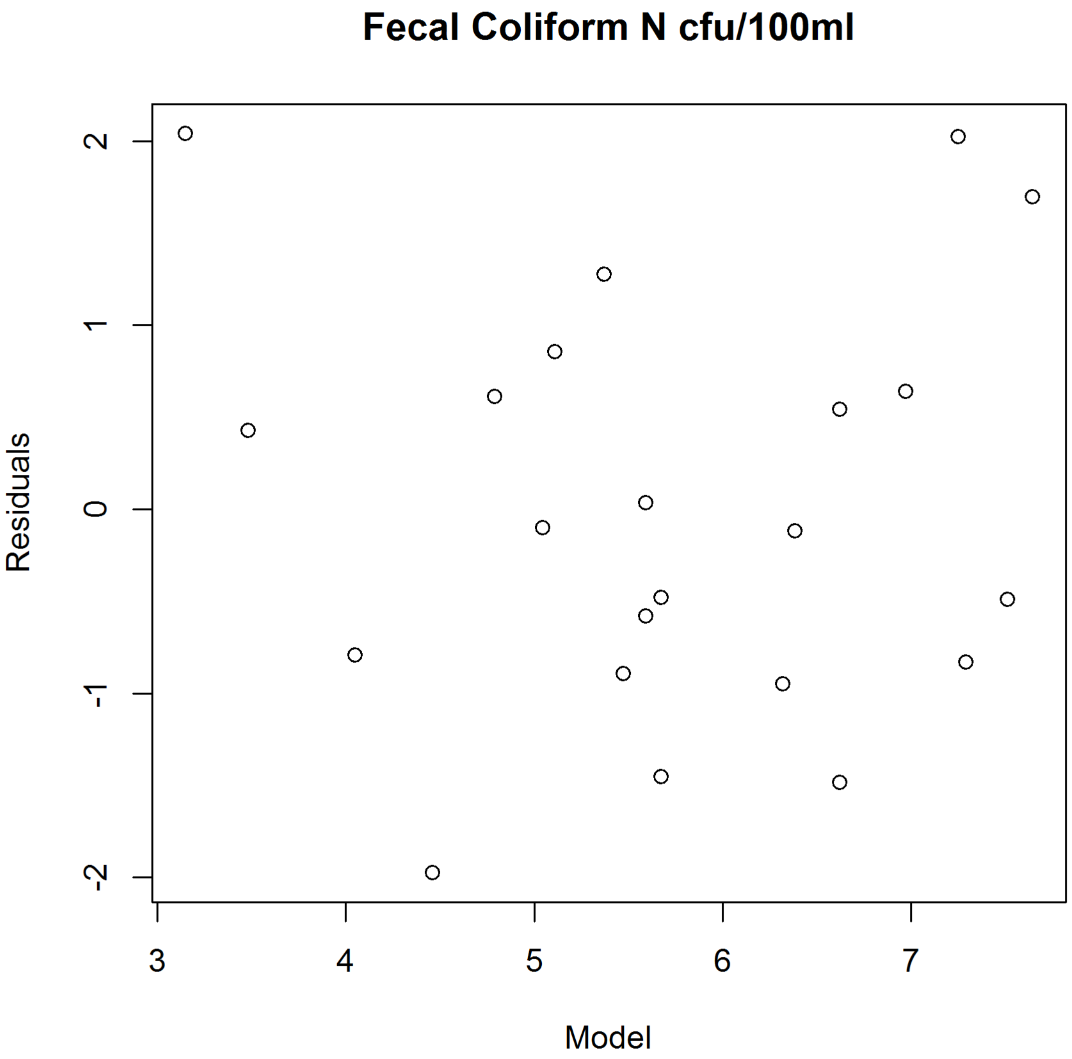
Copper T ug/l
Frequency
Residuals
0
1
2
3
4
5
6
7
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6

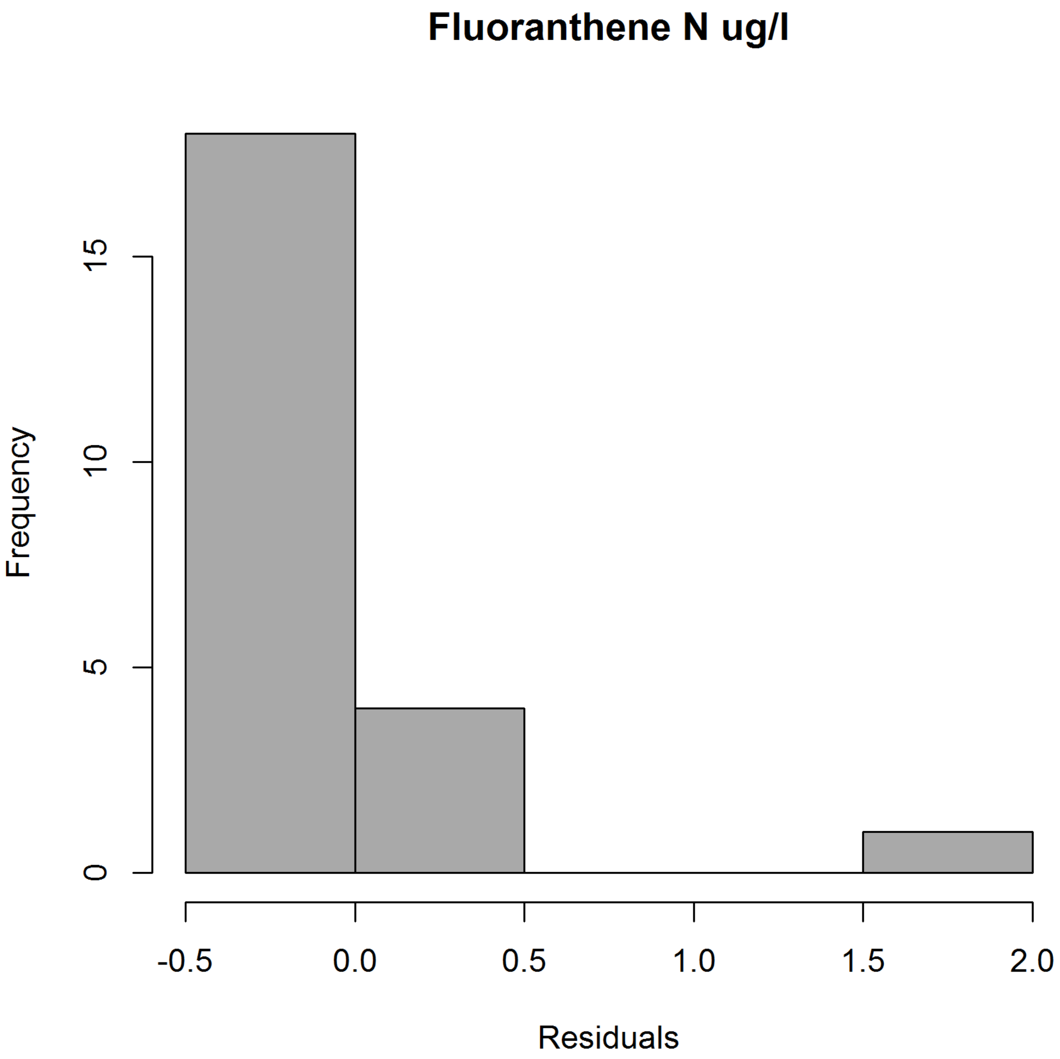

Copper T ug/l
Residuals
Model
0.4
0.2
0.0
-0.2
-0.4
3.0
3.5
4.0
4.5

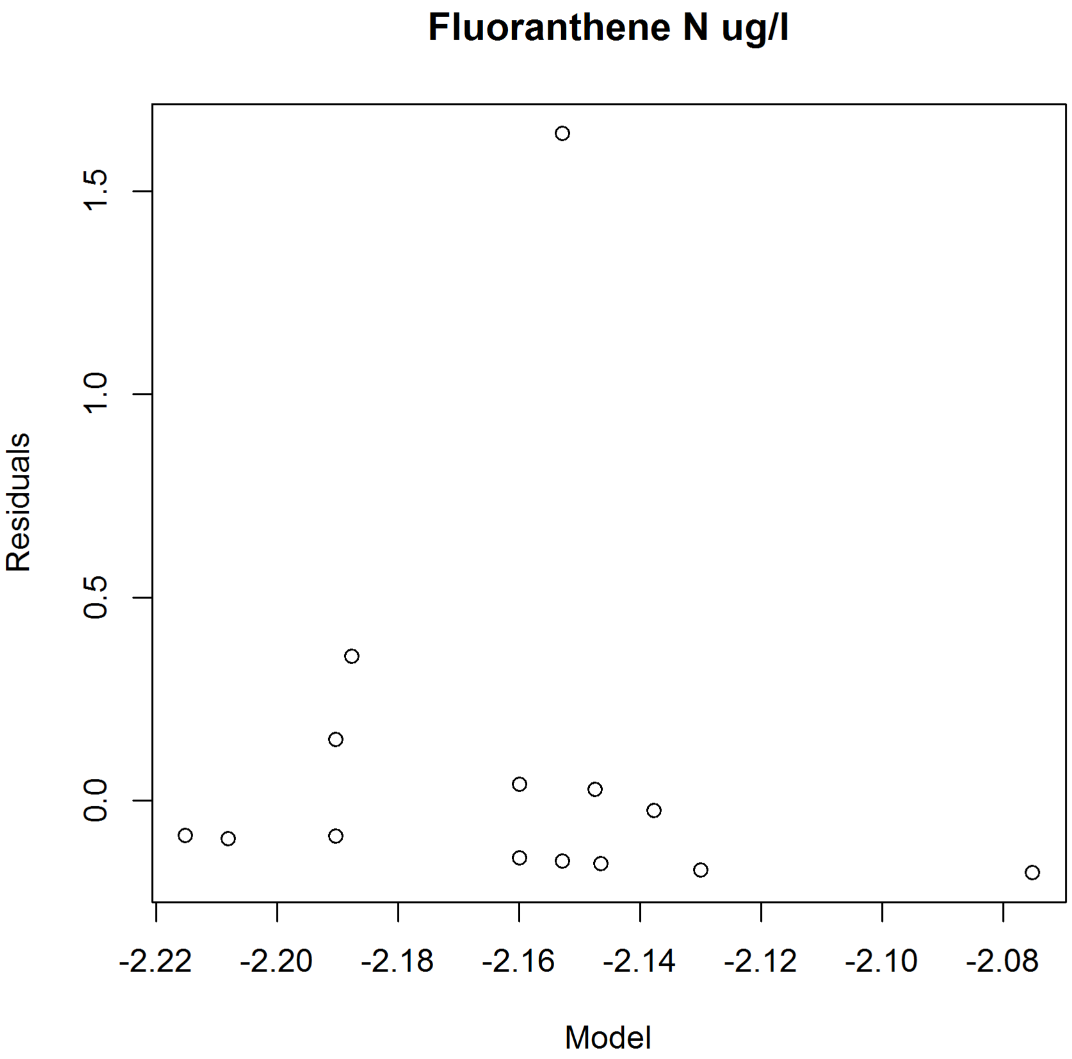

Copper T ug/l
Impact
Control
3.0
3.5
4.0
4.5
3.5
4.0
4.5
Year 1
Year 2



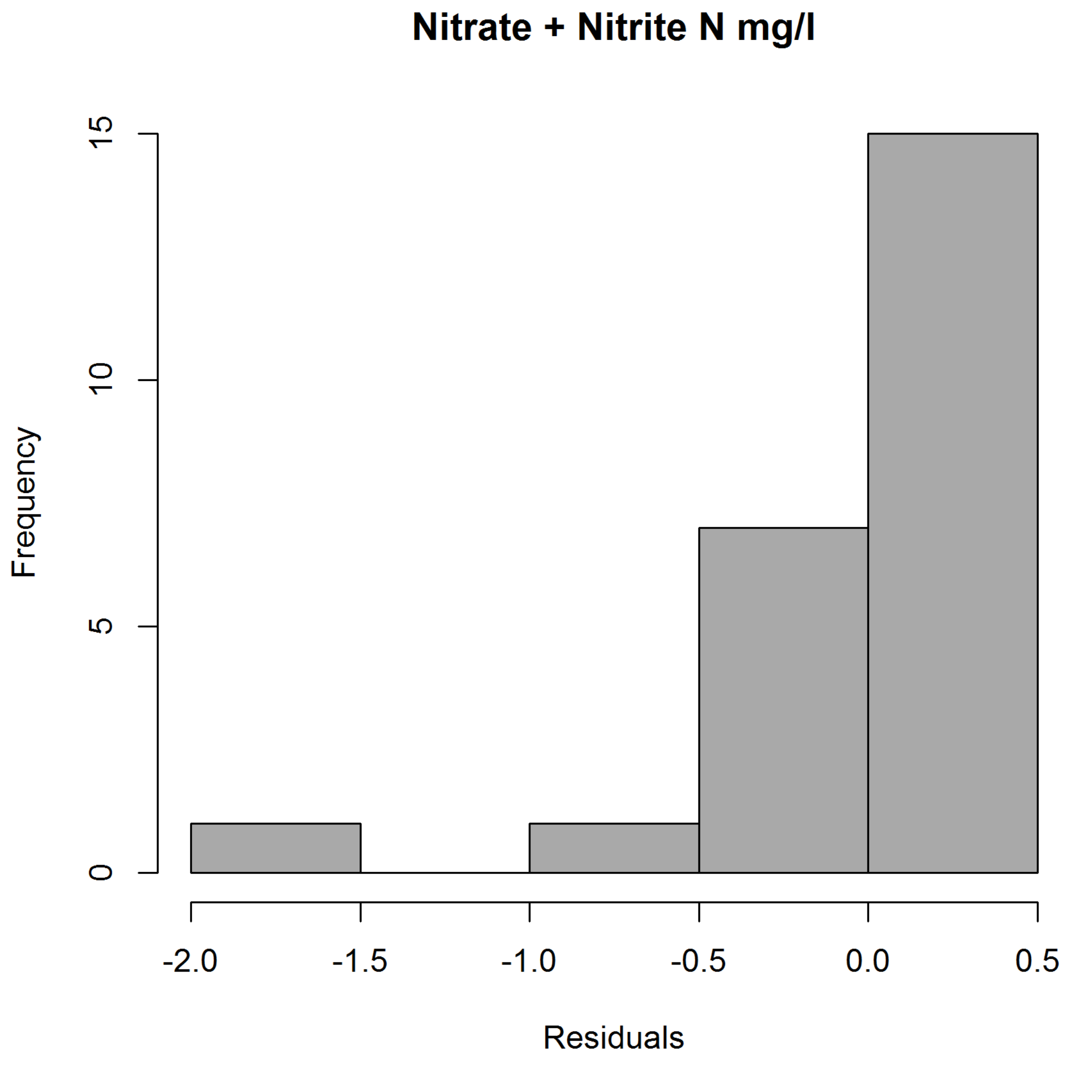
Fecal Coliform N cfu/100ml
Frequency
0
1
2
3
4
5
-2
-1
0
1
2
Residuals


Fecal Coliform N cfu/100ml
Residuals
Model
2
1
0
-1
-2
3
4
5
6
7

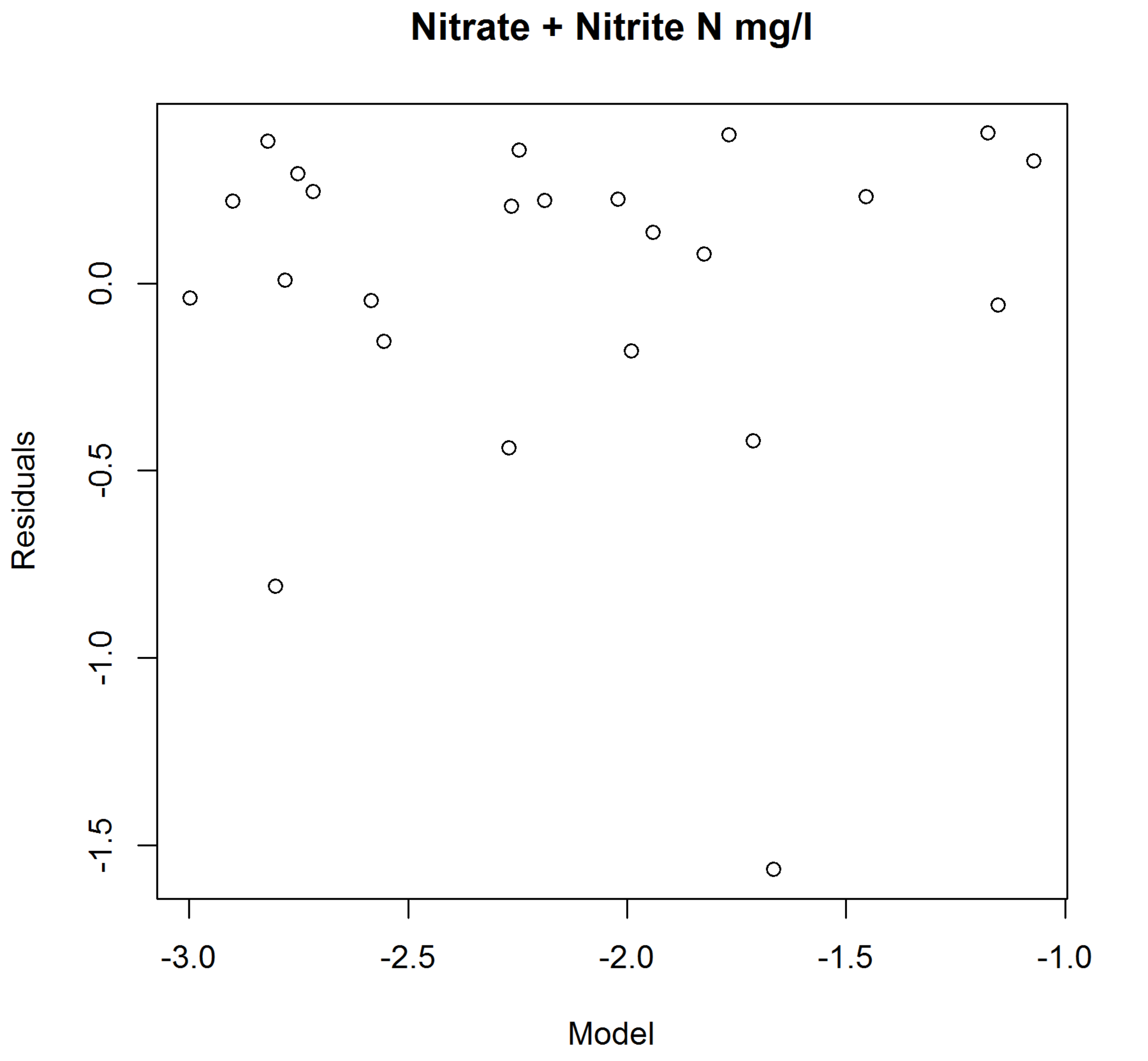

Fluoranthene N ug/l
Frequency
0
5
10
15
-0.5
0.0
0.5
1.0
1.5
2.0
Residuals



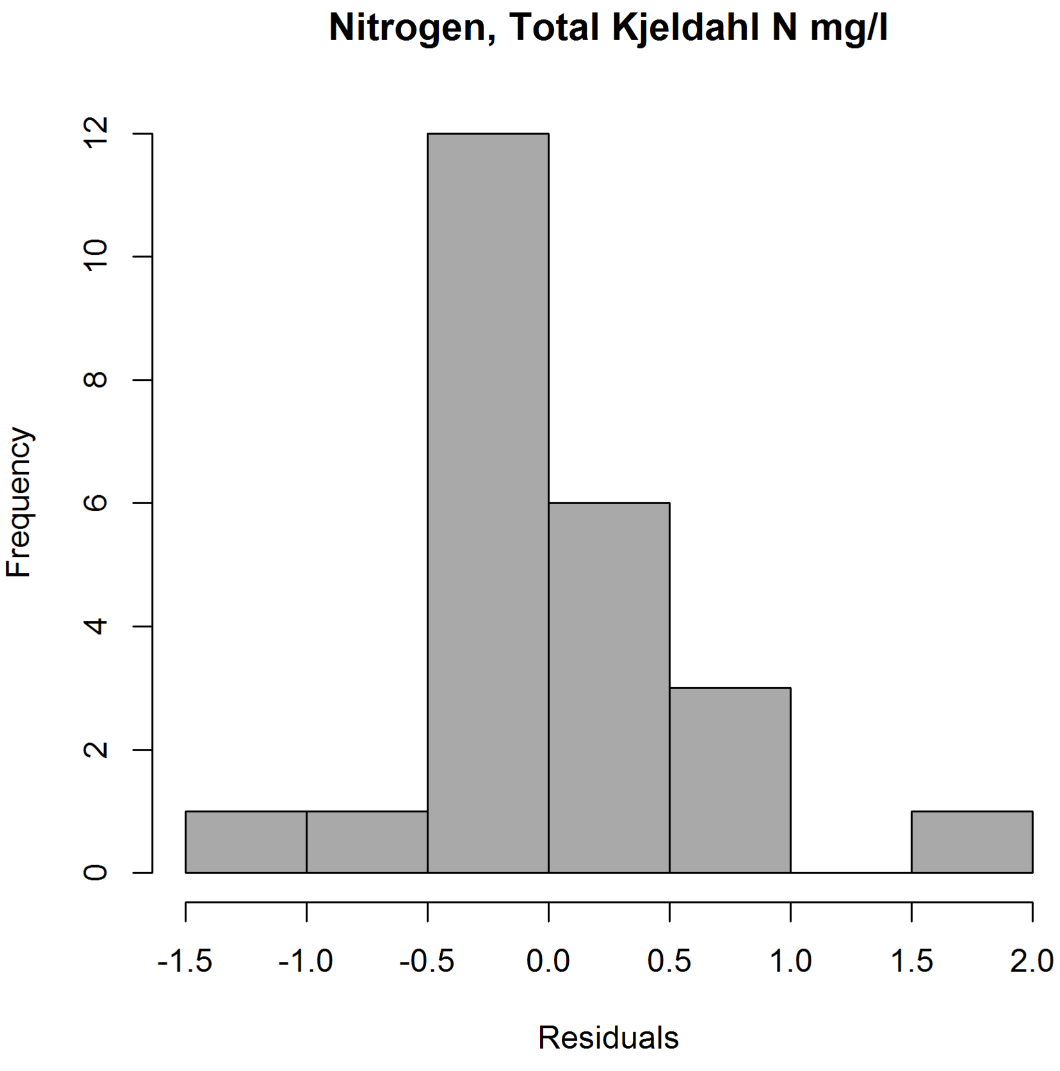
Fluoranthene N ug/l
Residuals
Model
1.5
1.0
0.5
0.0
-2.22
-2.20
-2.18
-2.16
-2.14
-2.12
-2.10
-2.08



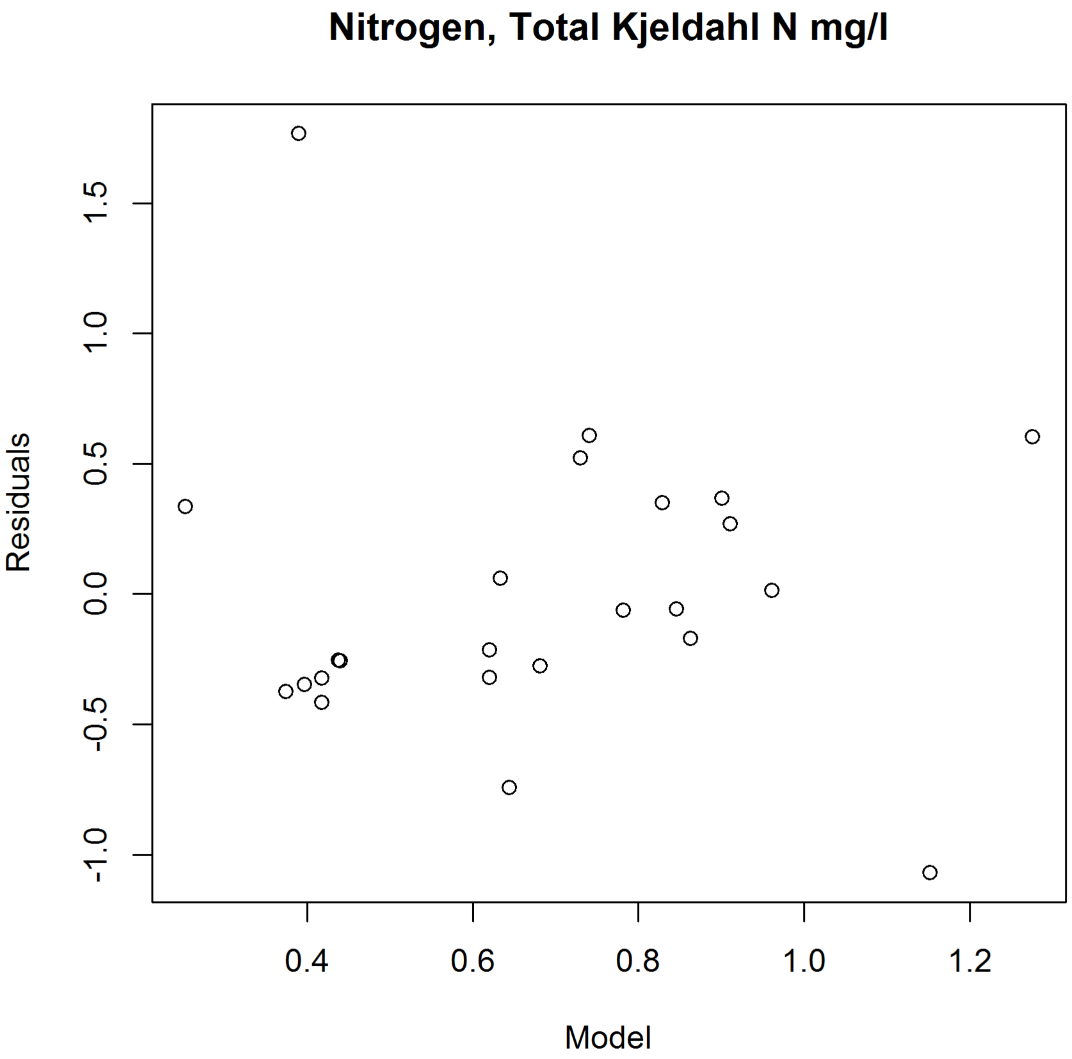
Nitrate + Nitrite N mg/l
Frequency
0
5
10
15
-2.0
-1.5
-1.0
-0.5
0.0
0.5
Residuals

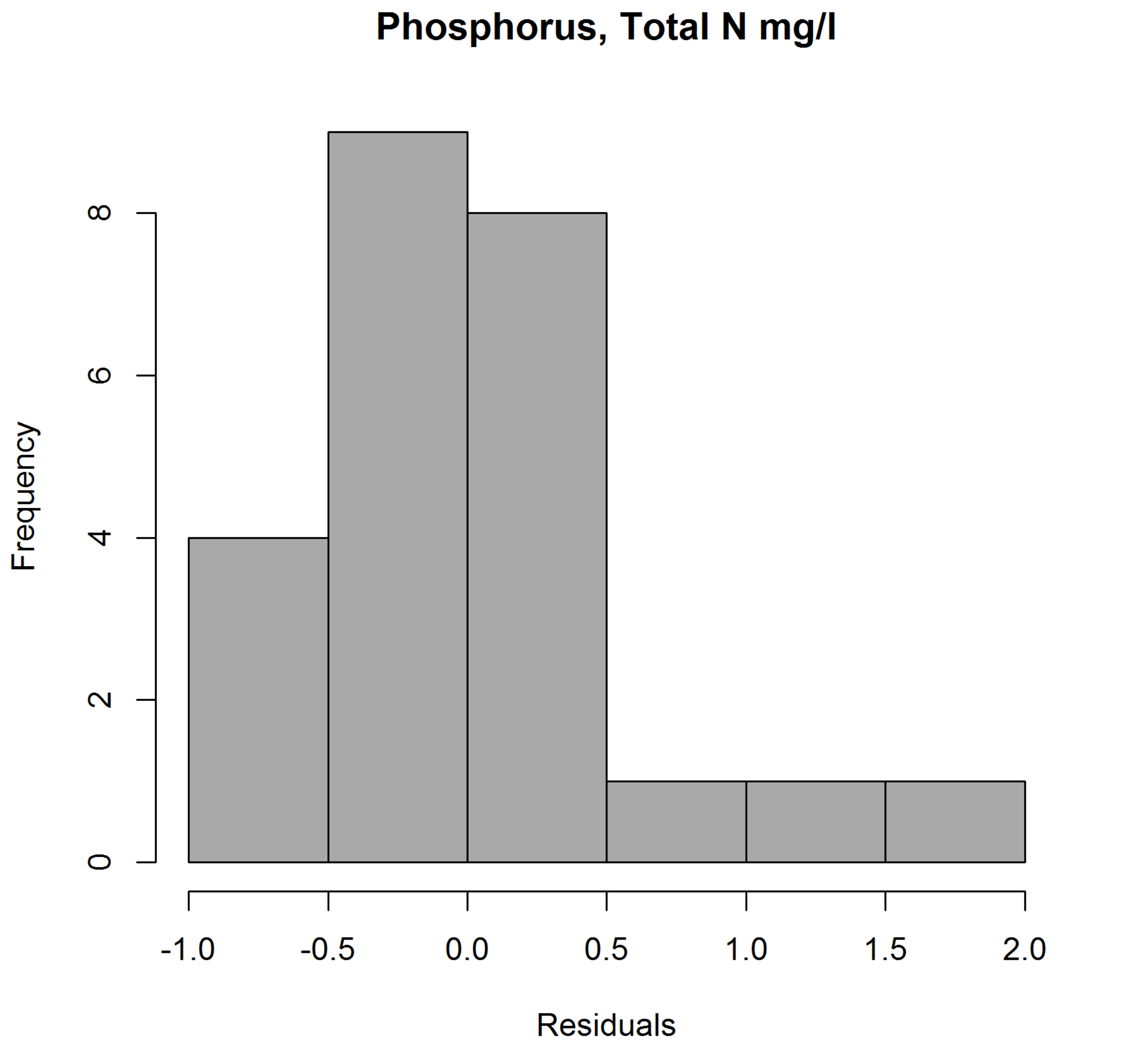


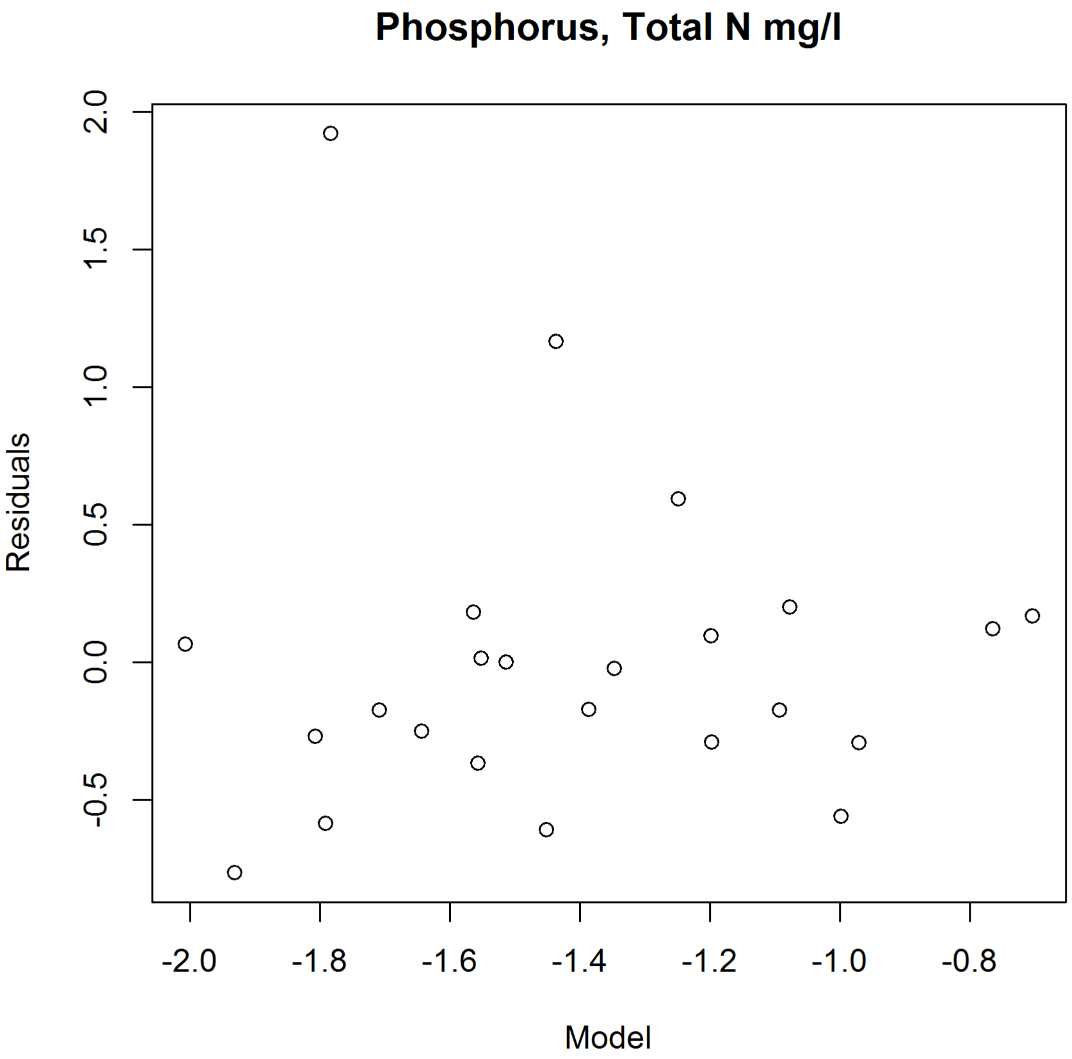
Nitrate + Nitrite N mg/l
Residuals
0.0
-0.5
-1.0
-1.5
-3.0
-2.5
-2.0
-1.5
-1.0
Model

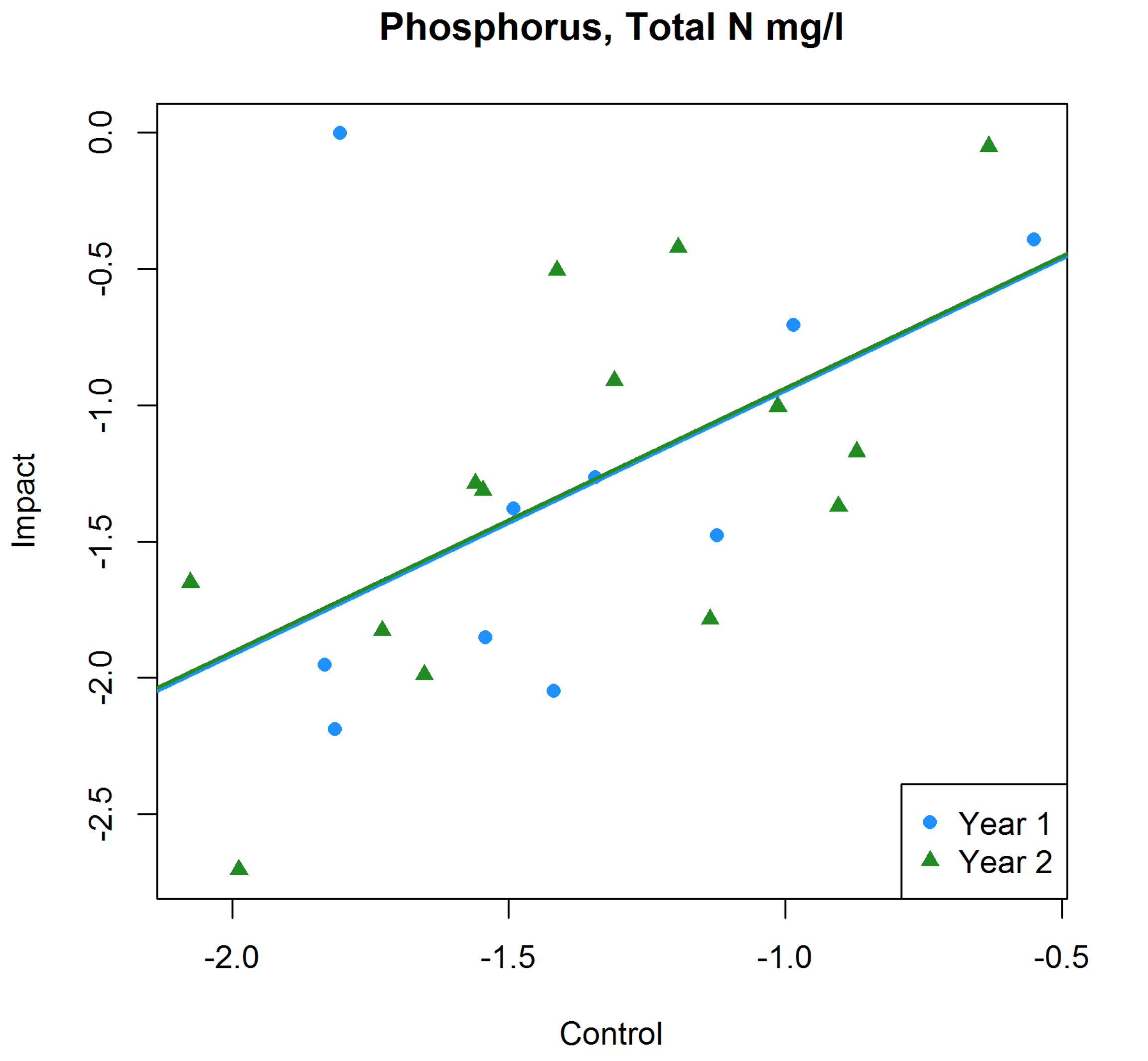


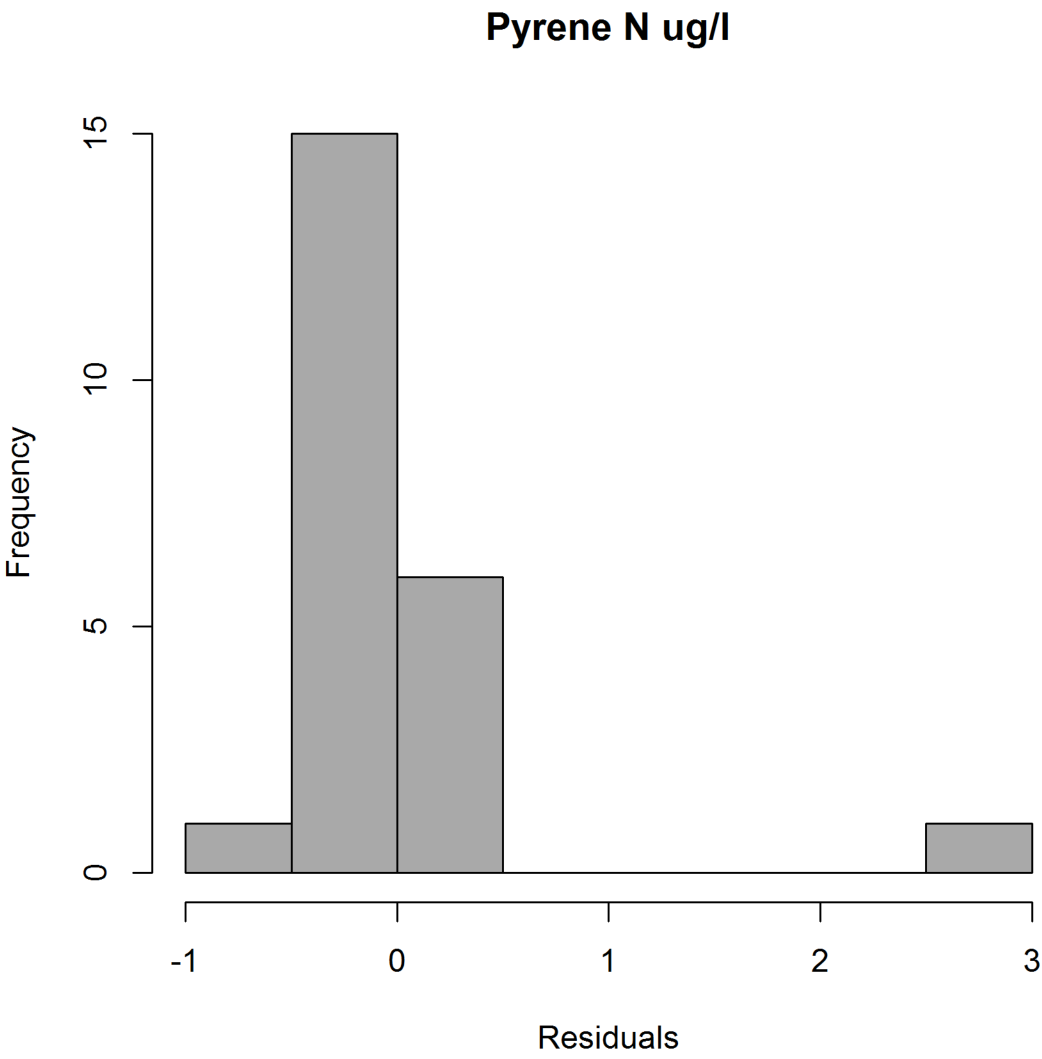
Nitrogen, Total Kjeldahl N mg/l
Frequency
0
2
4
6
8
10
12
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Residuals


Nitrogen, Total Kjeldahl N mg/l
Residuals
Model
-1.0
-0.5
0.0
0.5
1.0
1.5
0.4
0.6
0.8
1.0
1.2

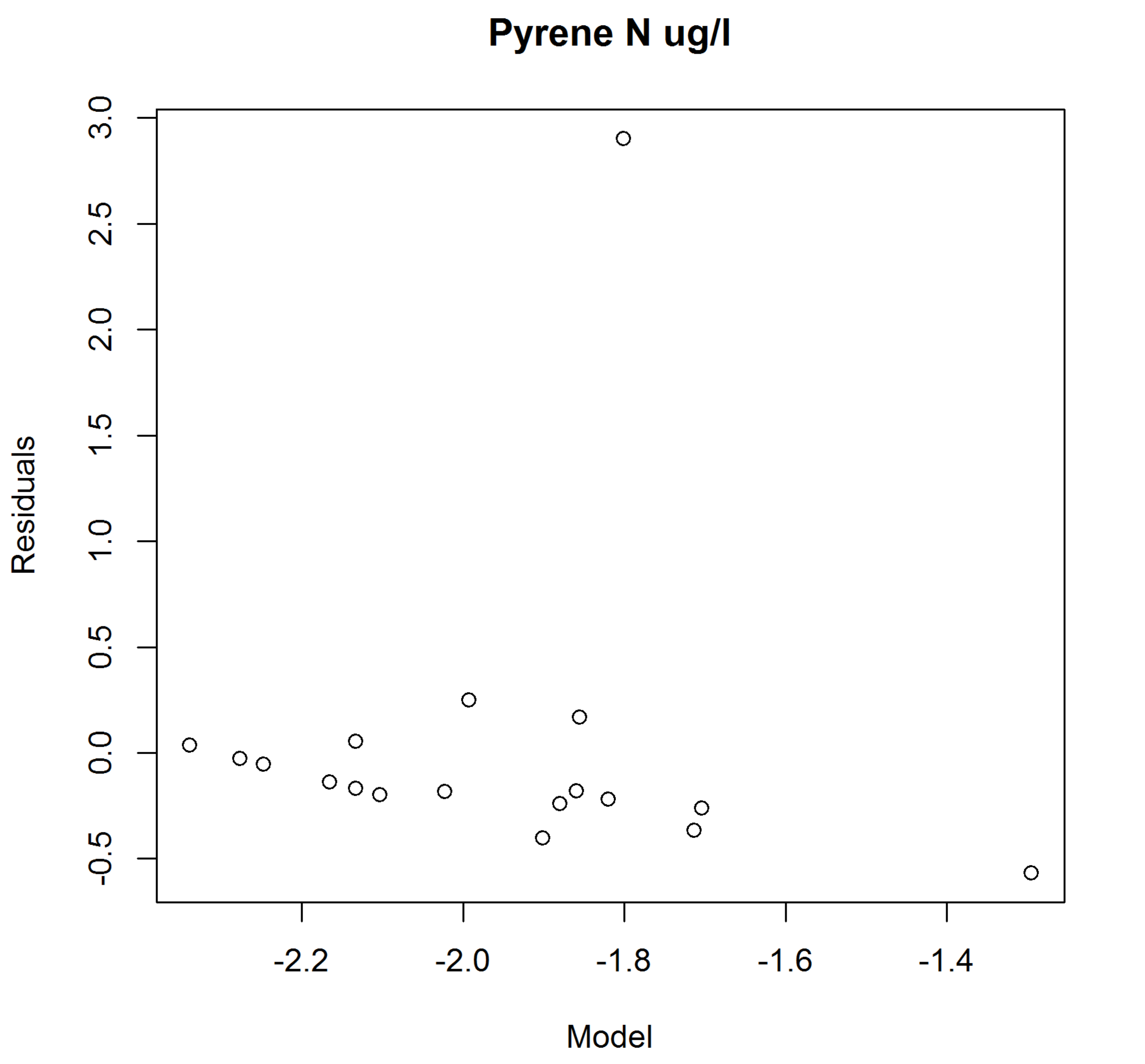

Phosphorus, Total N mg/l
Frequency
0
2
4
6
8
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Residuals


Phosphorus, Total N mg/l
Residuals
Model
2.0
1.5
1.0
0.5
0.0
-0.5
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8

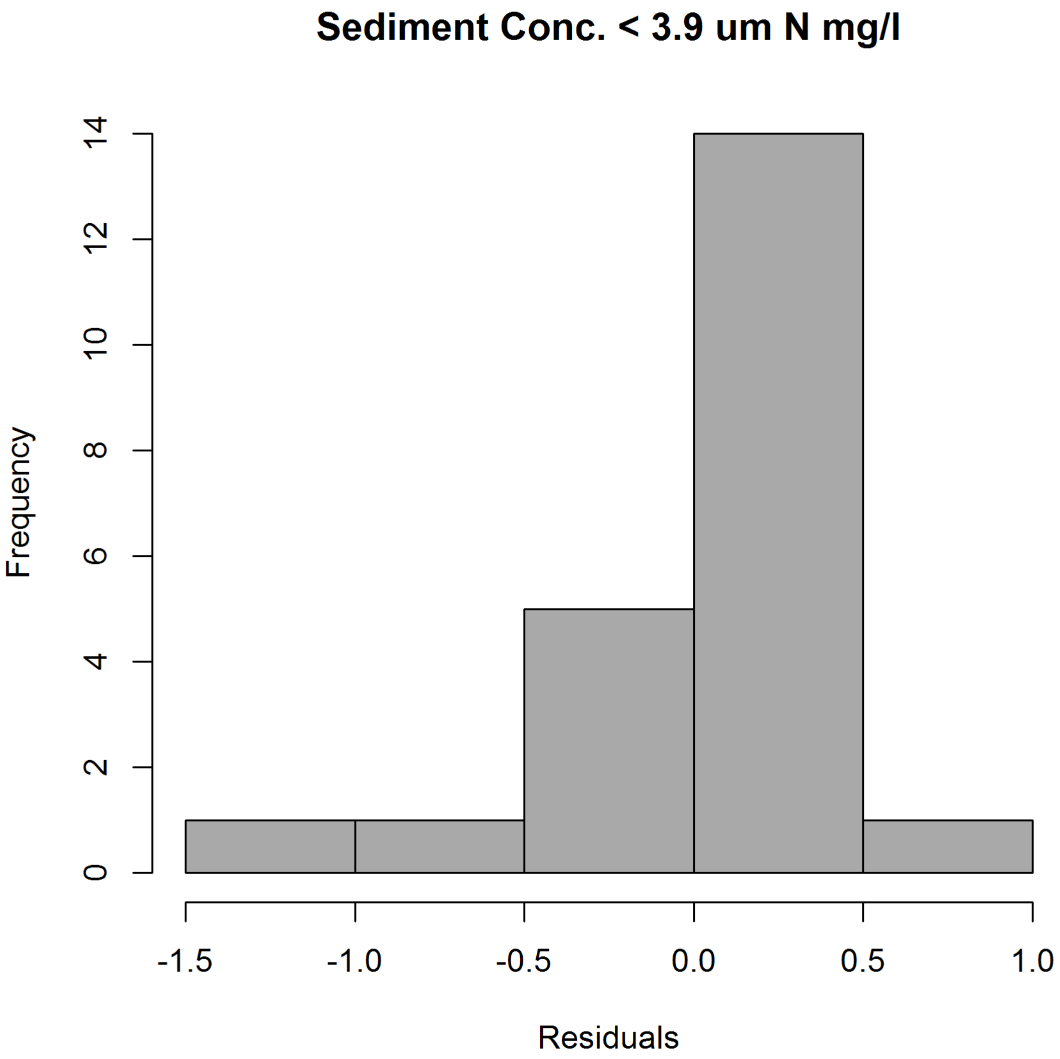

Phosphorus, Total N mg/l
Impact
Control
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-2.0
-1.5
-1.0
-0.5
Year 1
Year 2



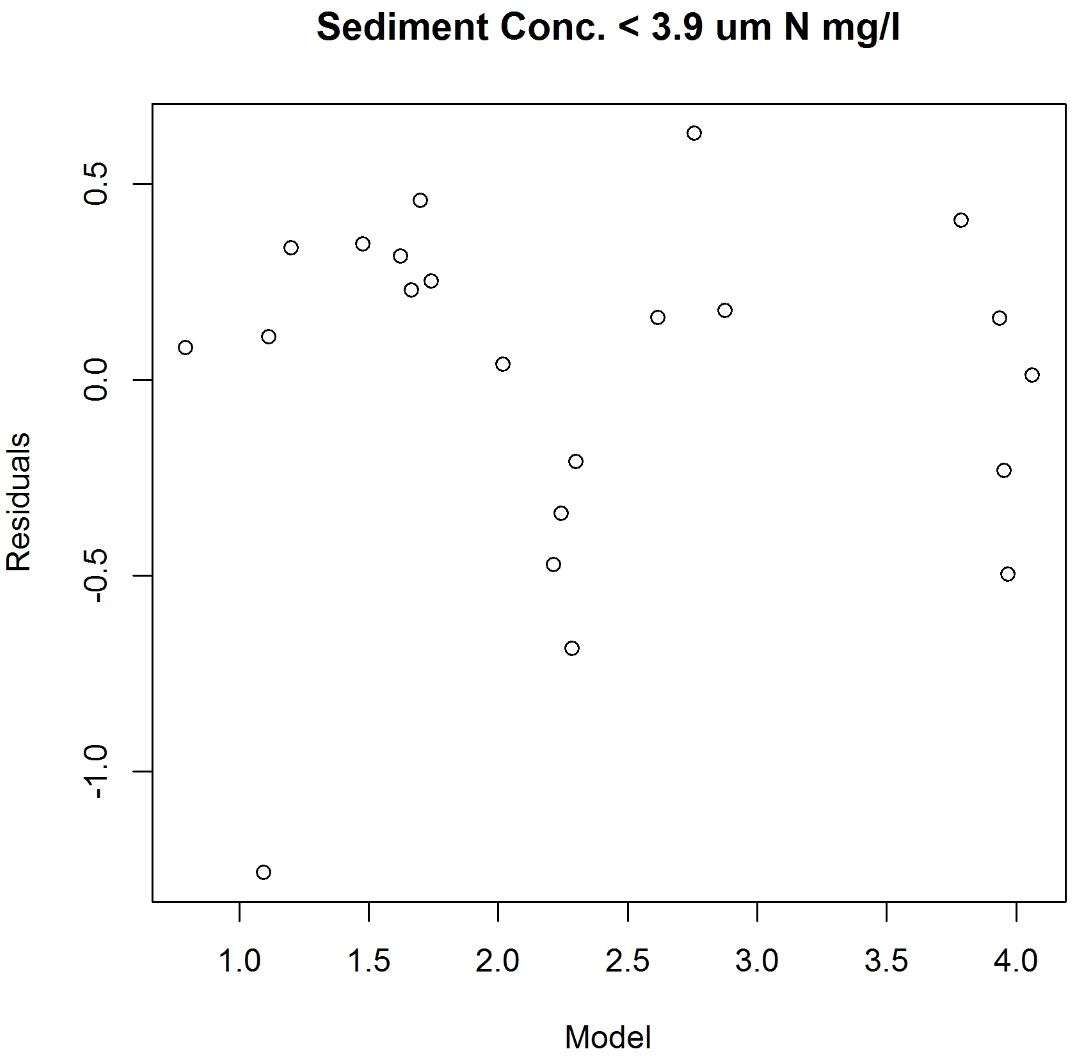
Pyrene N ug/l
Frequency
15
10
5
0
-1
0
1
2
3
Residuals

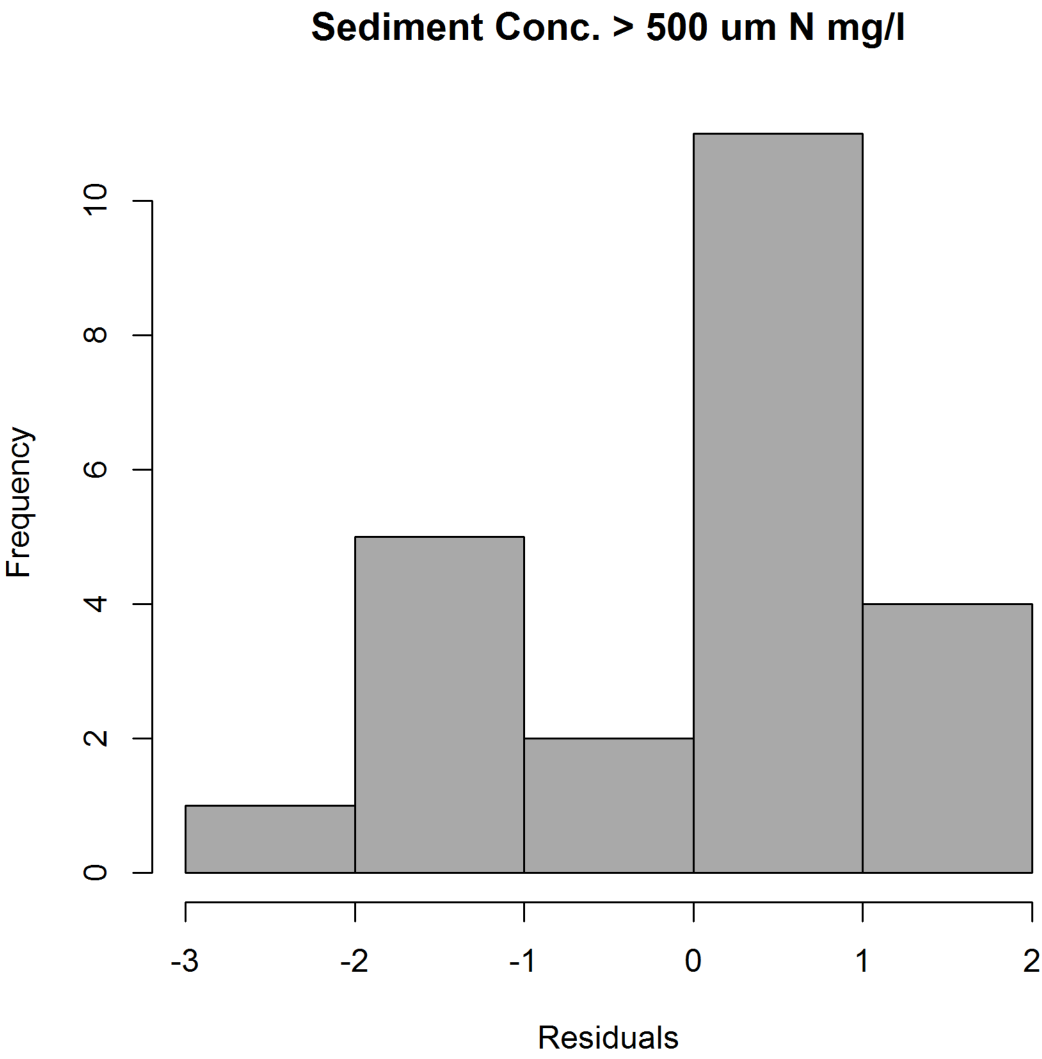


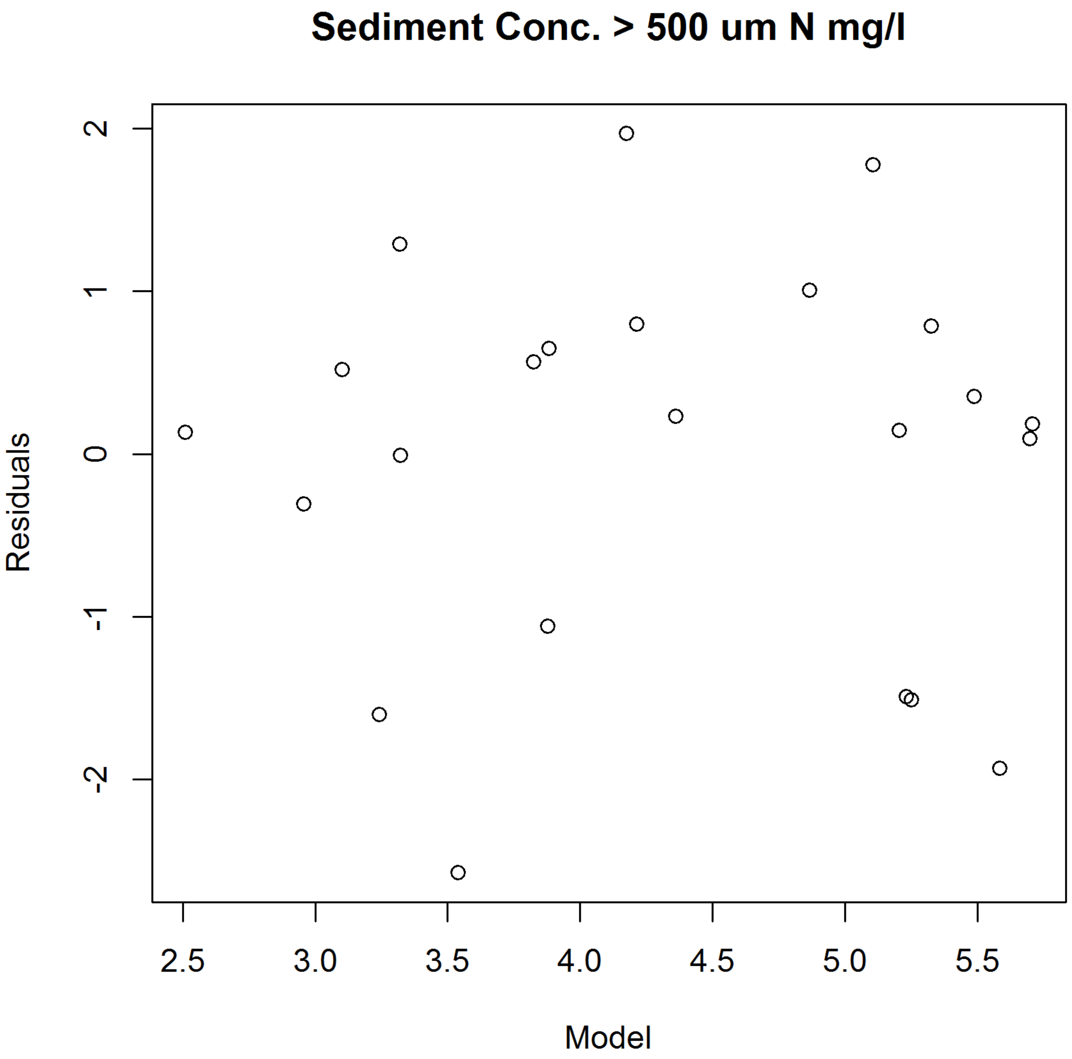
Pyrene N ug/l
Residuals
Model
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-2.2
-2.0
-1.8
-1.6
-1.4

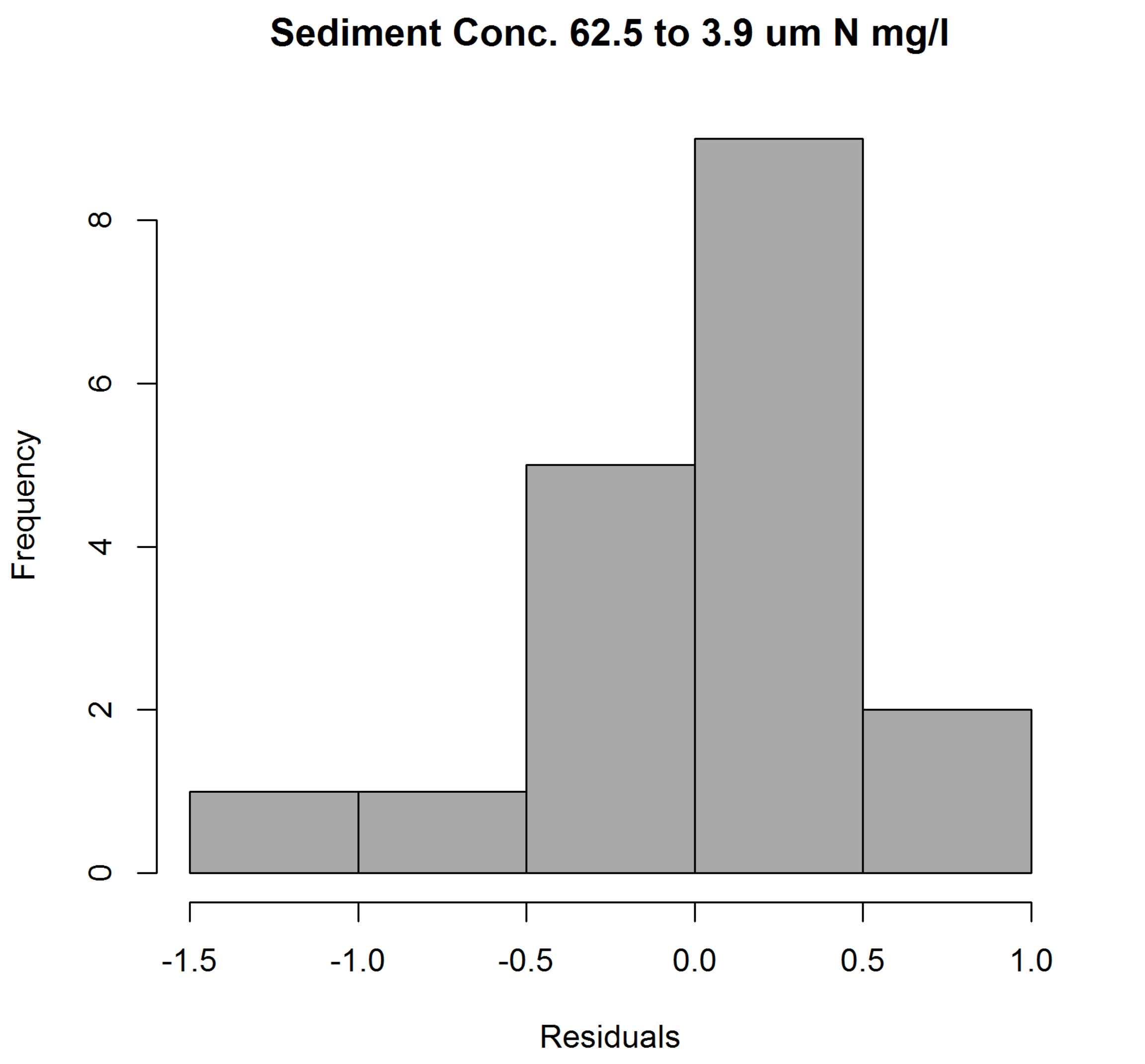


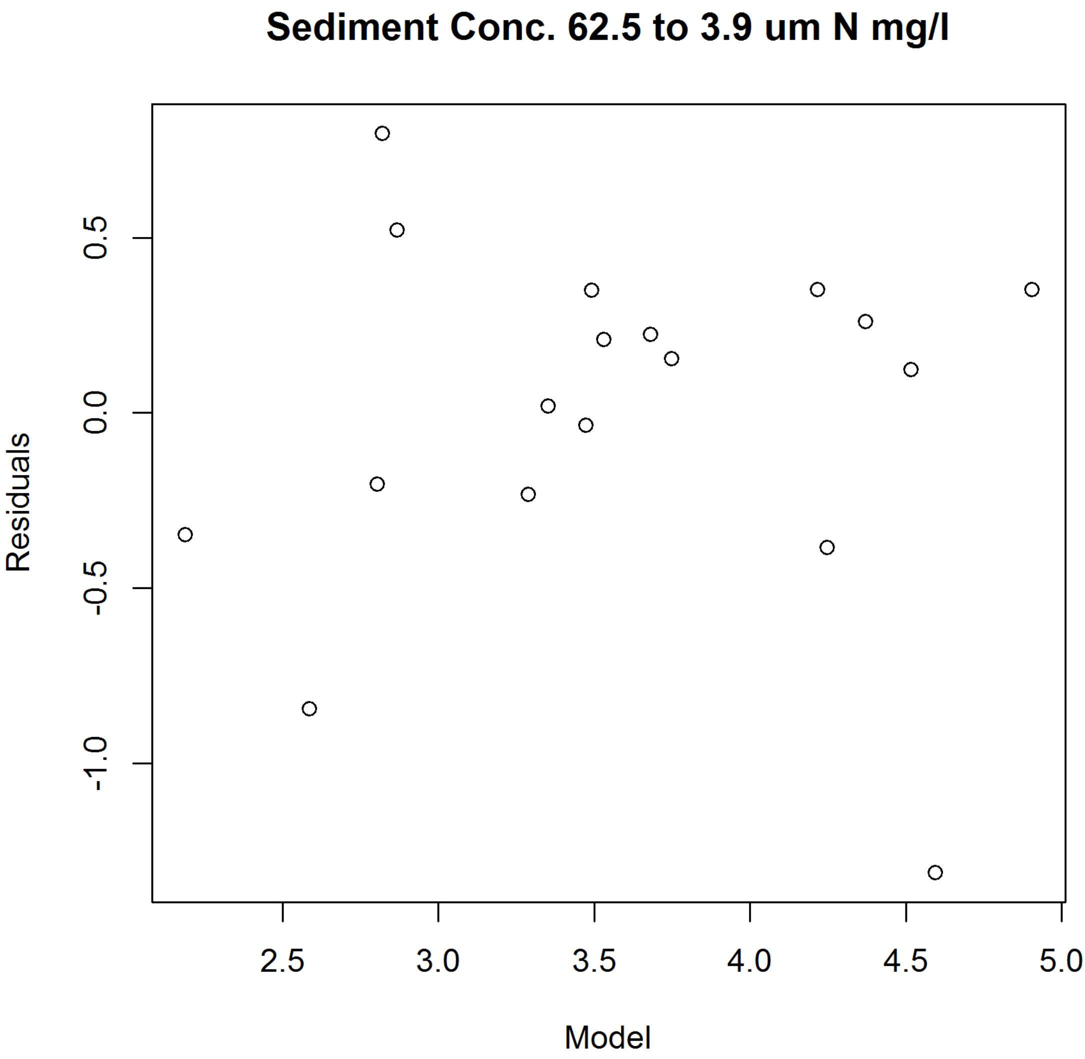
Sediment Conc. < 3.9 um N mg/l
Frequency
0
2
4
6
8
10
12
14
-1.5
-1.0
-0.5
0.0
0.5
1.0
Residuals


Sediment Conc. < 3.9 um N mg/l
Residuals
Model
0.5
0.0
-0.5
-1.0
1.0
1.5
2.0
2.5
3.0
3.5
4.0

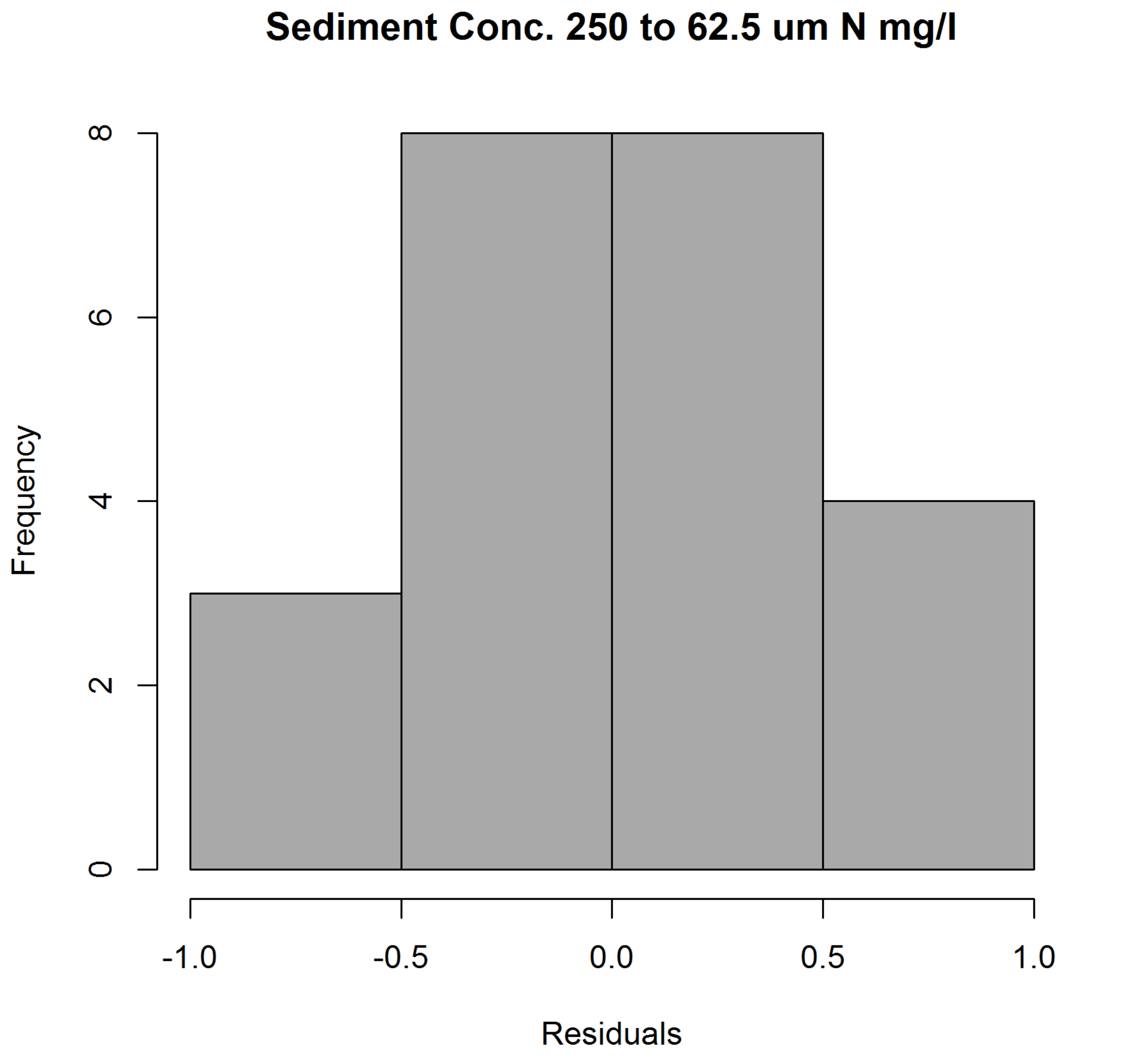

Sediment Conc. > 500 um N mg/l
Frequency
0
2
4
6
8
10
-3
-2
-1
0
1
2
Residuals


Sediment Conc. > 500 um N mg/l
Residuals
Model
2
1
0
-1
-2
2.5
3.0
3.5
4.0
4.5
5.0
5.5

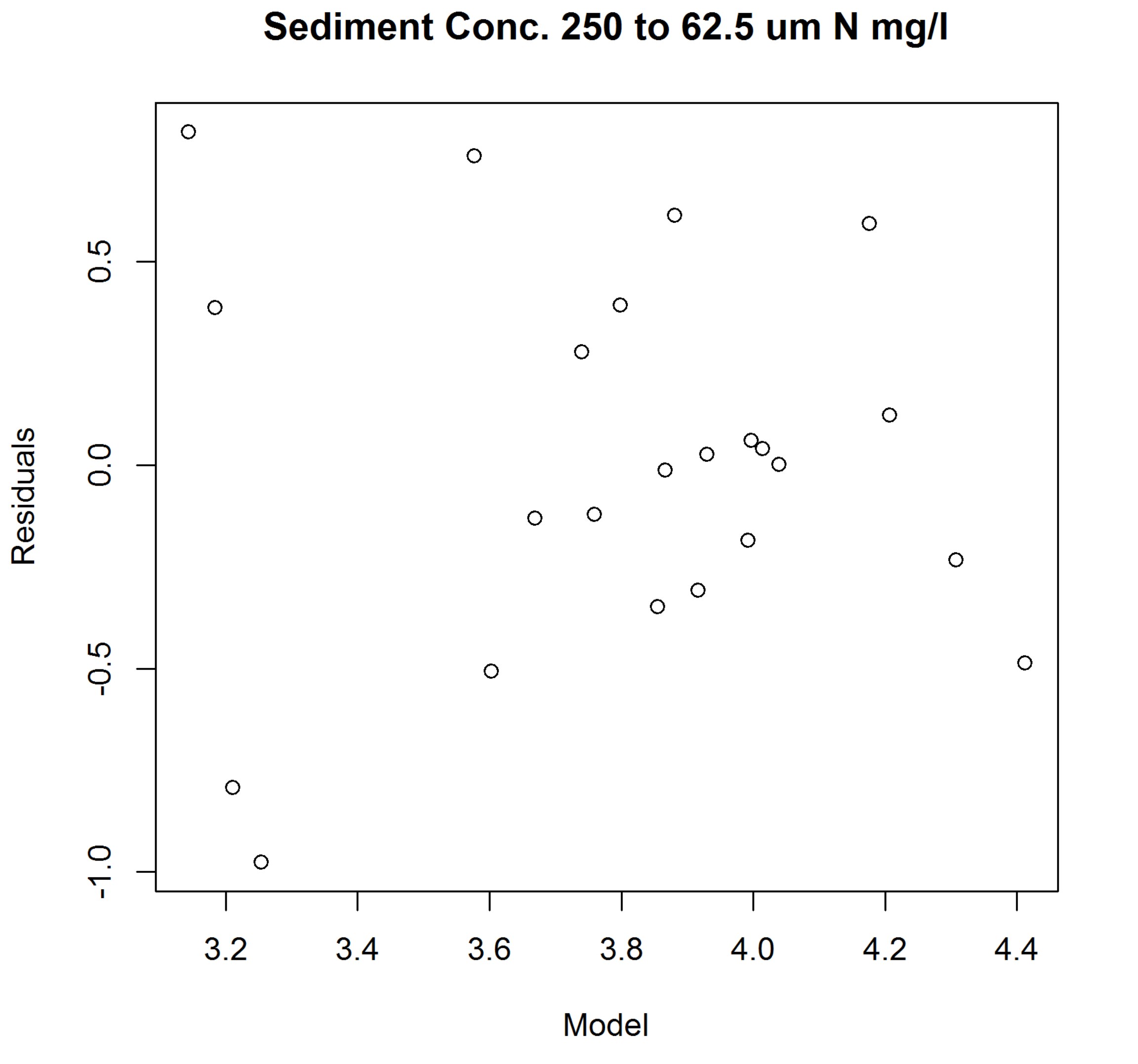

Sediment Conc. 62.5 to 3.9 um N mg/l
Frequency
0
2
4
6
8
-1.5
-1.0
-0.5
0.0
0.5
1.0
Residuals



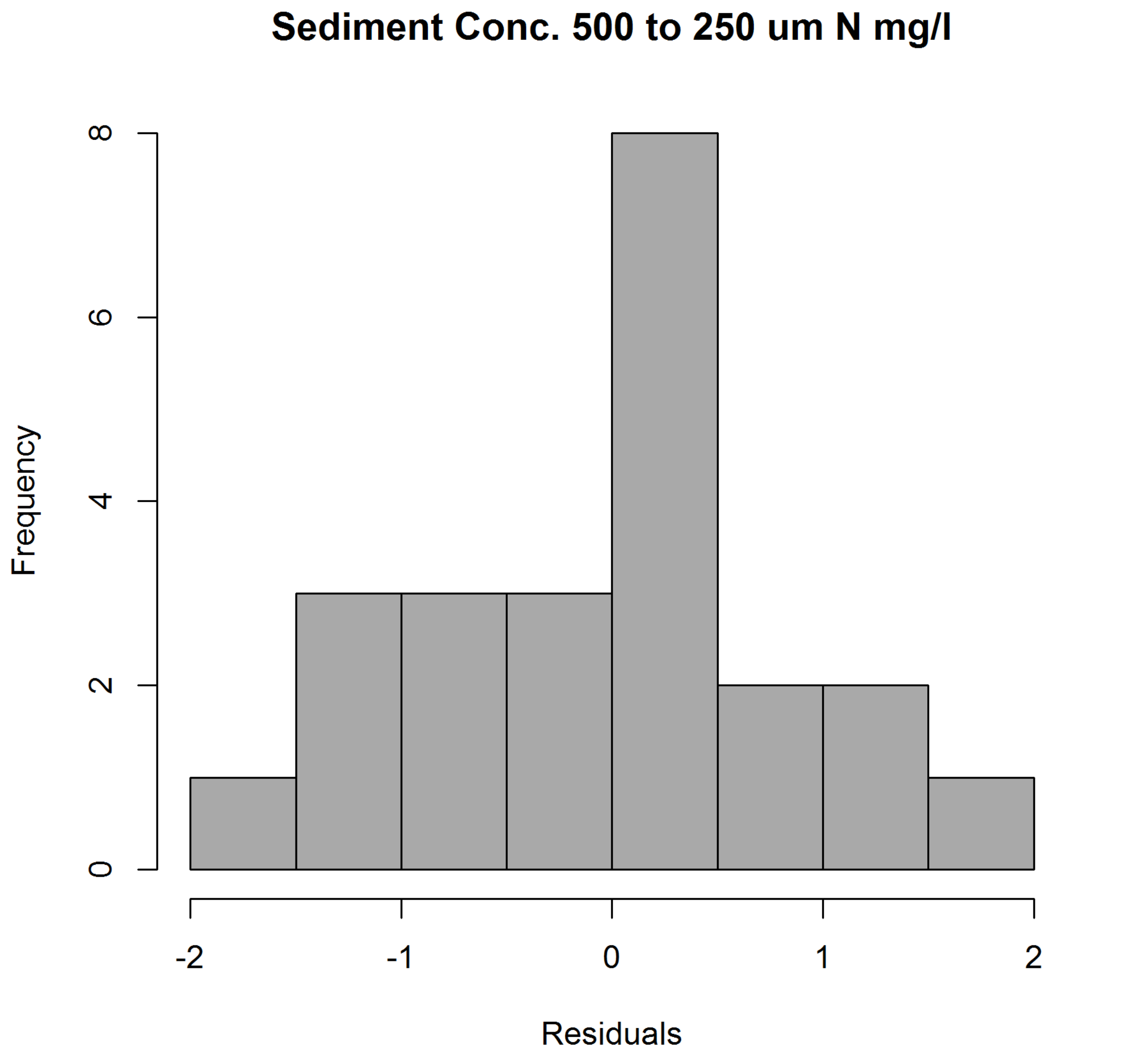
Sediment Conc. 62.5 to 3.9 um N mg/l
Residuals
Model
0.5
0.0
-0.5
-1.0
2.5
3.0
3.5
4.0
4.5
5.0

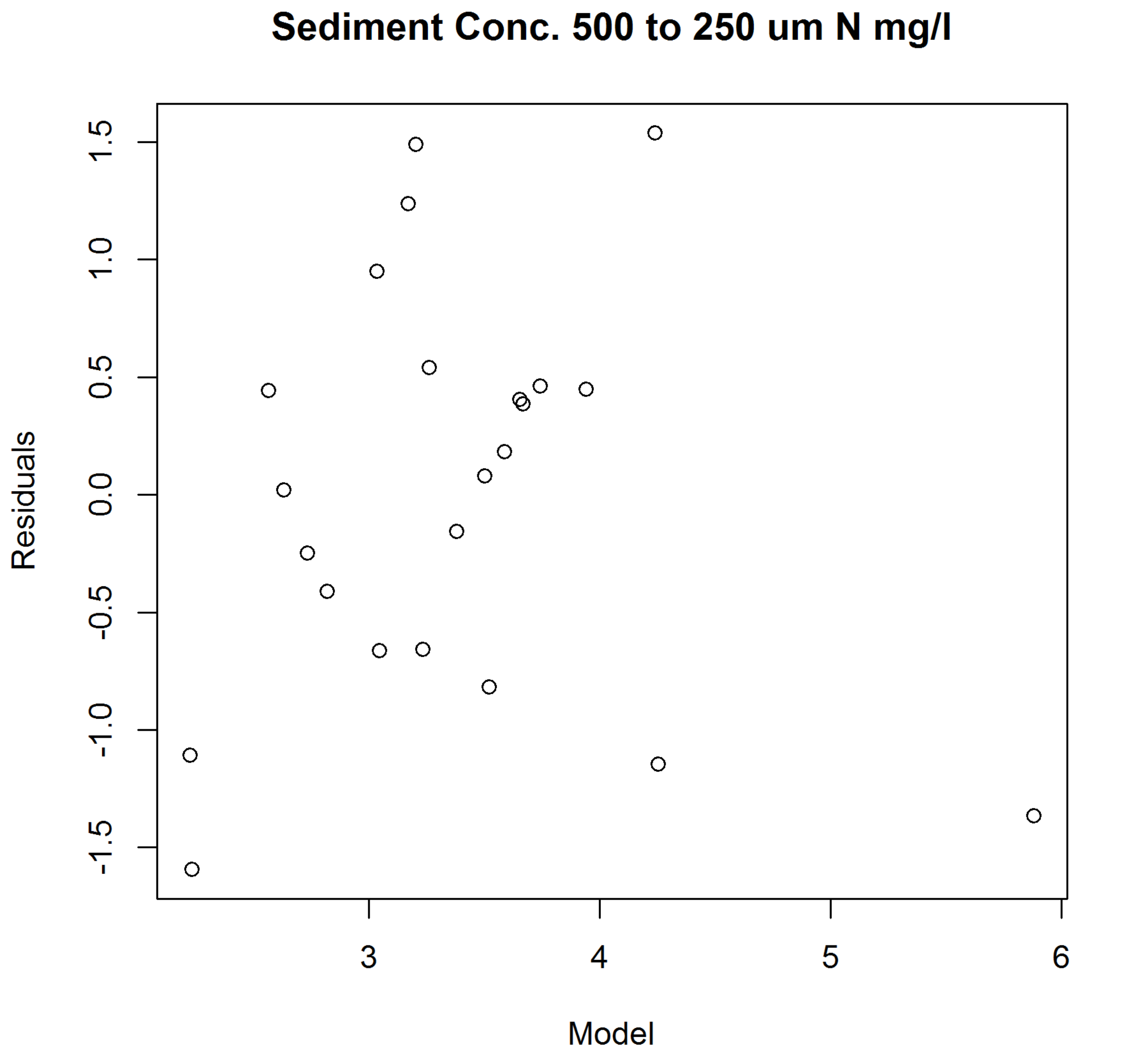


Sediment Conc. 250 to 62.5 um N mg/l
Frequency
0
2
4
6
8
-1.0
-0.5
0.0
0.5
1.0
Residuals

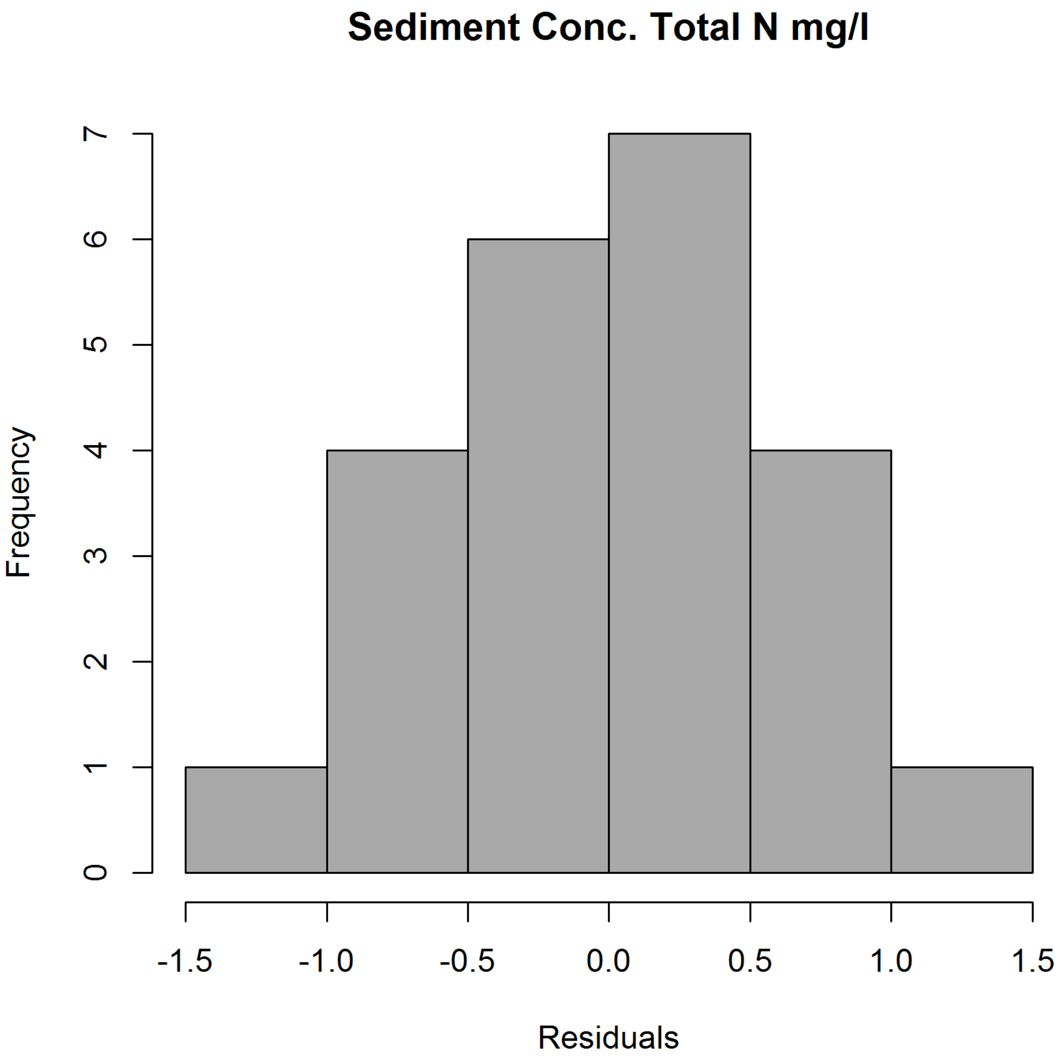


Sediment Conc. 250 to 62.5 um N mg/l
Residuals
Model
0.5
0.0
-0.5
-1.0
3.2
3.4
3.6
3.8
4.0
4.2
4.4

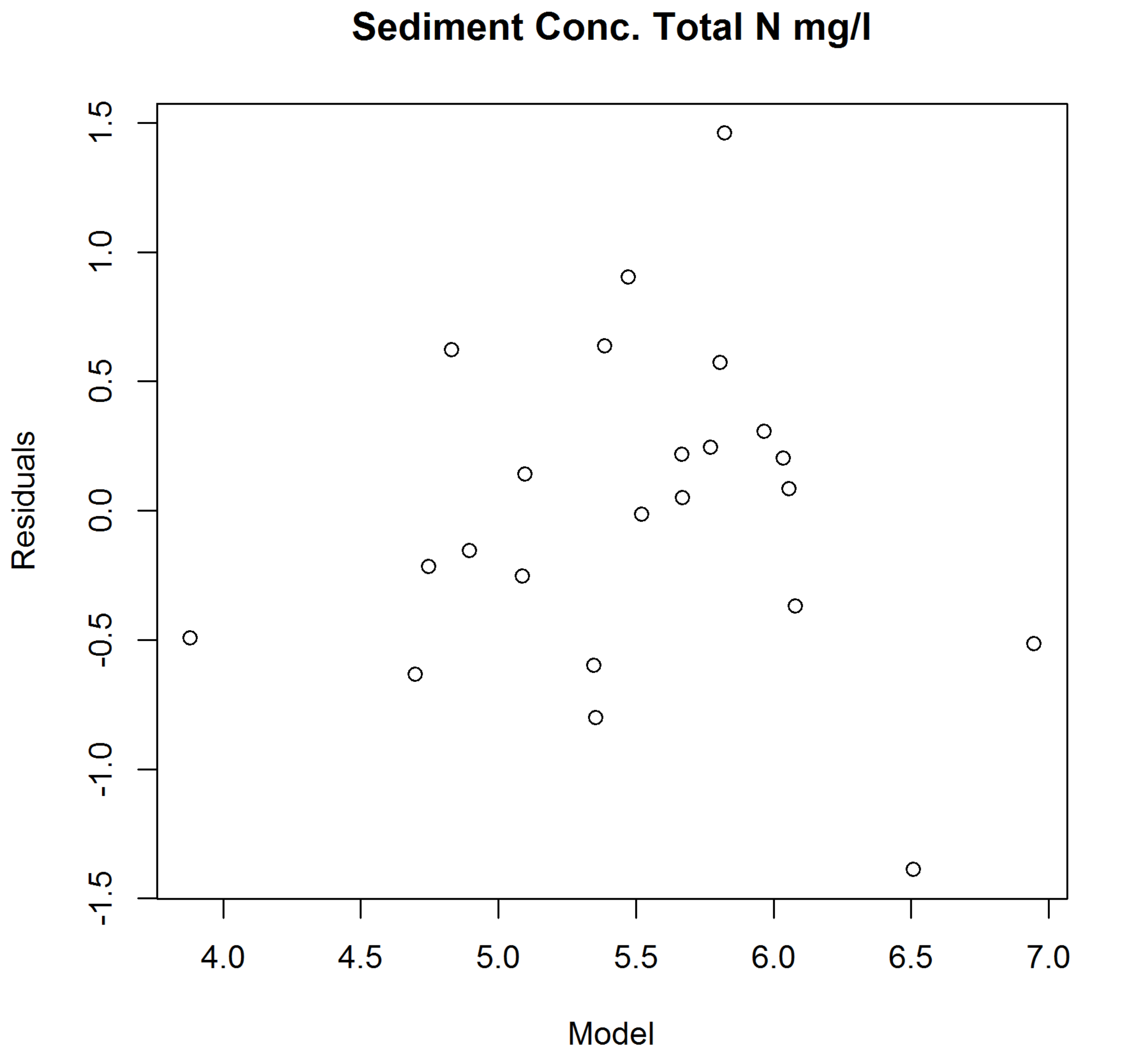

Sediment Conc. 500 to 250 um N mg/l
Frequency
0
2
4
6
8
-2
-1
0
1
2
Residuals

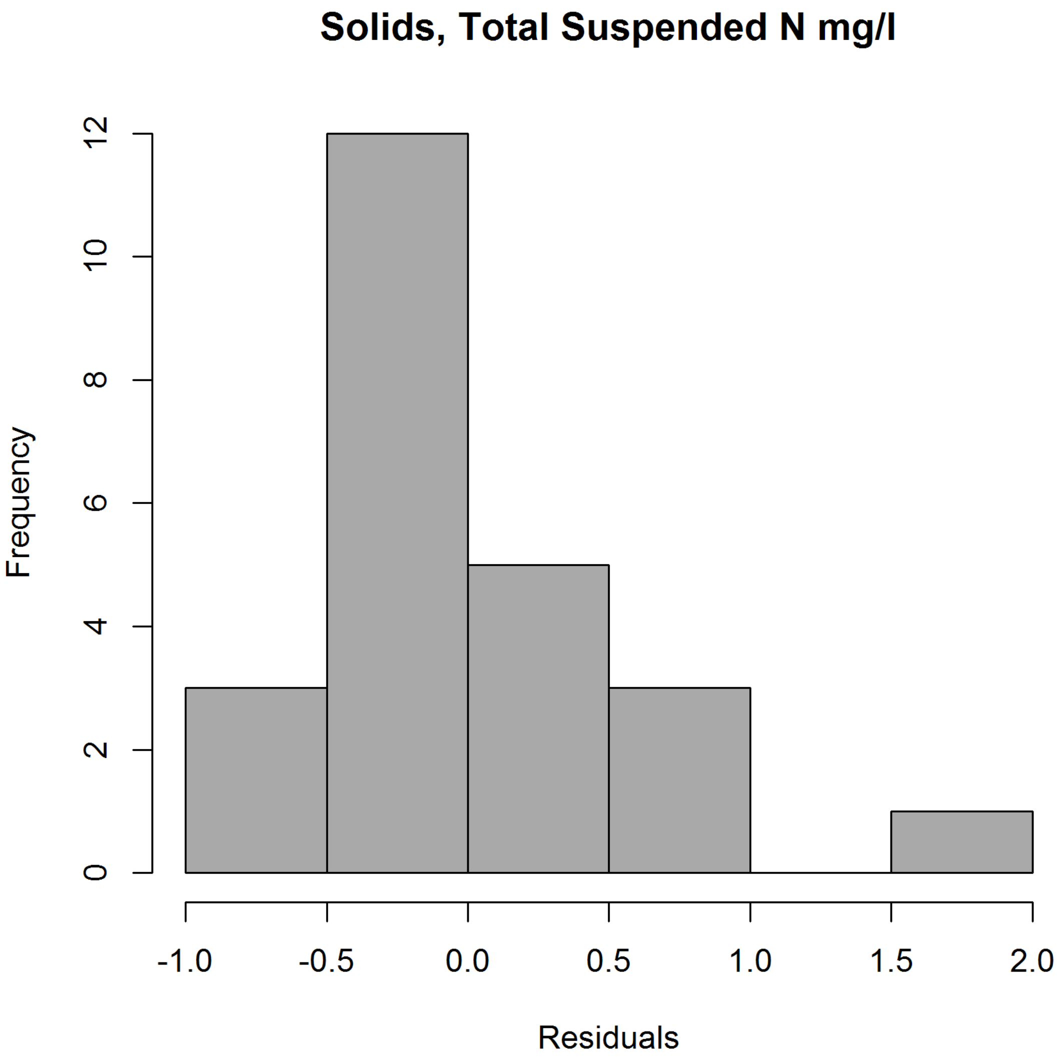


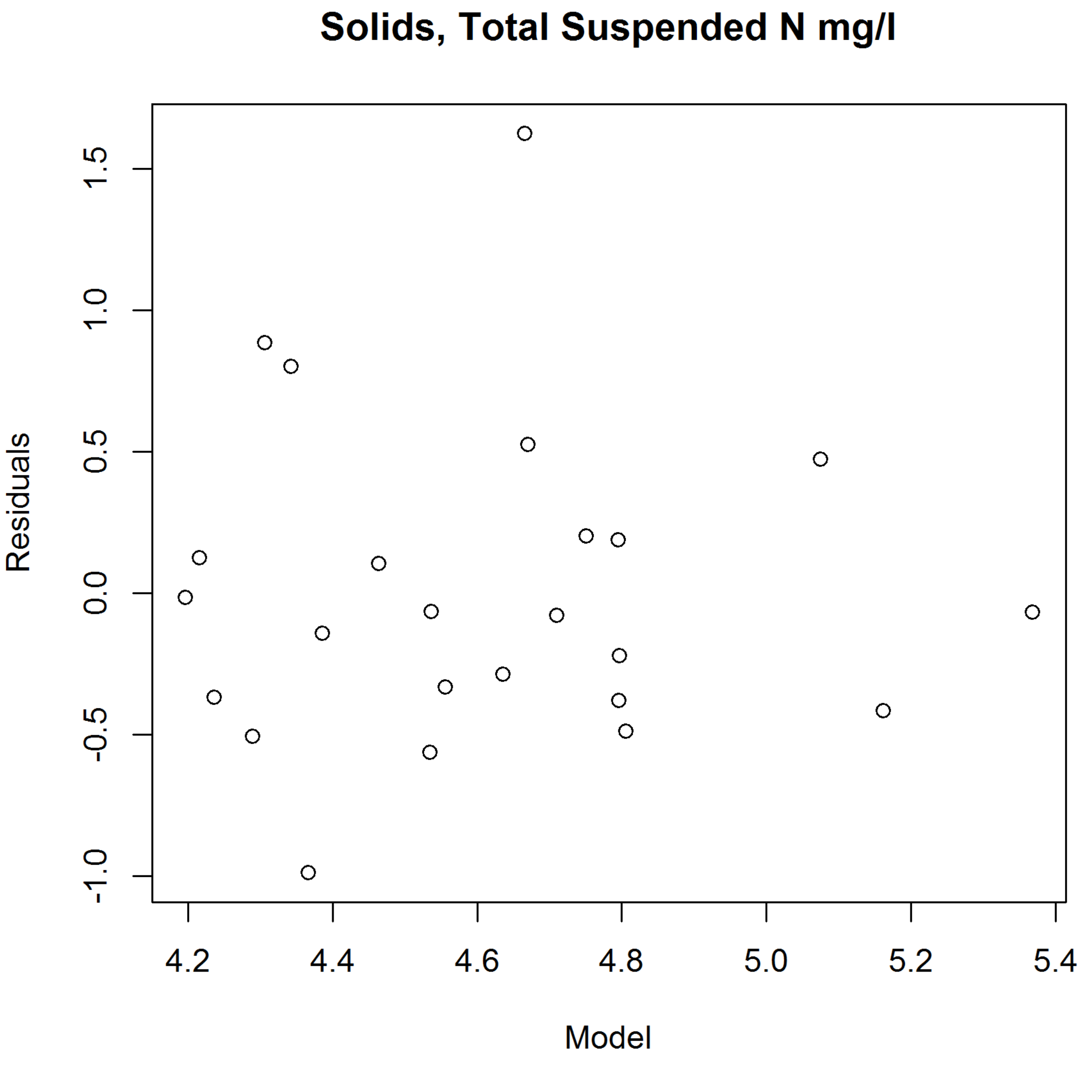
Sediment Conc. 500 to 250 um N mg/l
Residuals
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
3
4
5
6
Model

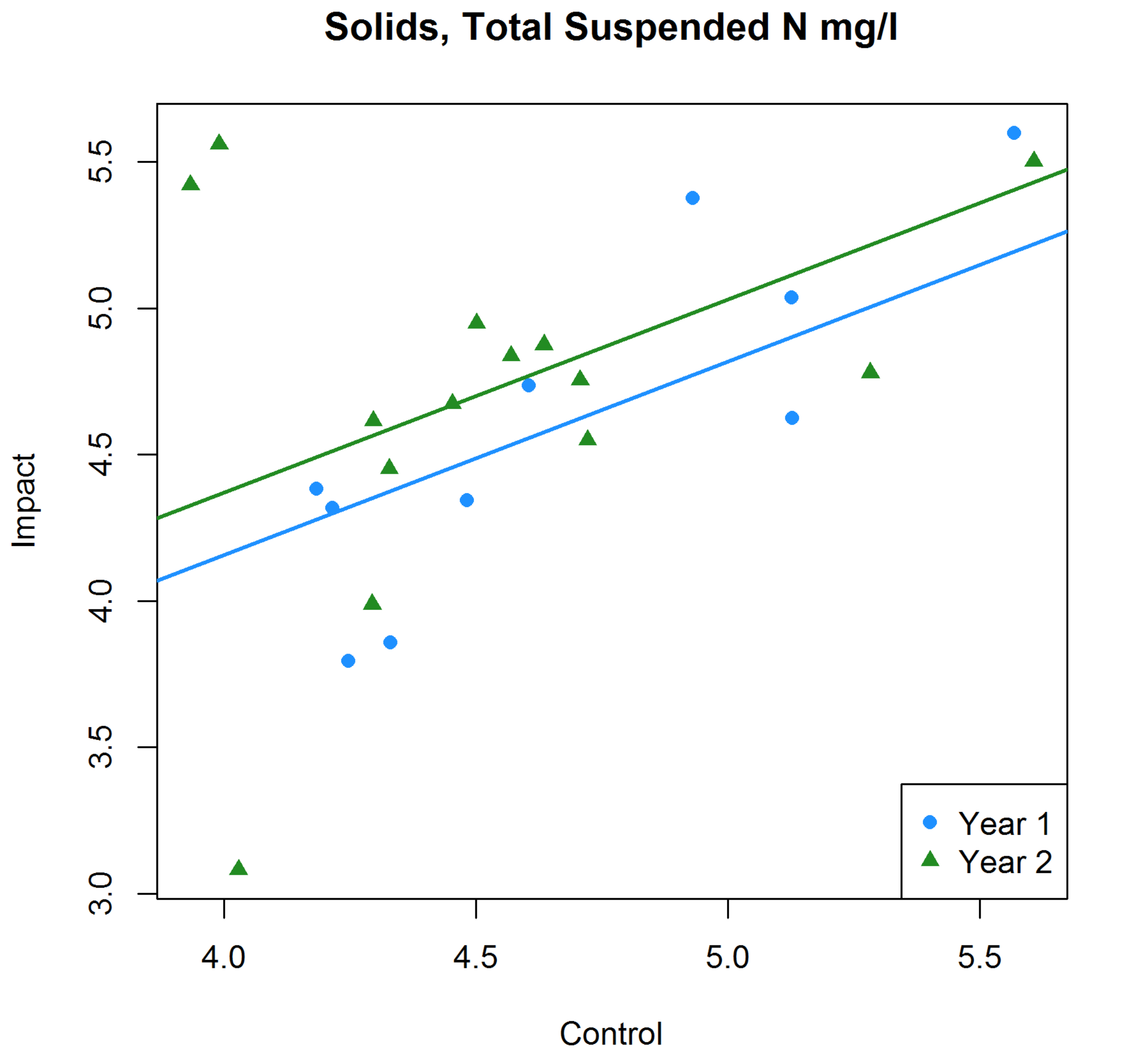


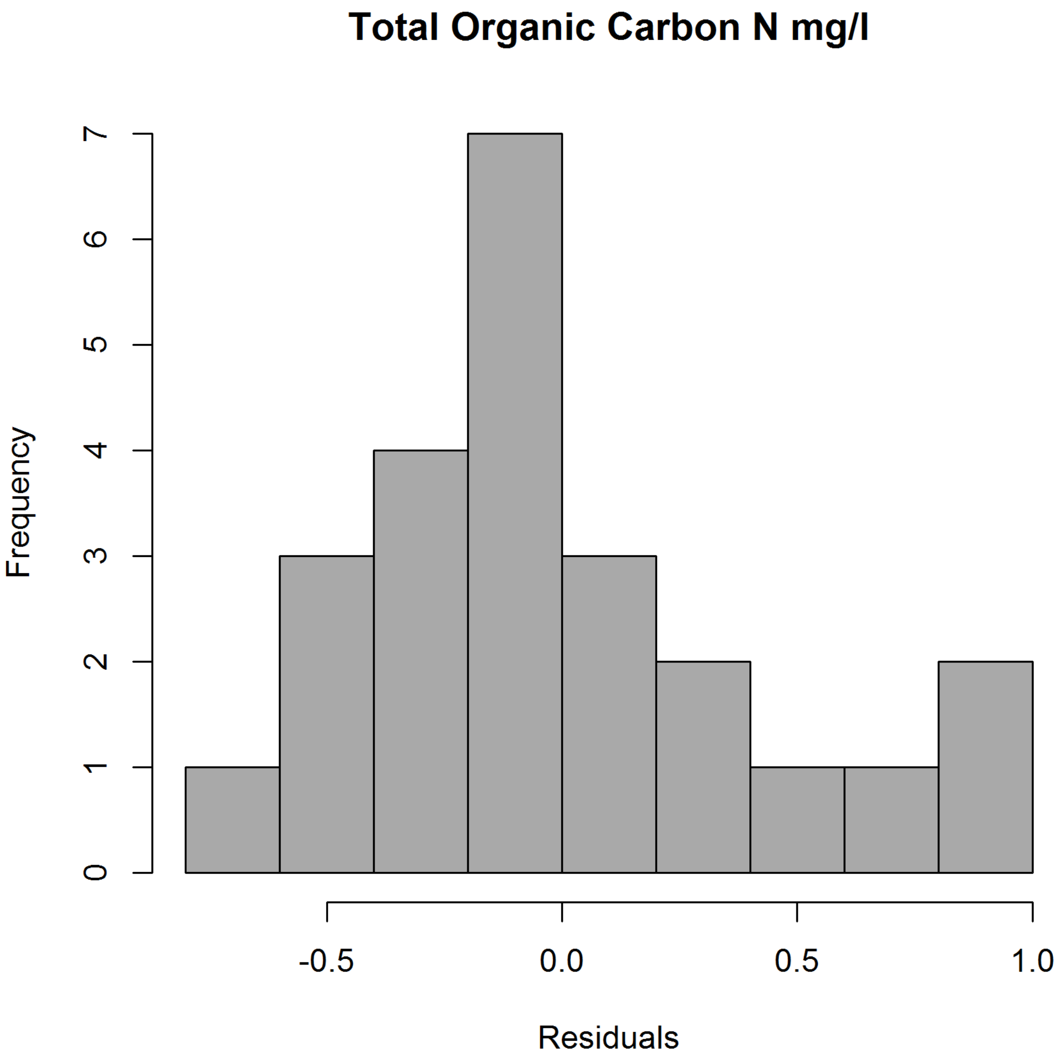
Sediment Conc. Total N mg/l
Frequency
0
1
2
3
4
5
6
7
Residuals
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5


Sediment Conc. Total N mg/l
Residuals
Model
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0

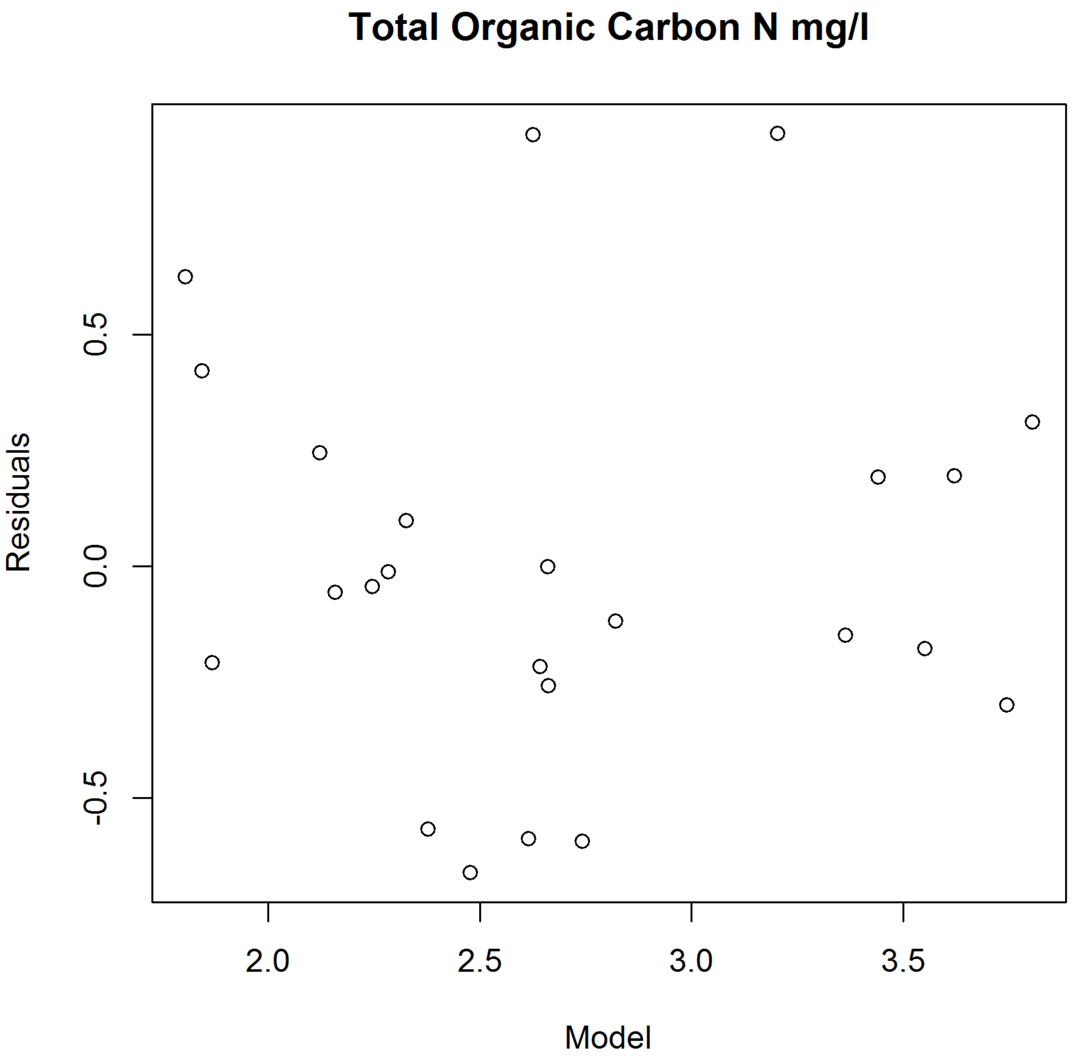

Solids, Total Suspended N mg/l
Frequency
0
2
4
6
8
10
12
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Residuals


Solids, Total Suspended N mg/l
Residuals
Model
1.5
1.0
0.5
0.0
-0.5
-1.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4

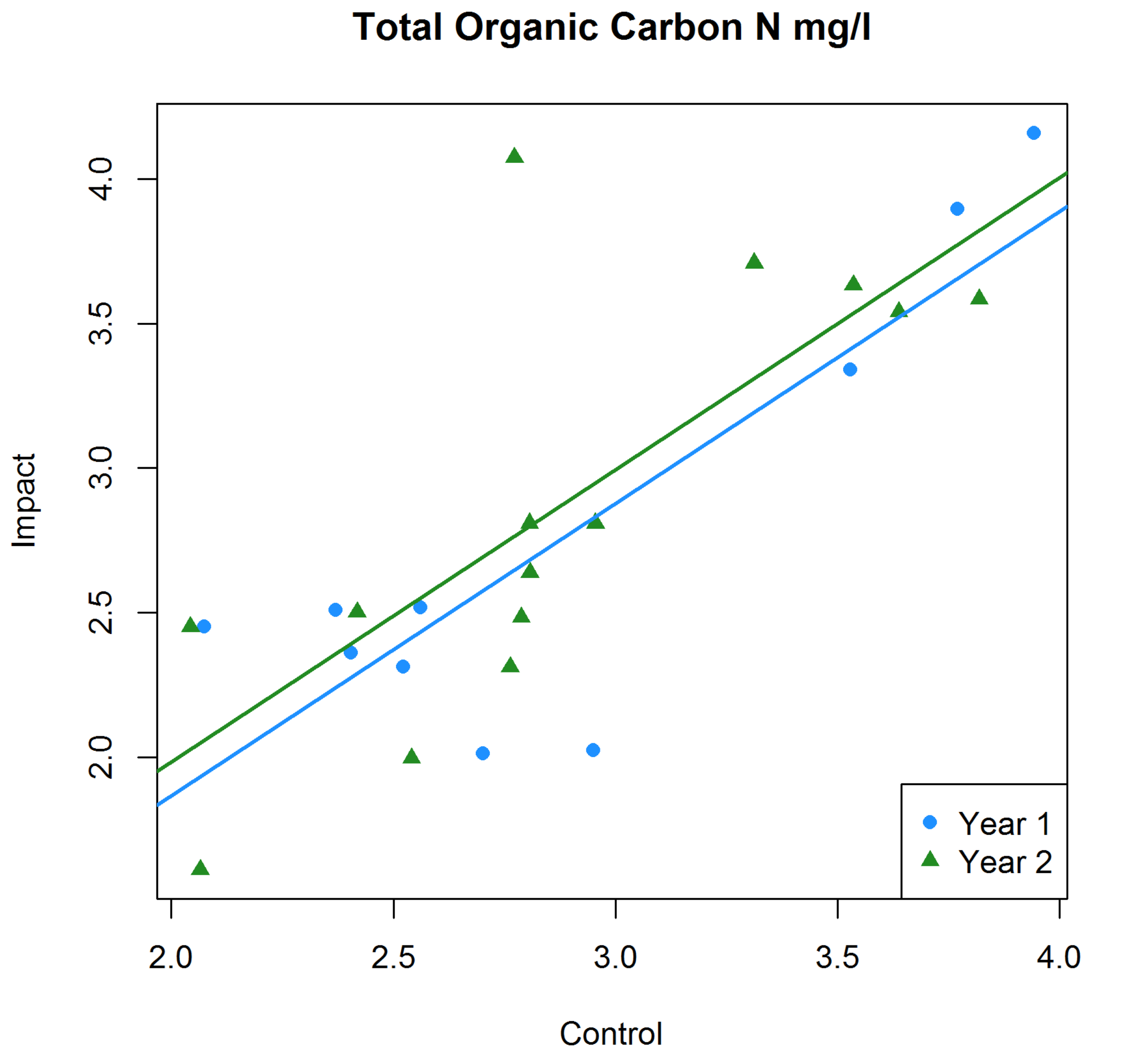

Solids, Total Suspended N mg/l
Impact
Control
5.5
5.0
4.5
4.0
3.5
3.0
4.0
4.5
5.0
5.5
Year 1
Year 2



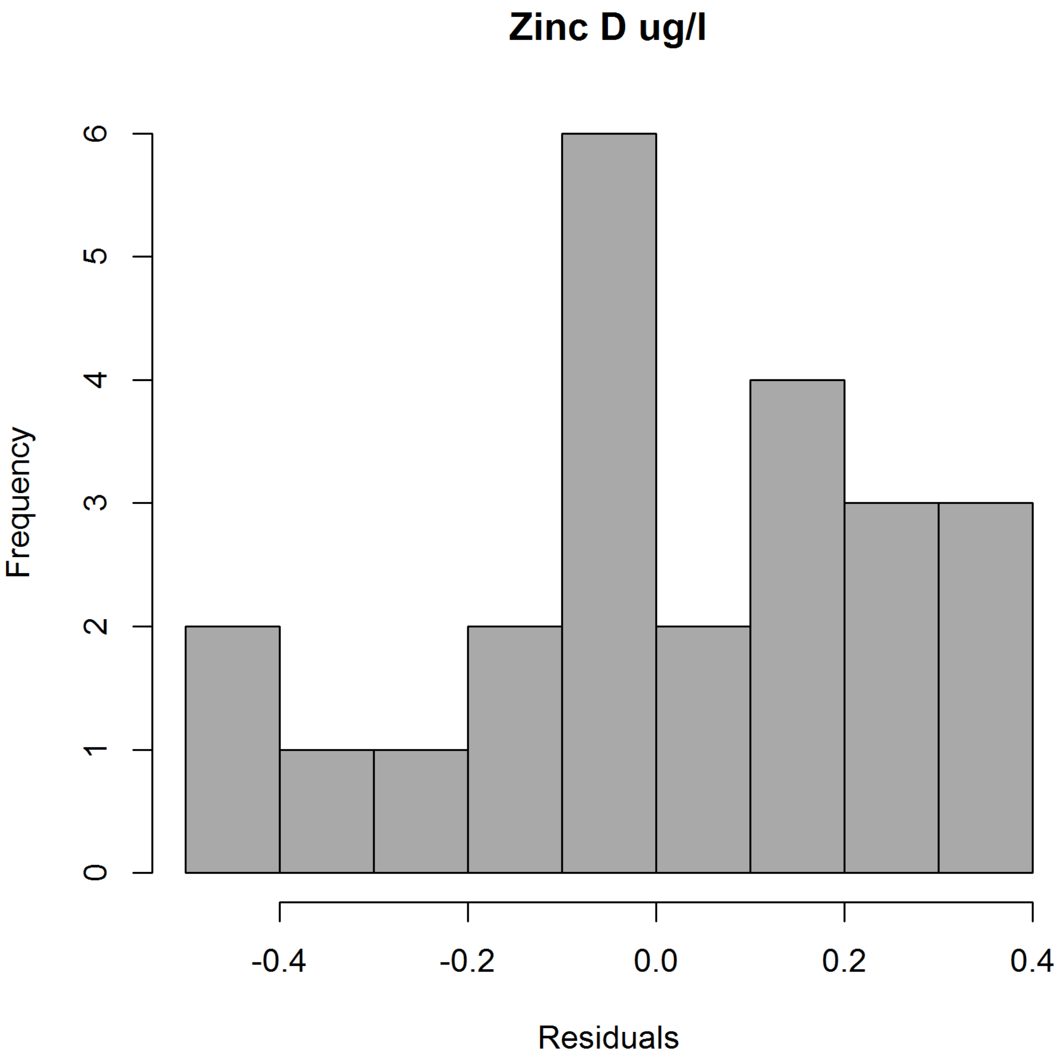
Total Organic Carbon N mg/l
Frequency
0
1
2
3
4
5
6
7
-0.5
0.0
0.5
1.0
Residuals



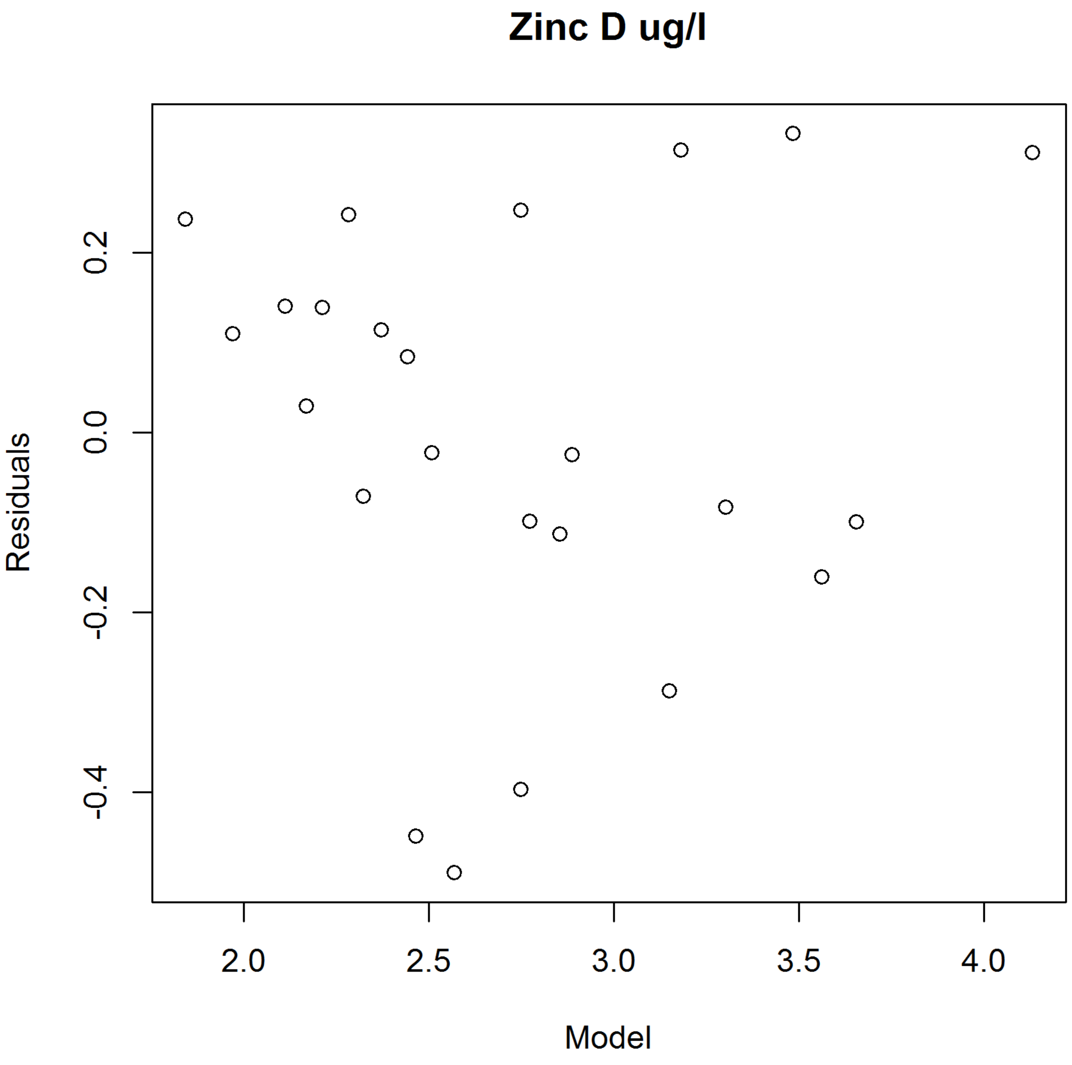
Total Organic Carbon N mg/l
Residuals
-0.5
0.0
0.5
2.0
2.5
3.0
3.5
Model



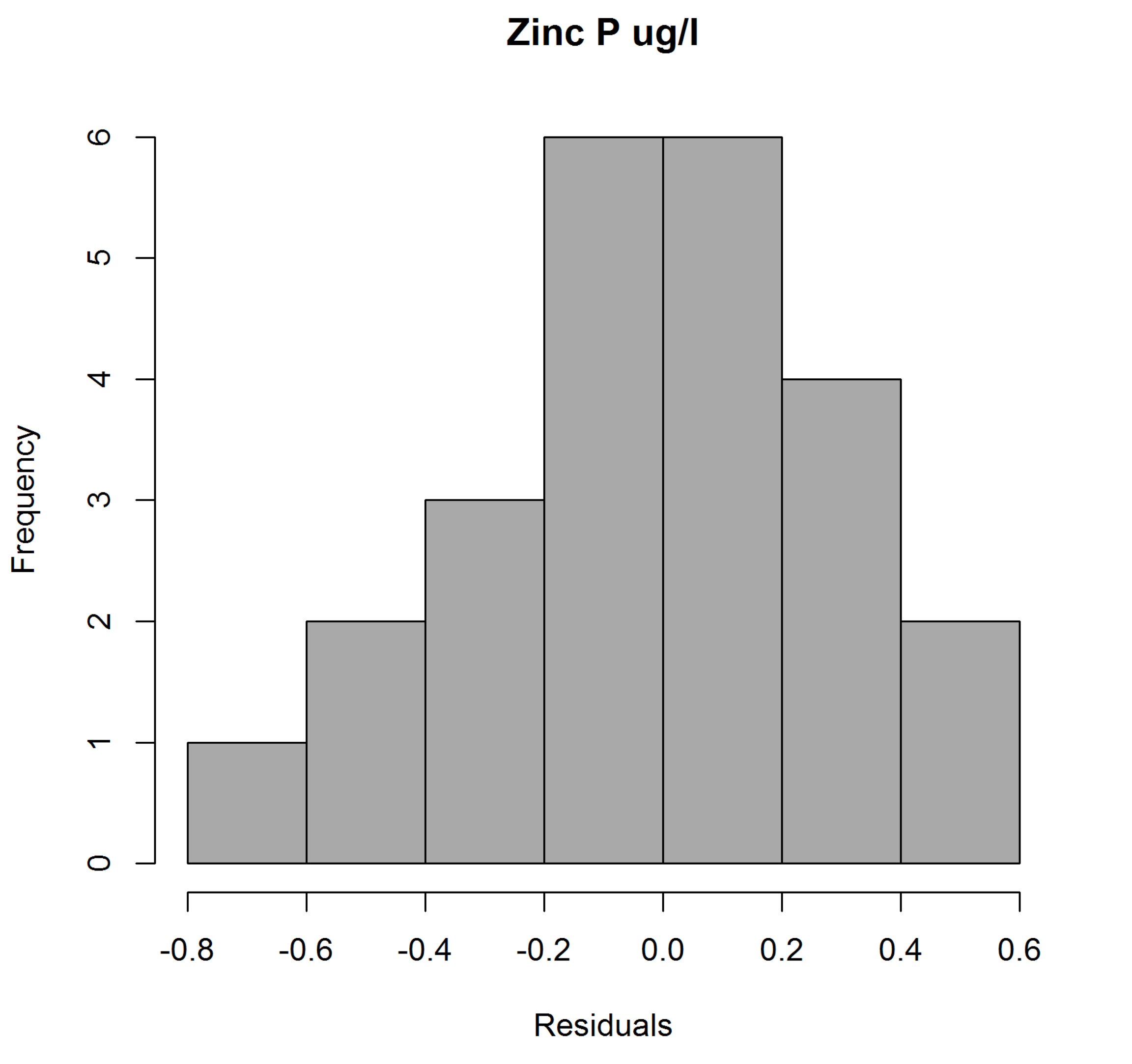
Total Organic Carbon N mg/l
Impact
4.0
3.5
3.0
2.5
2.0
2.0
2.5
3.0
3.5
4.0
Control
Year 1
Year 2



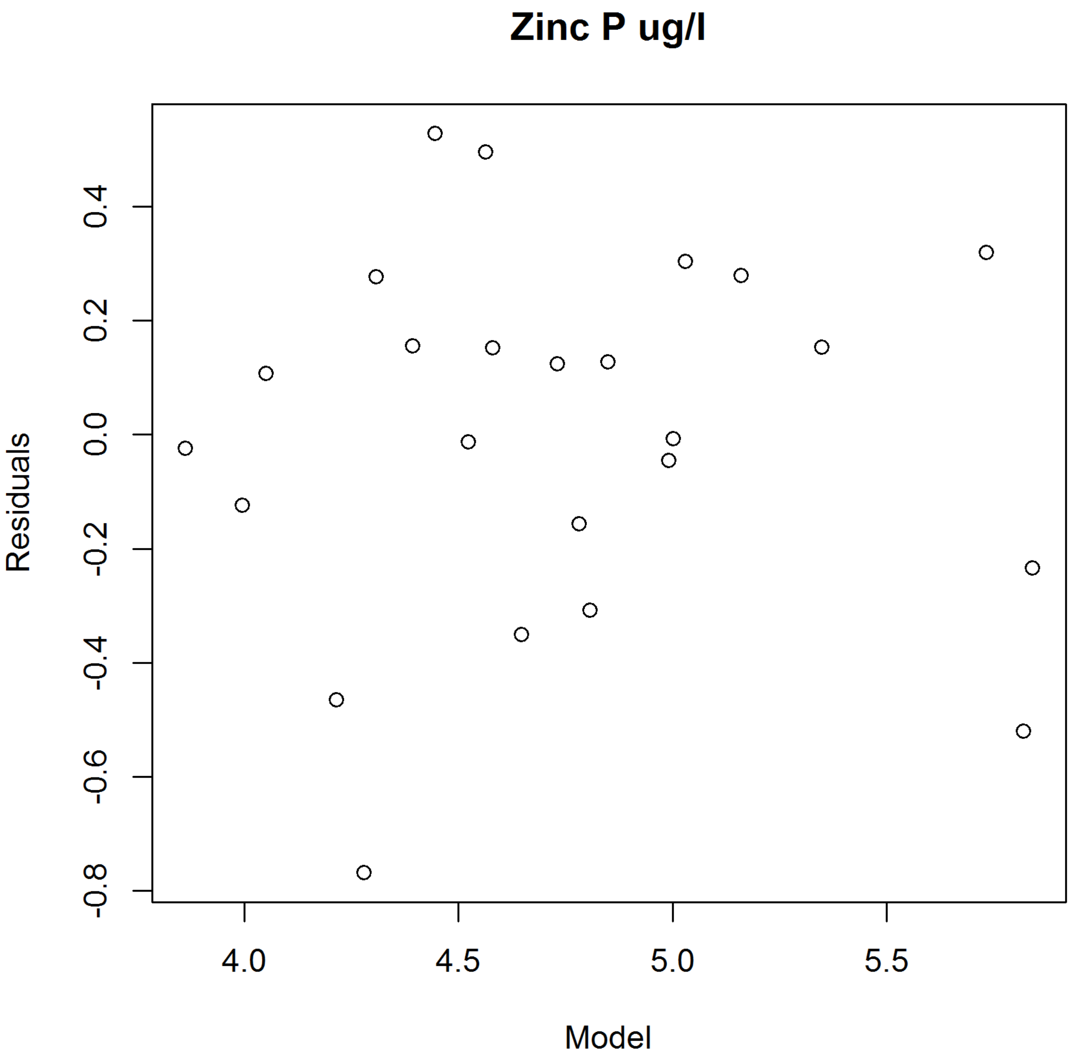
Zinc D ug/l
Frequency
0
1
2
3
4
5
6
-0.4
-0.2
0.0
0.2
0.4
Residuals

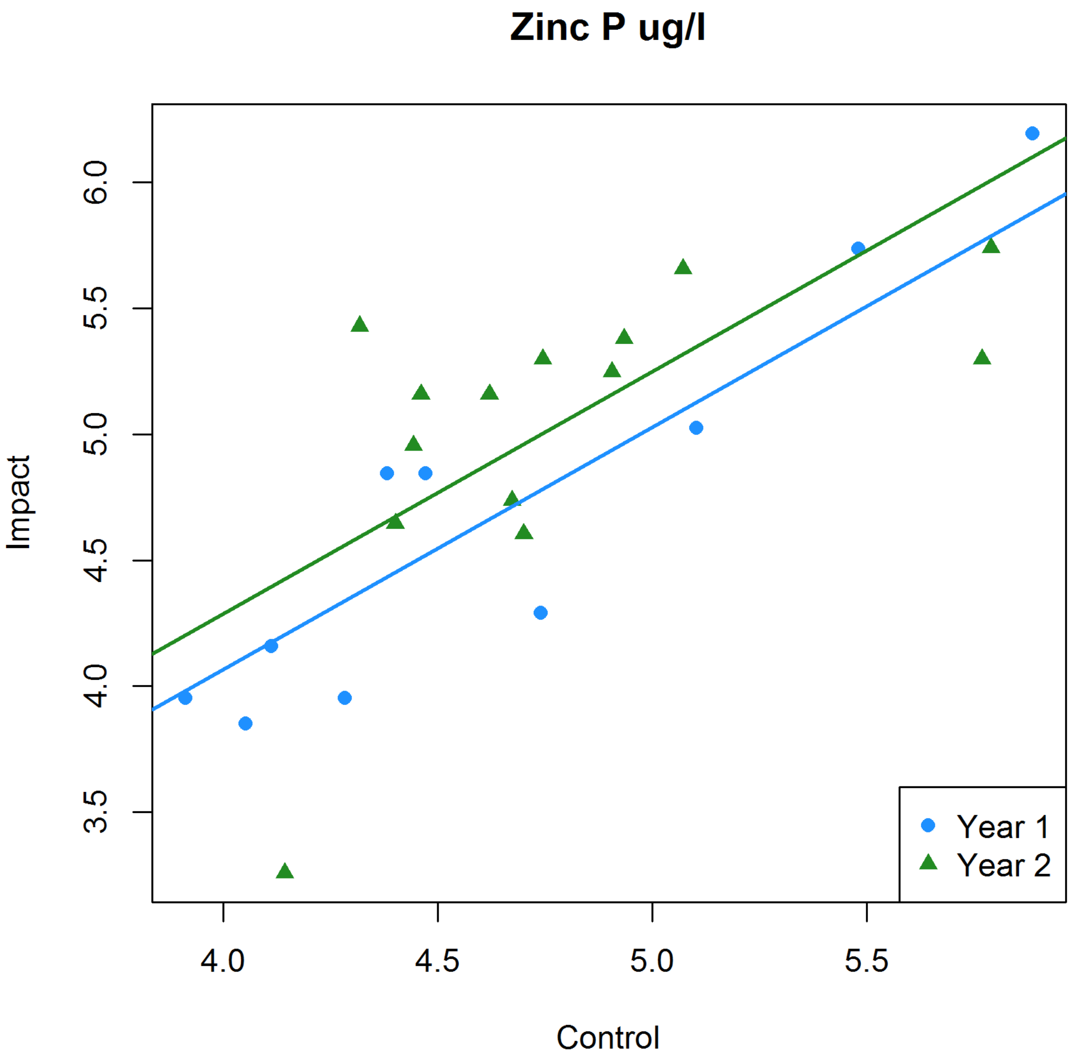


Zinc D ug/l
Residuals
Model
0.2
0.0
-0.2
-0.4
2.0
2.5
3.0
3.5
4.0

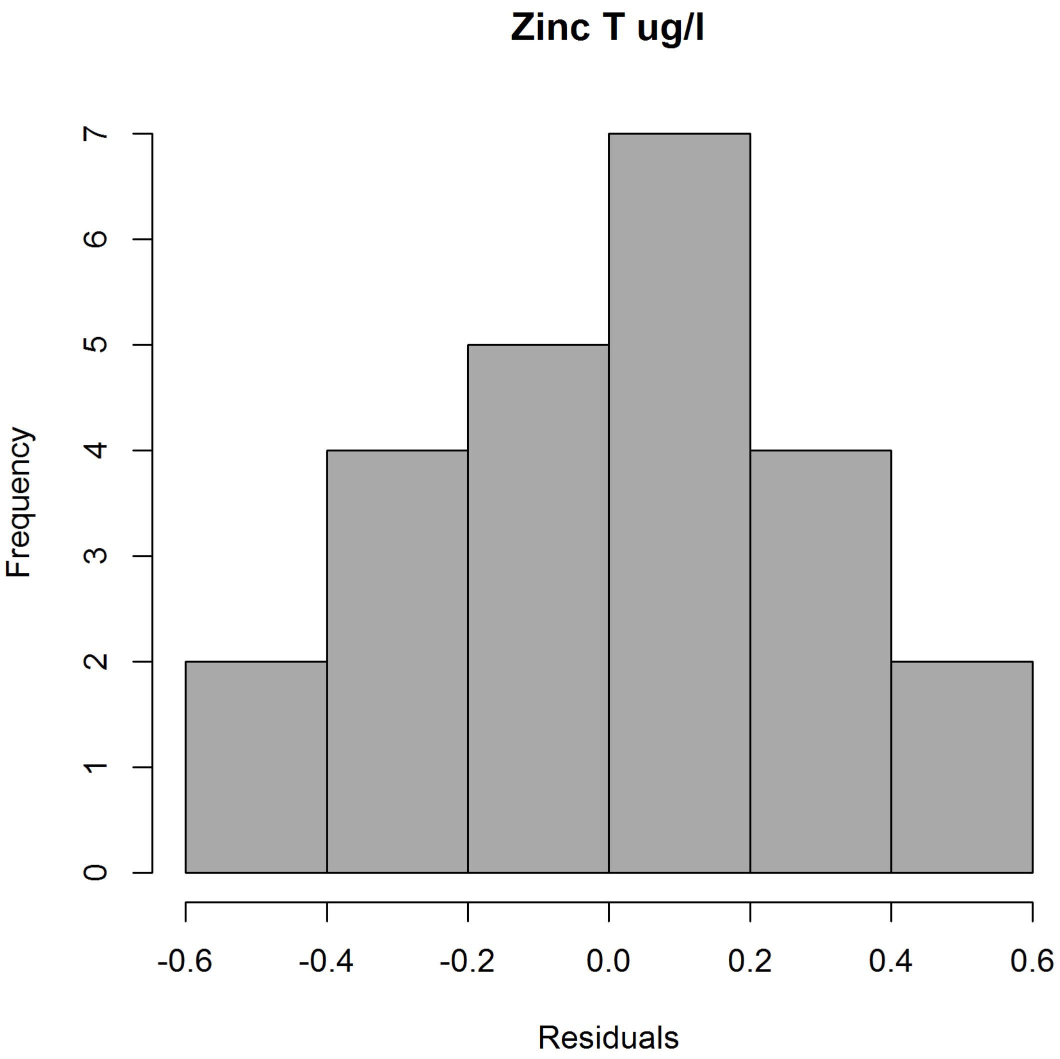


Zinc P ug/l
Frequency
0
1
2
3
4
5
6
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
Residuals

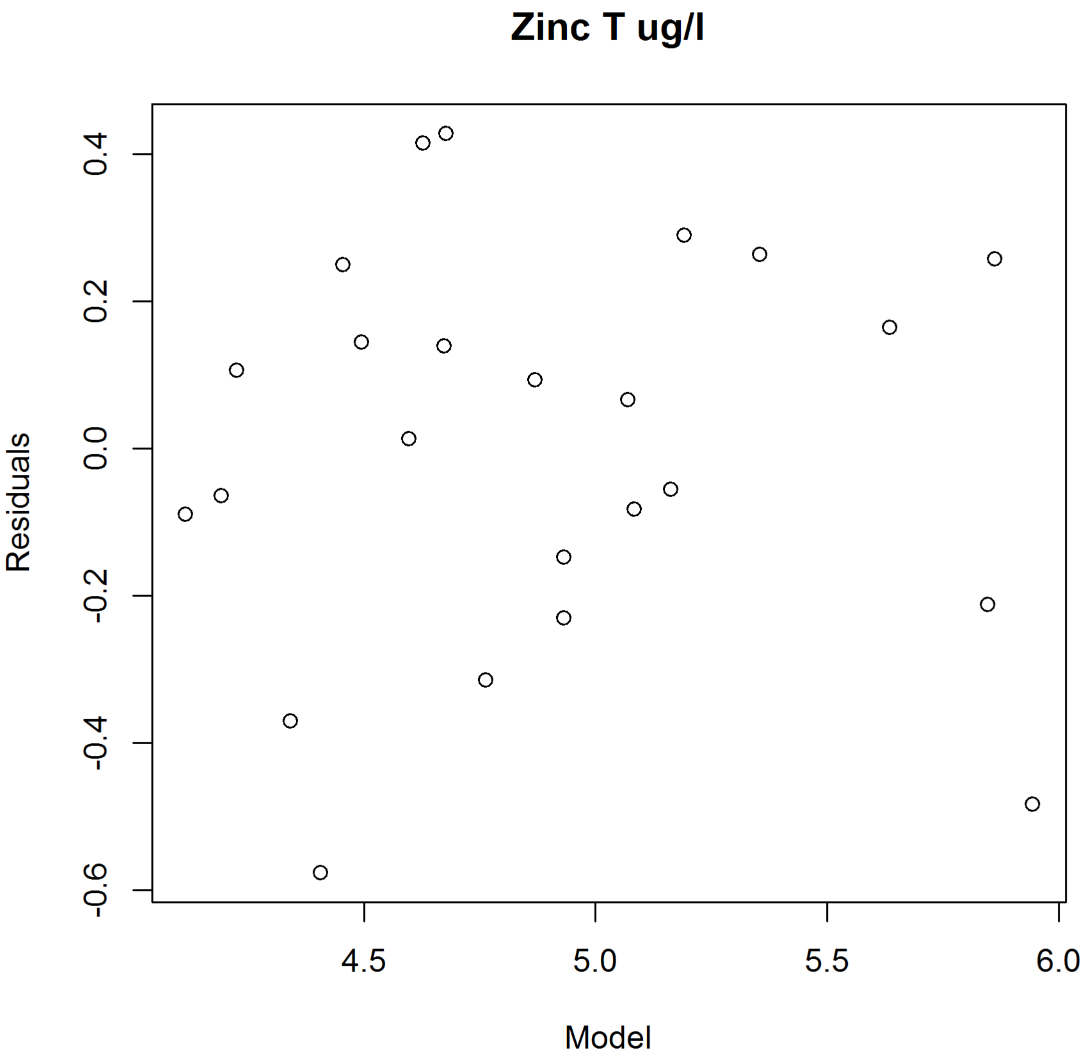

Zinc P ug/l
Residuals
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
4.0
4.5
5.0
5.5
Model



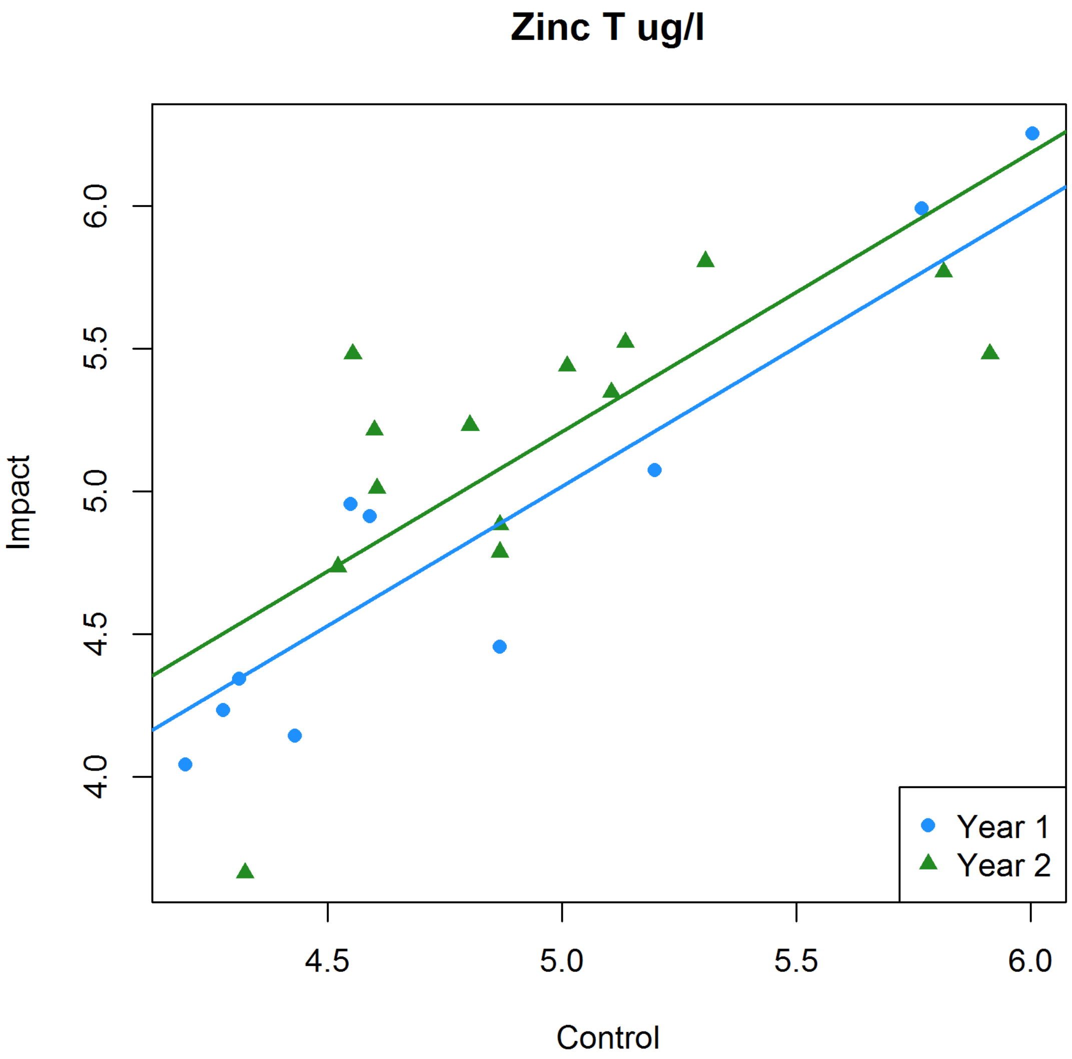
Zinc P ug/l
Impact
Control
6.0
5.5
5.0
4.5
4.0
3.5
4.0
4.5
5.0
5.5
Year 1
Year 2

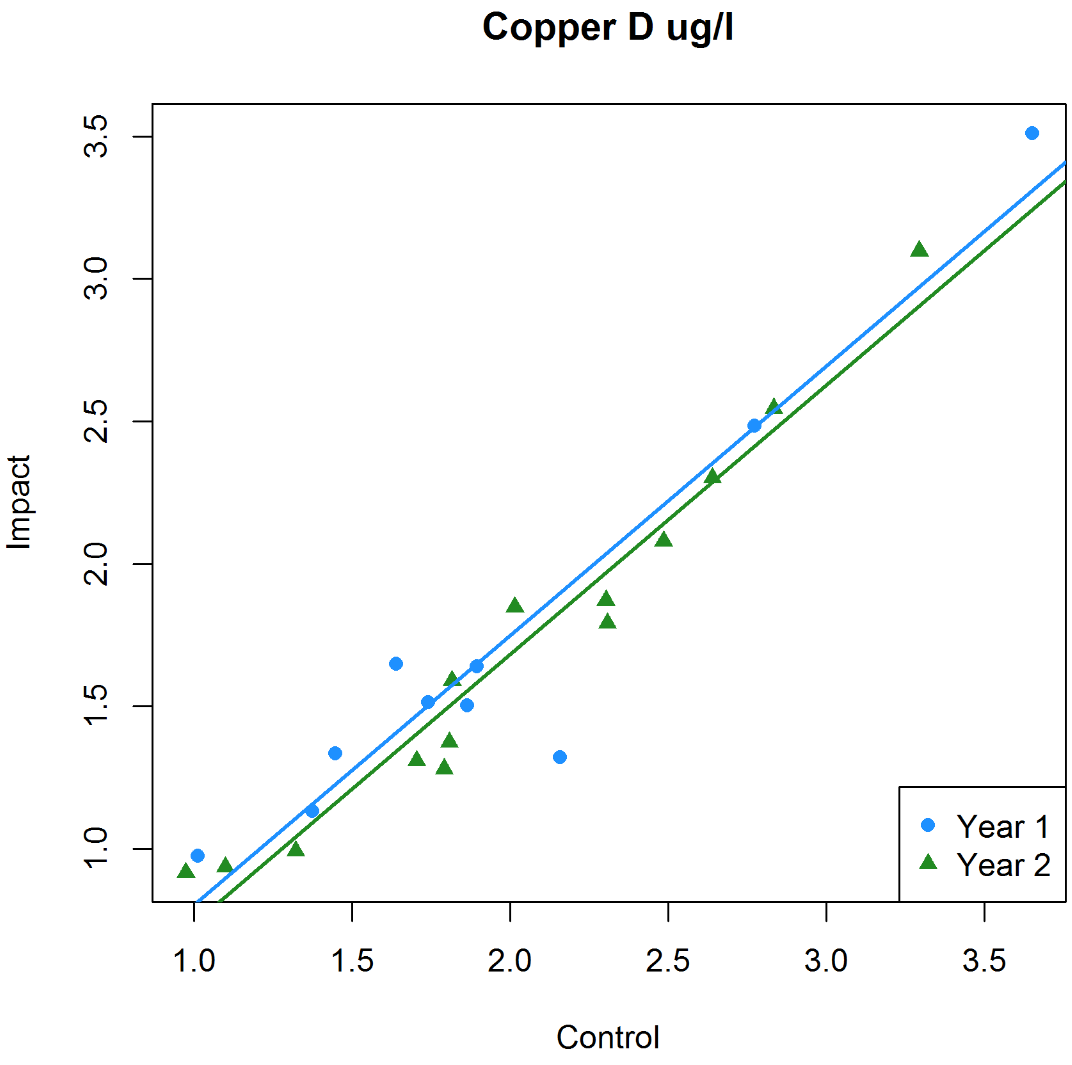


Zinc T ug/l
Frequency
Residuals
0
1
2
3
4
5
6
7
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6

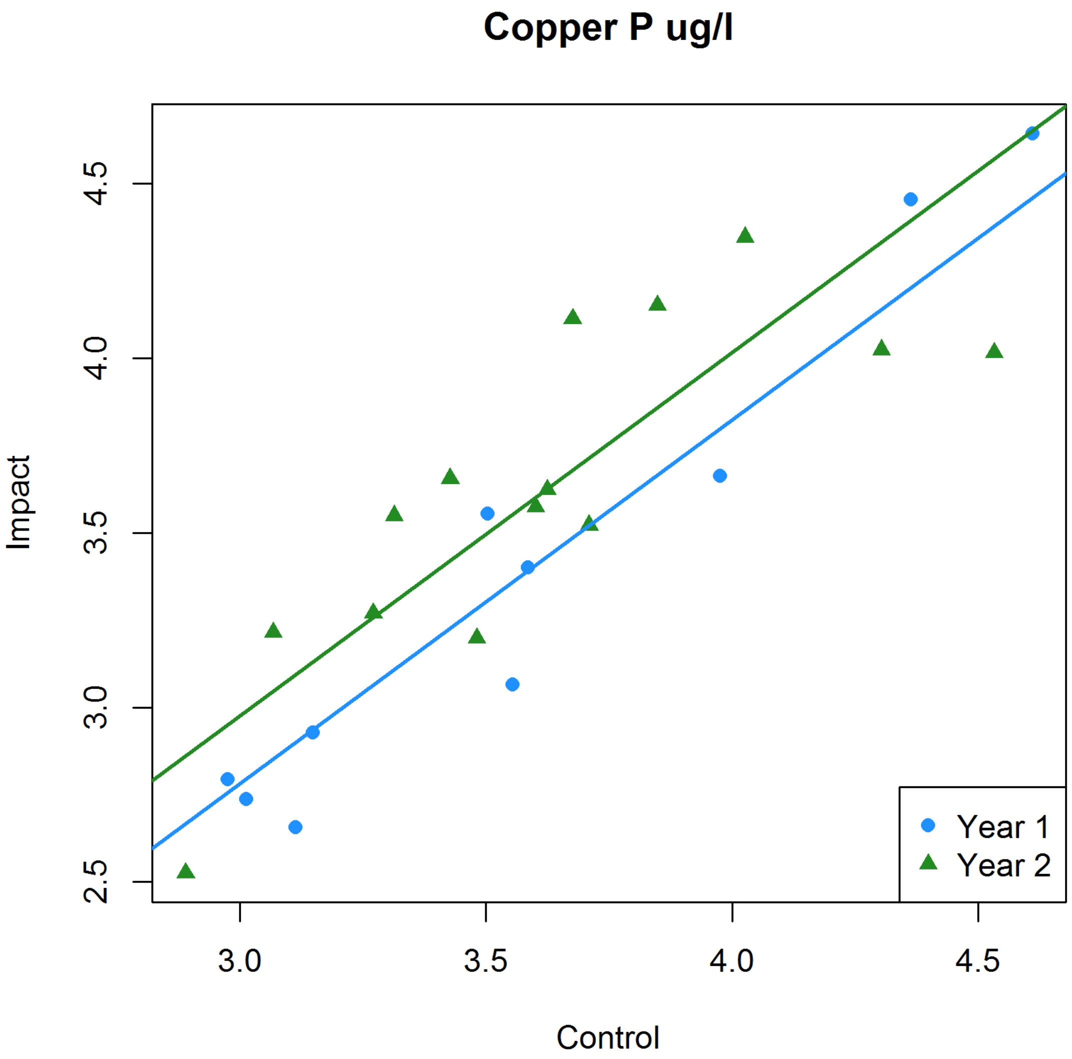


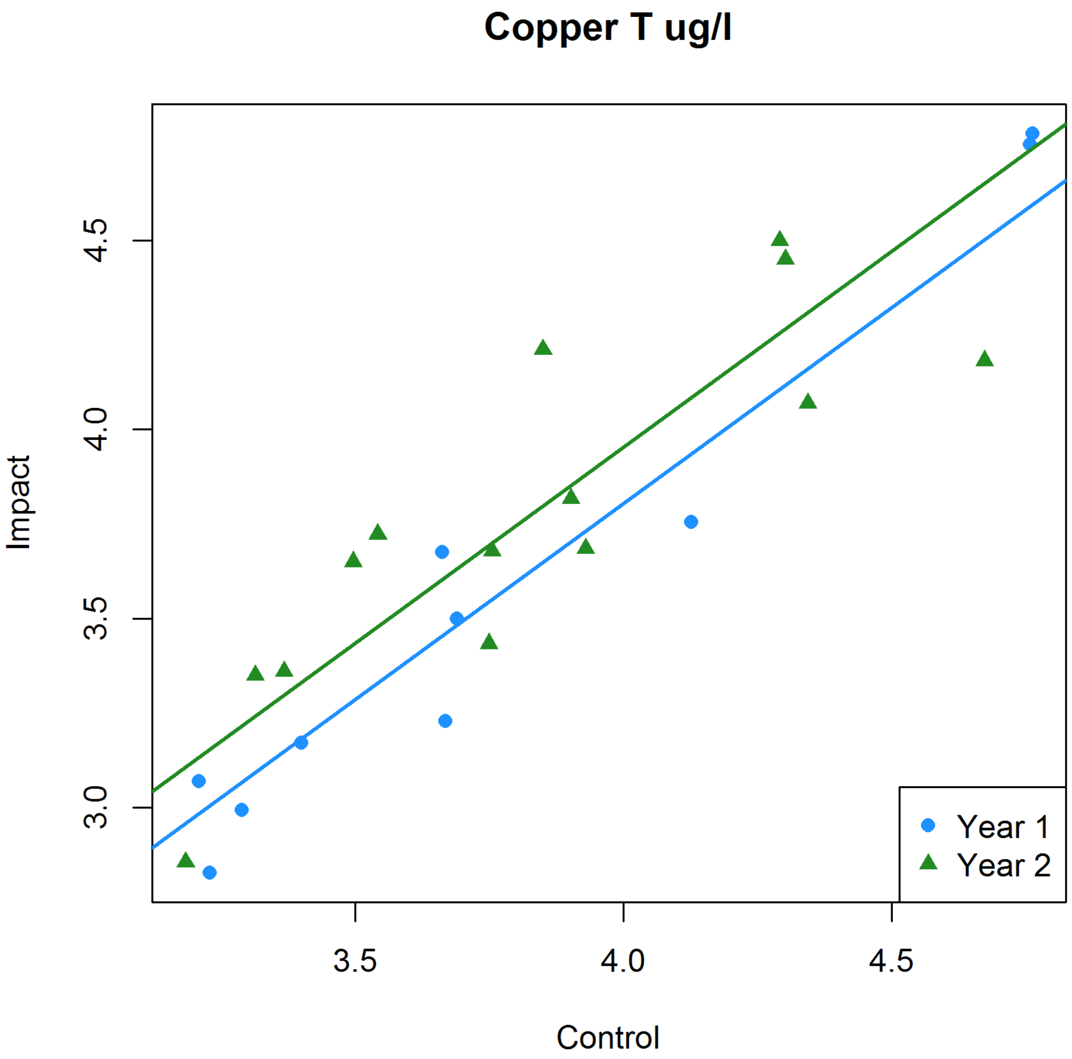
Zinc T ug/l
Residuals
0.4
0.2
0.0
-0.2
-0.4
-0.6
4.5
5.0
5.5
6.0
Model


Zinc T ug/l
Impact
Control
4.0
4.5
5.0
5.5
6.0
4.5
5.0
5.5
6.0
Year 1
Year 2

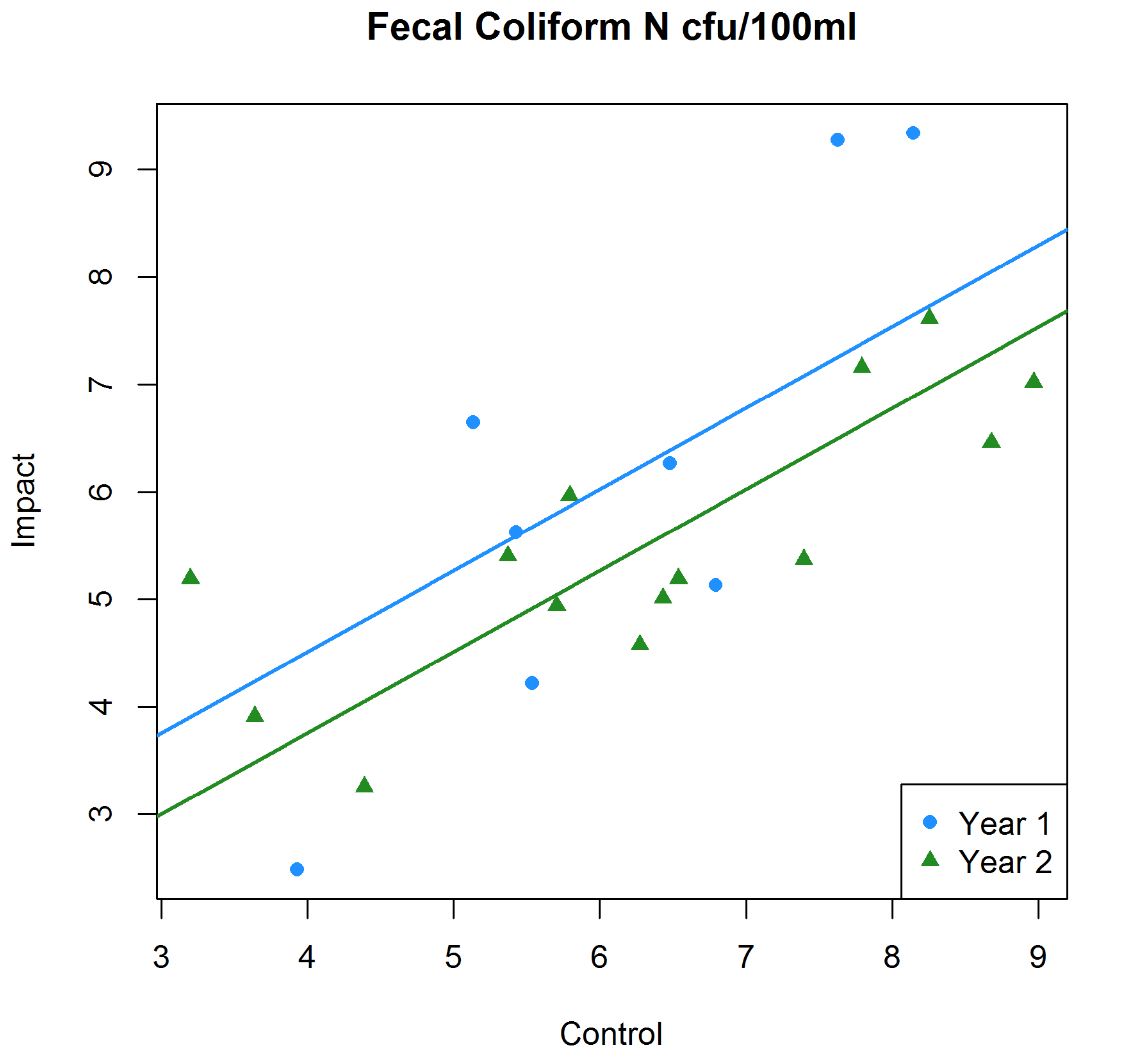


Copper D ug/l
Impact
Control
1.0
1.5
2.0
2.5
3.0
3.5
Year 1
Year 2

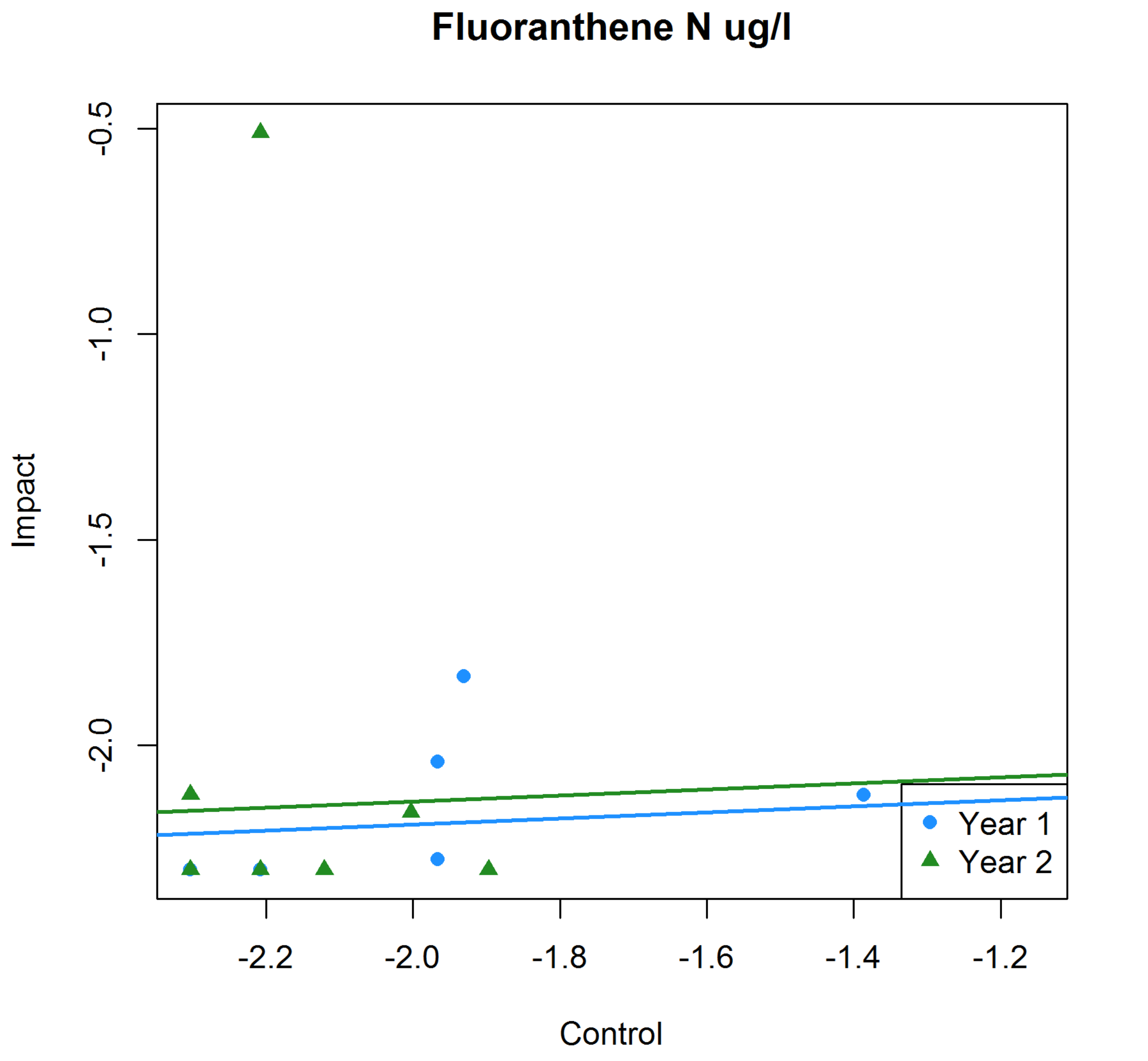

Copper P ug/l
Impact
Control
2.5
3.0
3.5
4.0
4.5
3.0
3.5
4.0
4.5
Year 1
Year 2



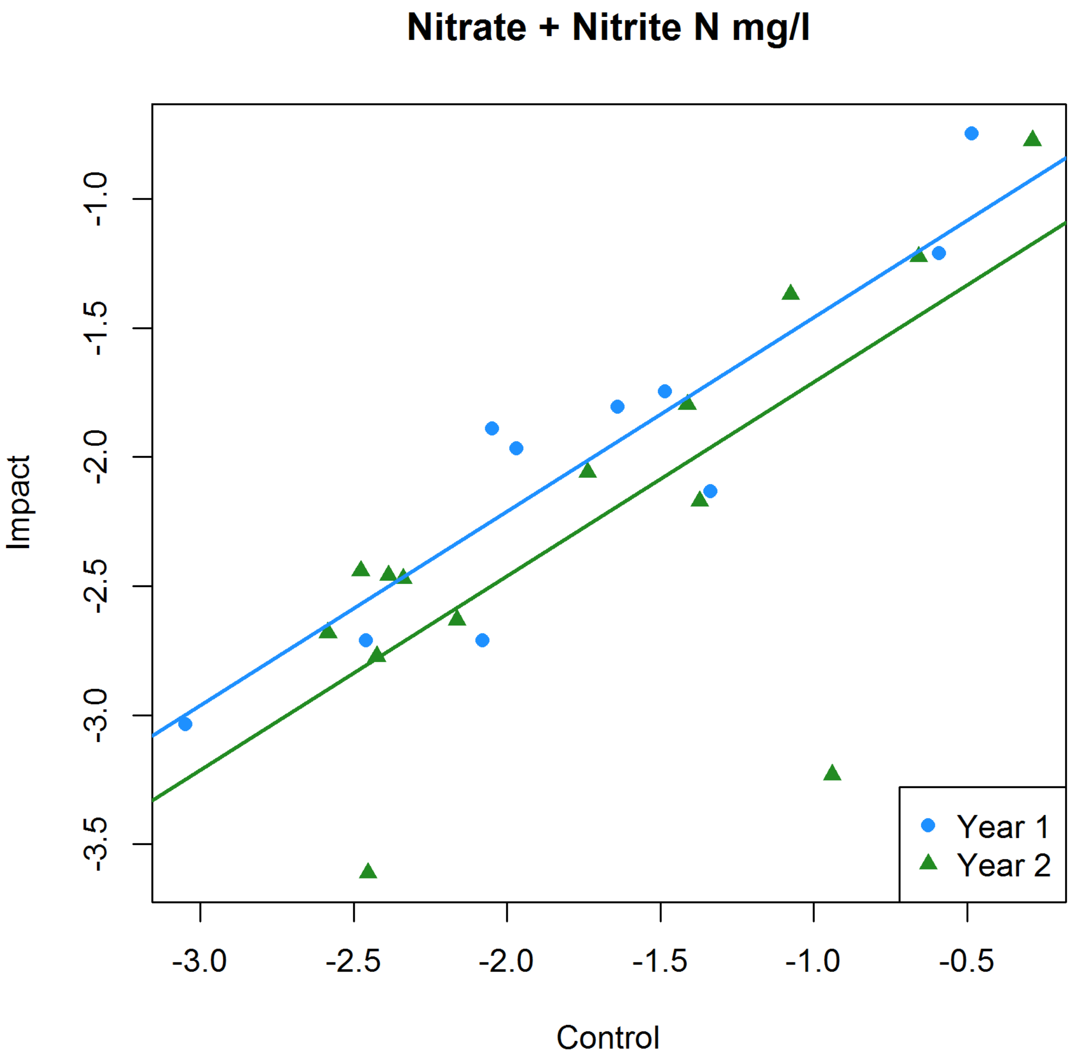
Copper T ug/l
Impact
Control
3.0
3.5
4.0
4.5
3.5
4.0
4.5
Year 1
Year 2



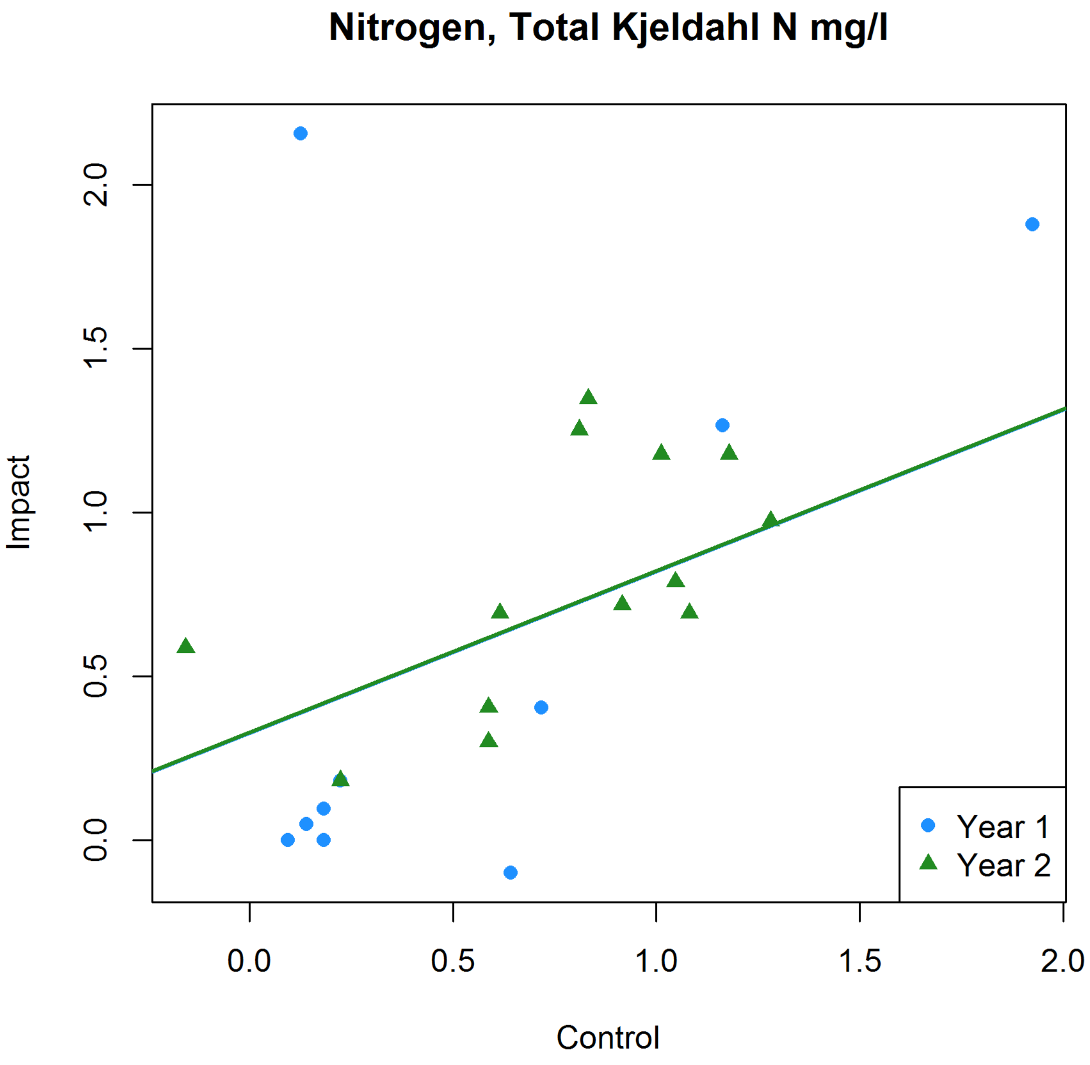
Fecal Coliform N cfu/100ml
Impact
Control
3
4
5
6
7
8
9
Year 1
Year 2

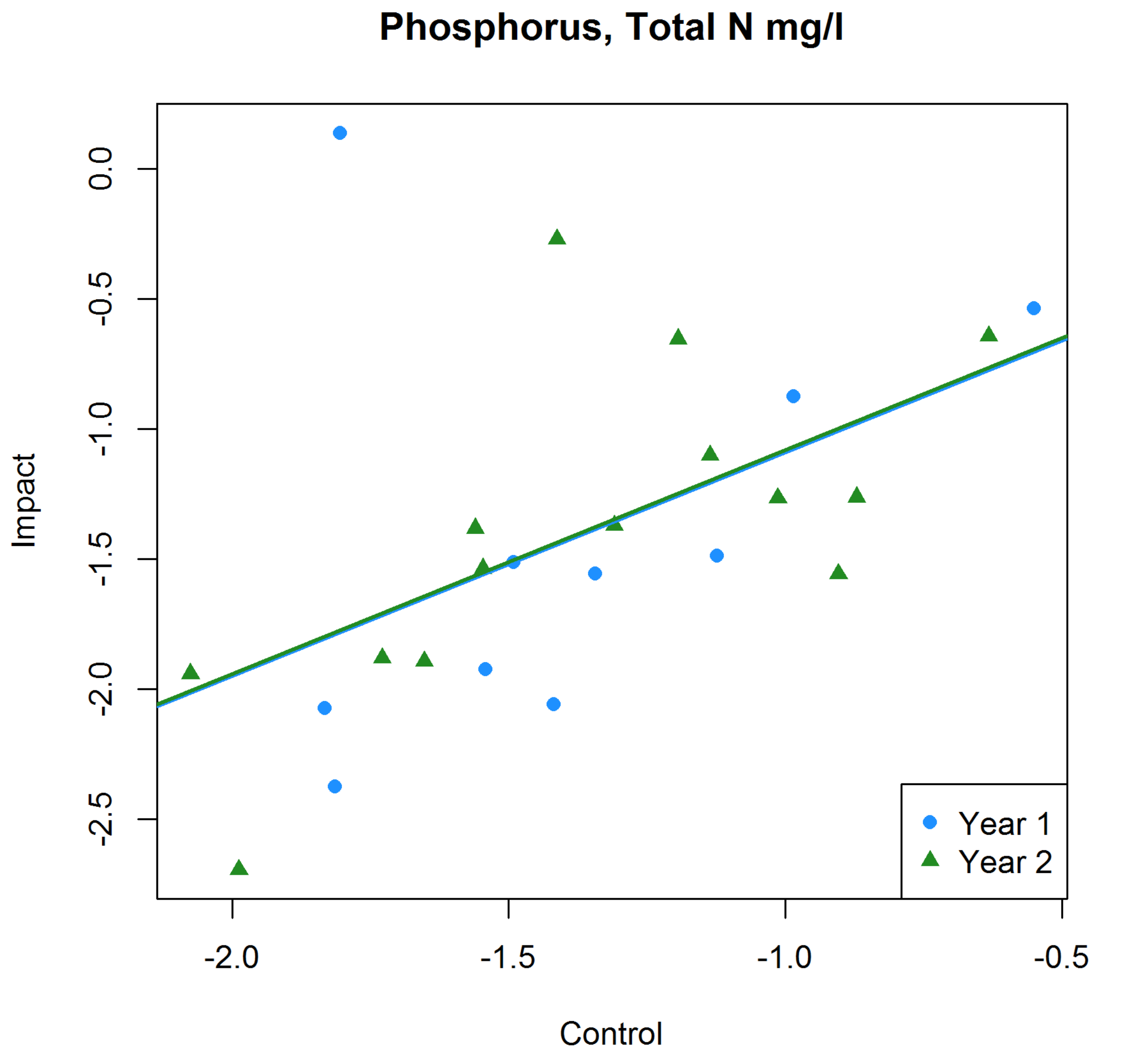


Fluoranthene N ug/l
Impact
-0.5
-1.0
-1.5
-2.0
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
Control
Year 1
Year 2

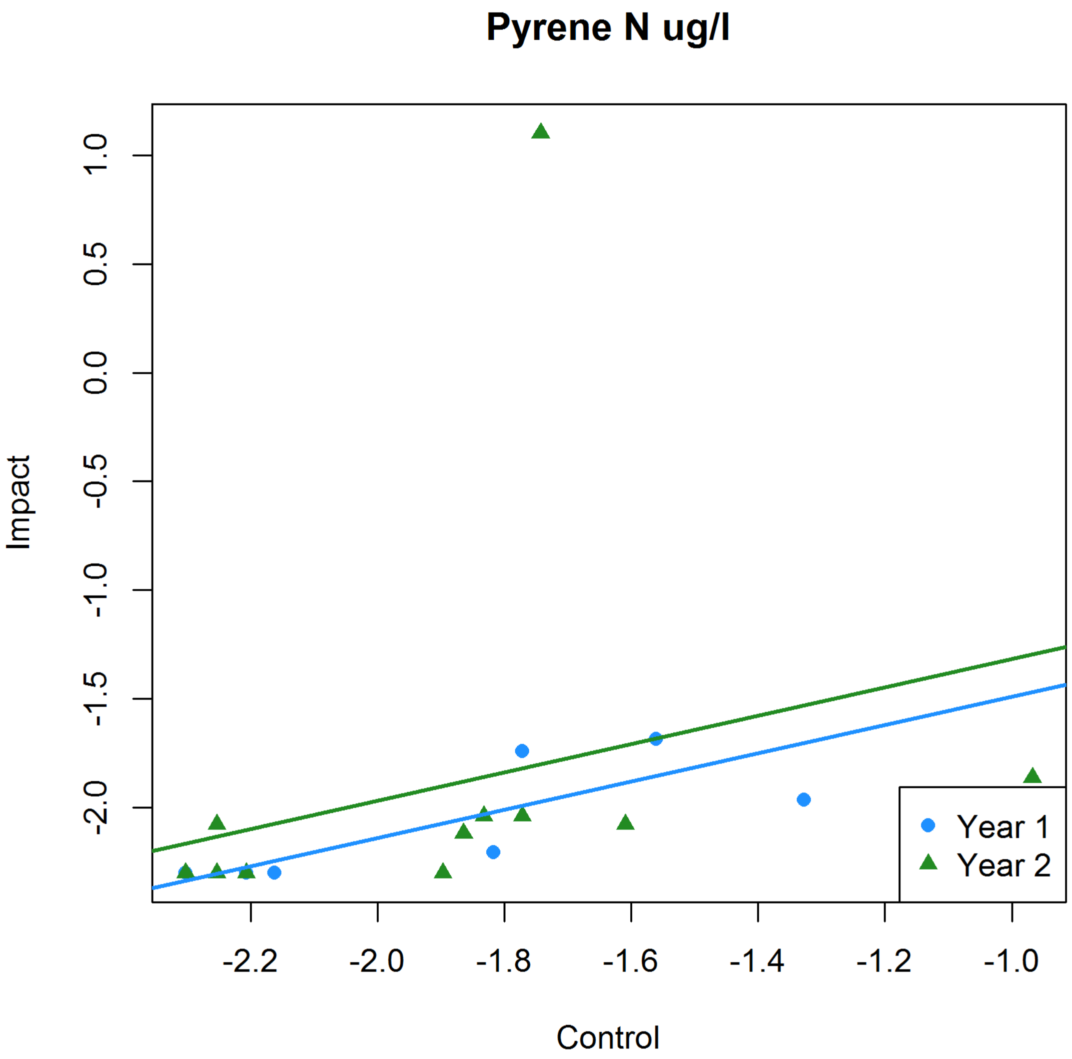


Nitrate + Nitrite N mg/l
Impact
Control
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
Year 1
Year 2

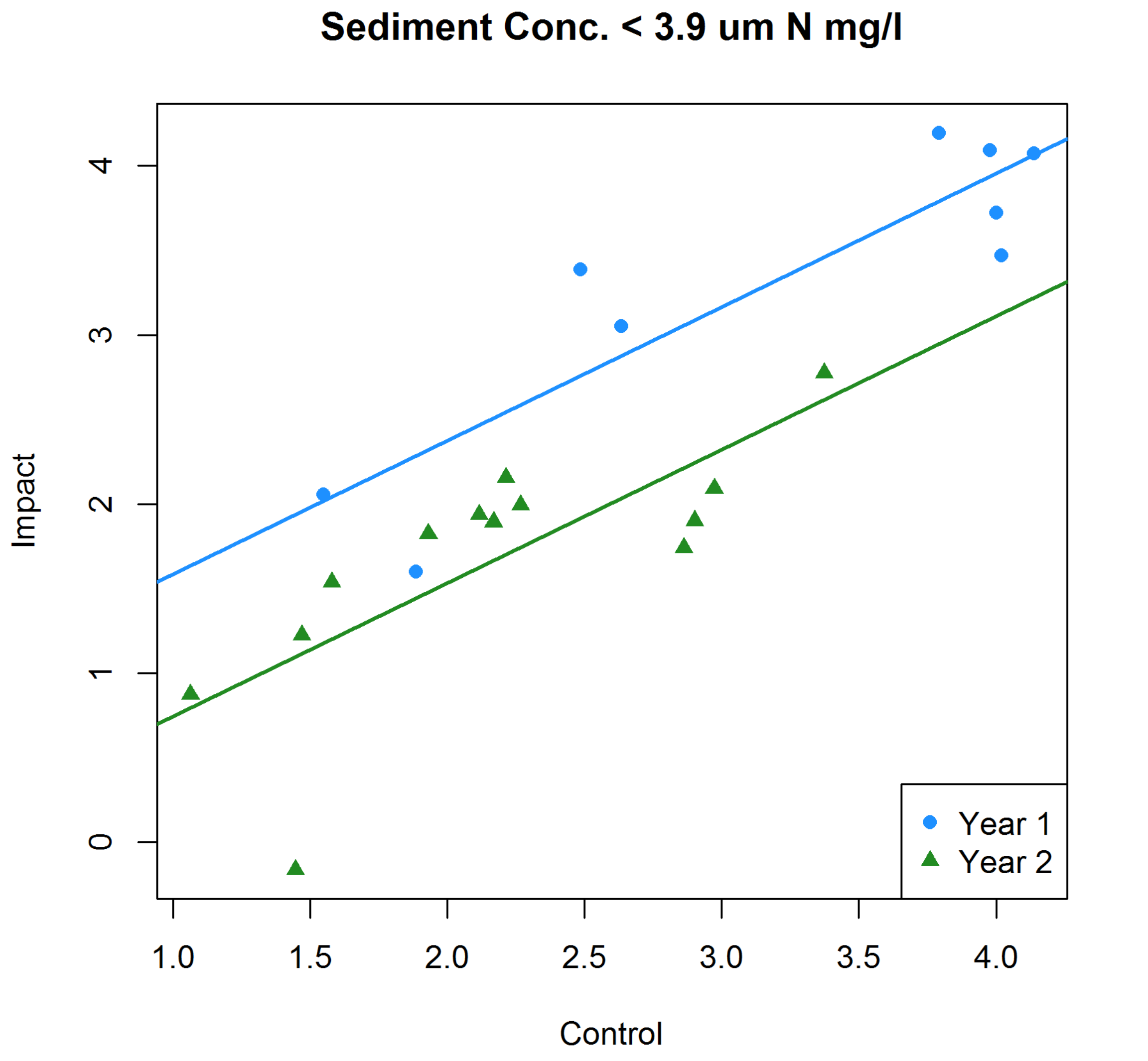

Nitrogen, Total Kjeldahl N mg/l
Impact
Control
0.0
0.5
1.0
1.5
2.0
Year 1
Year 2



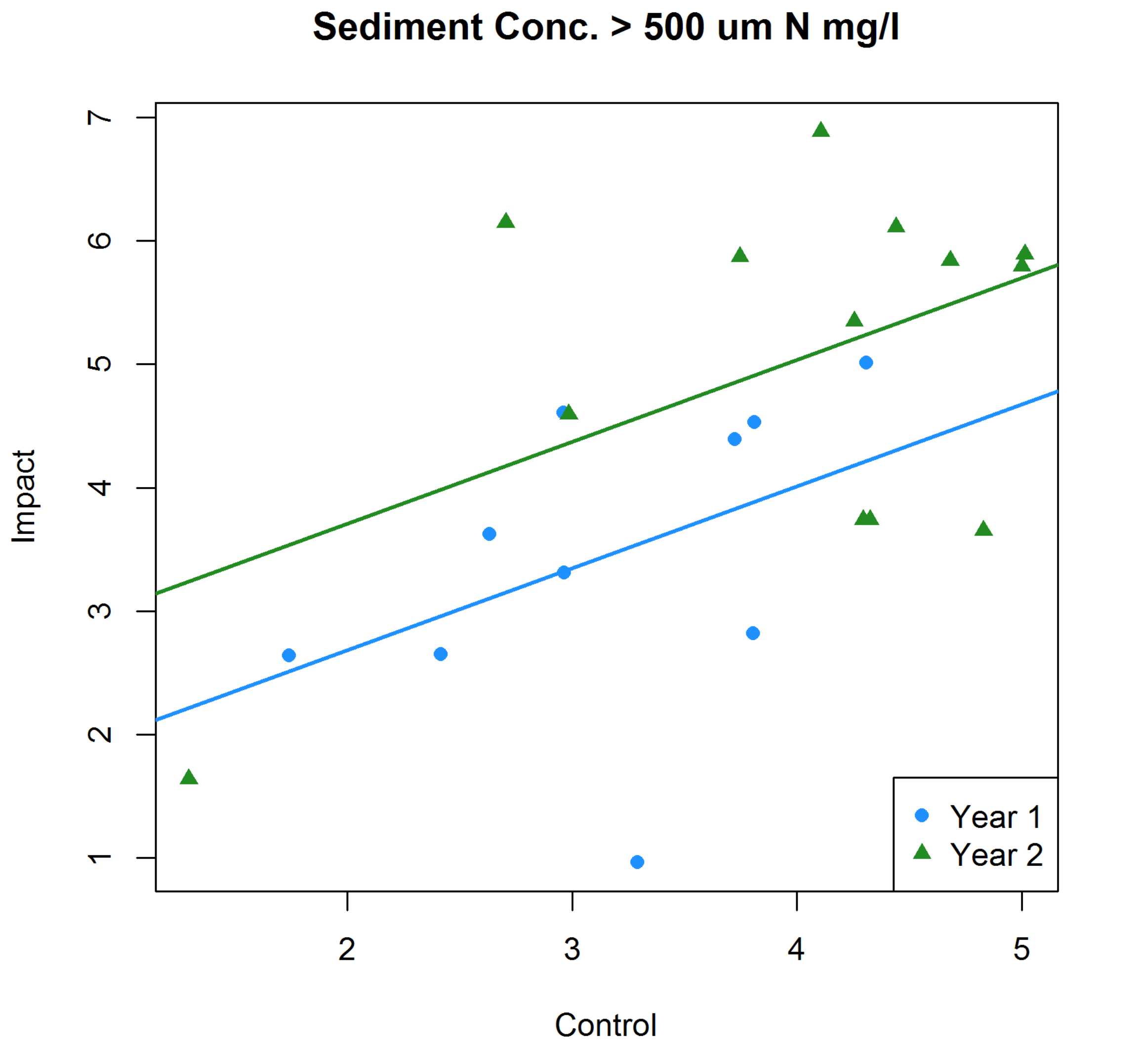
Phosphorus, Total N mg/l
Impact
Control
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-2.0
-1.5
-1.0
-0.5
Year 1
Year 2



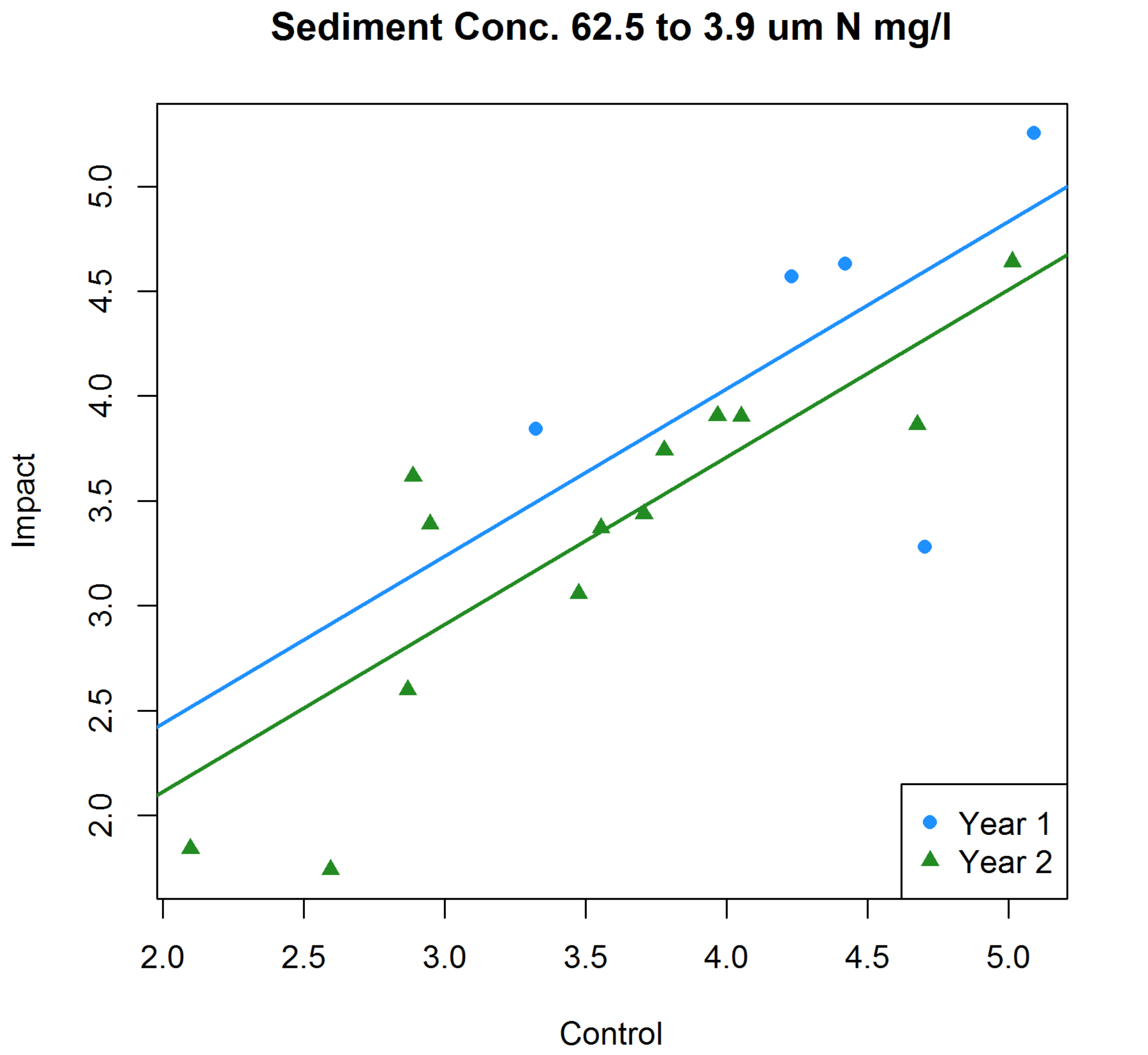
Pyrene N ug/l
Impact
Control
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
Year 1
Year 2



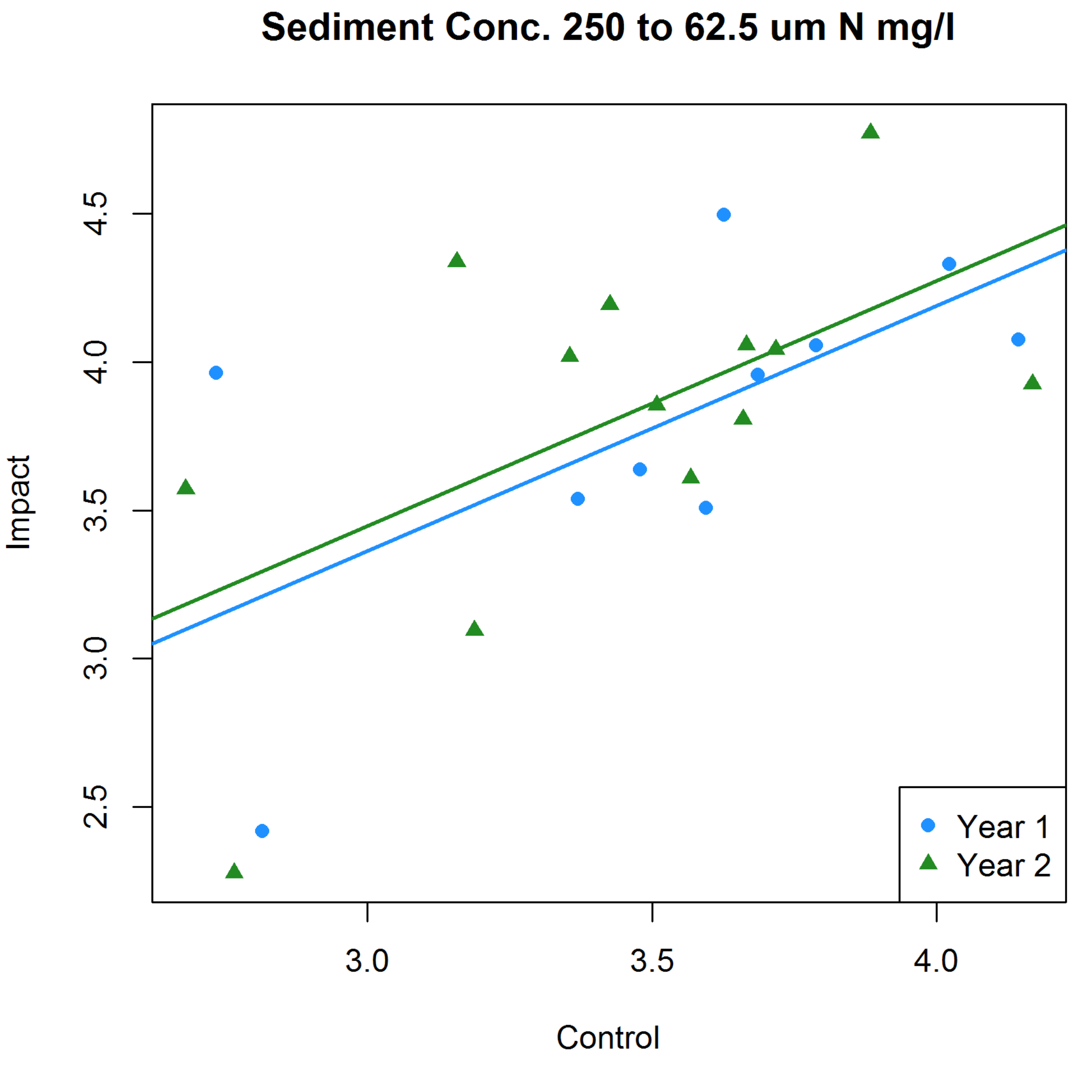
Sediment Conc. < 3.9 um N mg/l
Impact
0
1
2
3
4
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Control
Year 1
Year 2

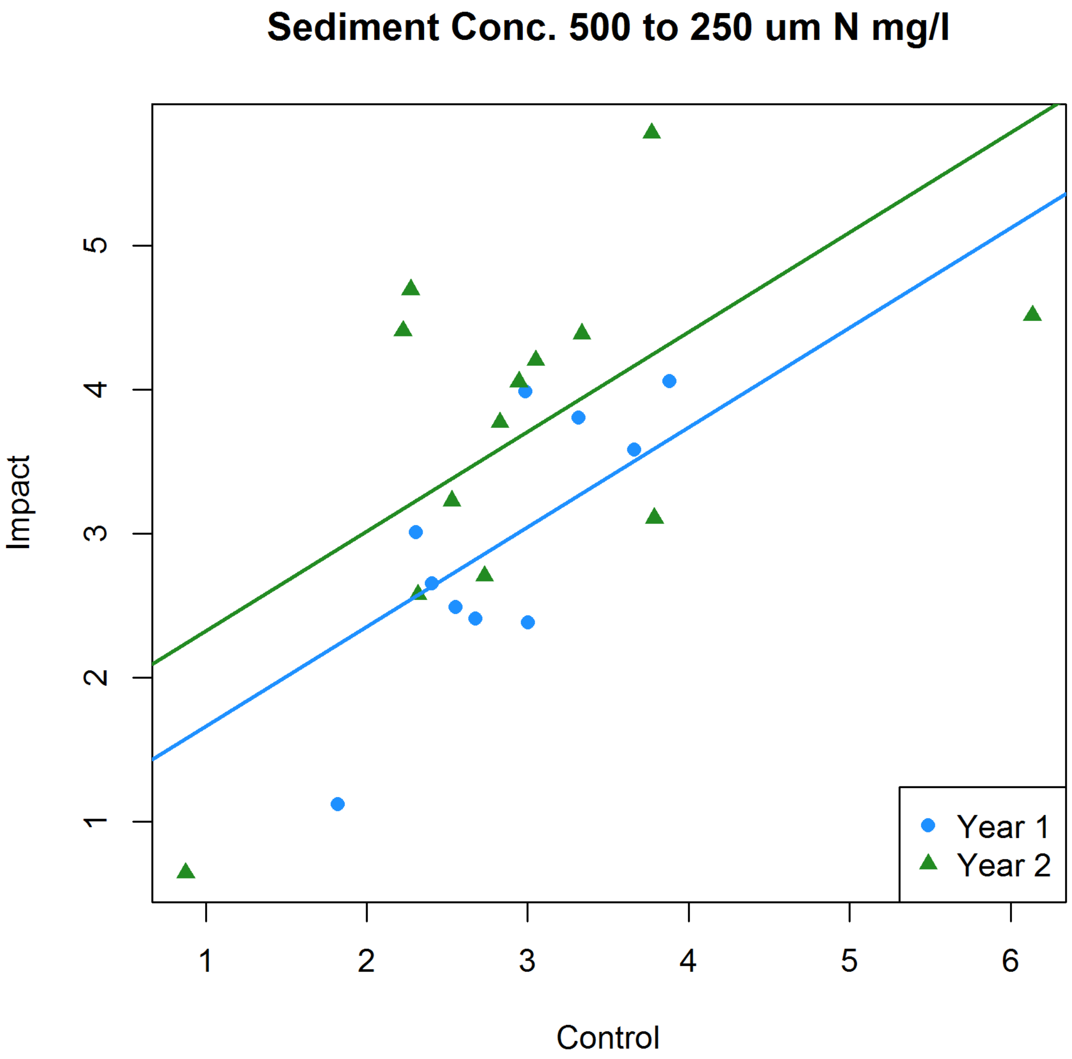


Sediment Conc. > 500 um N mg/l
Impact
Control
1
2
3
4
5
6
7
2
3
4
5
Year 1
Year 2

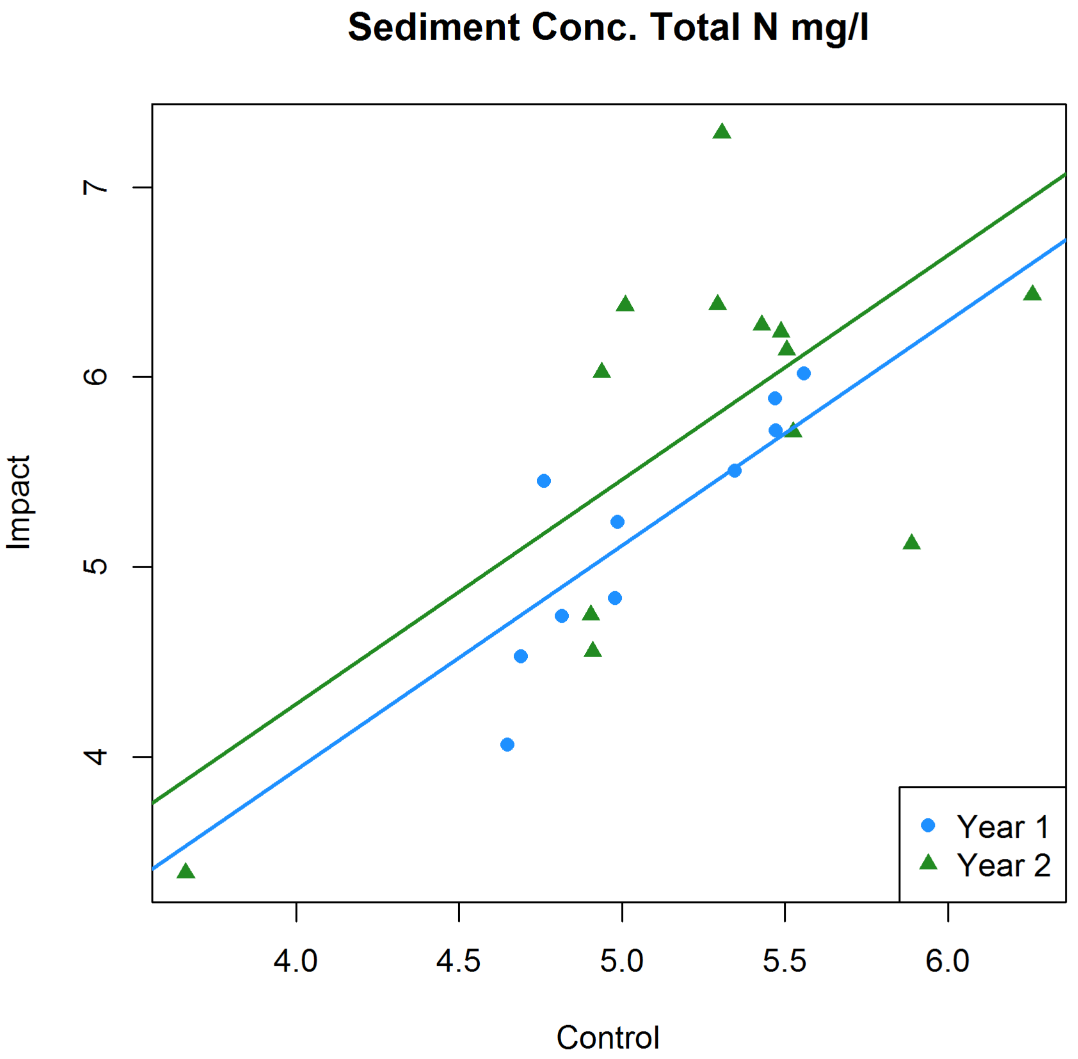


Sediment Conc. 62.5 to 3.9 um N mg/l
Impact
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Control
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Year 1
Year 2

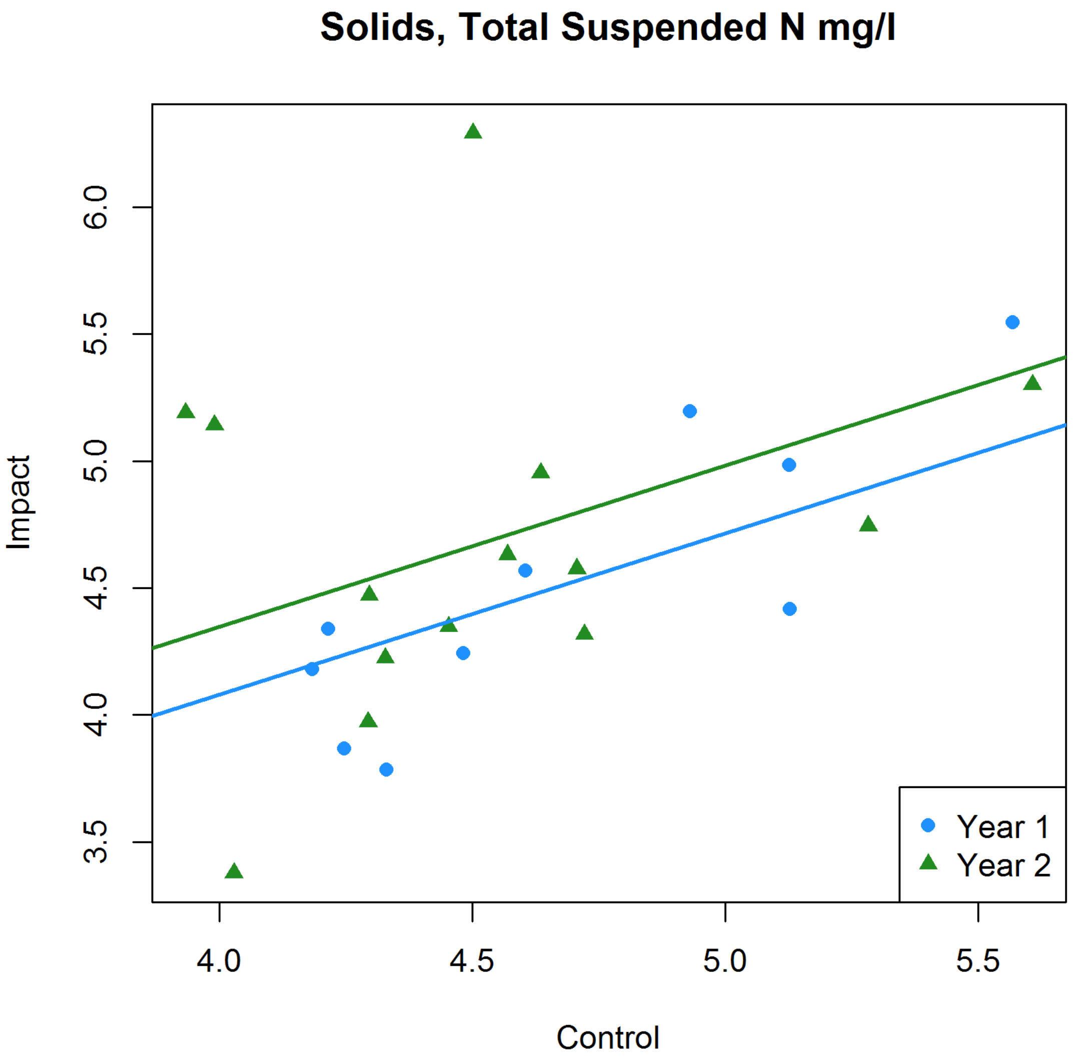

Sediment Conc. 250 to 62.5 um N mg/l
Impact
4.5
4.0
3.5
3.0
2.5
3.0
3.5
4.0
Control
Year 1
Year 2



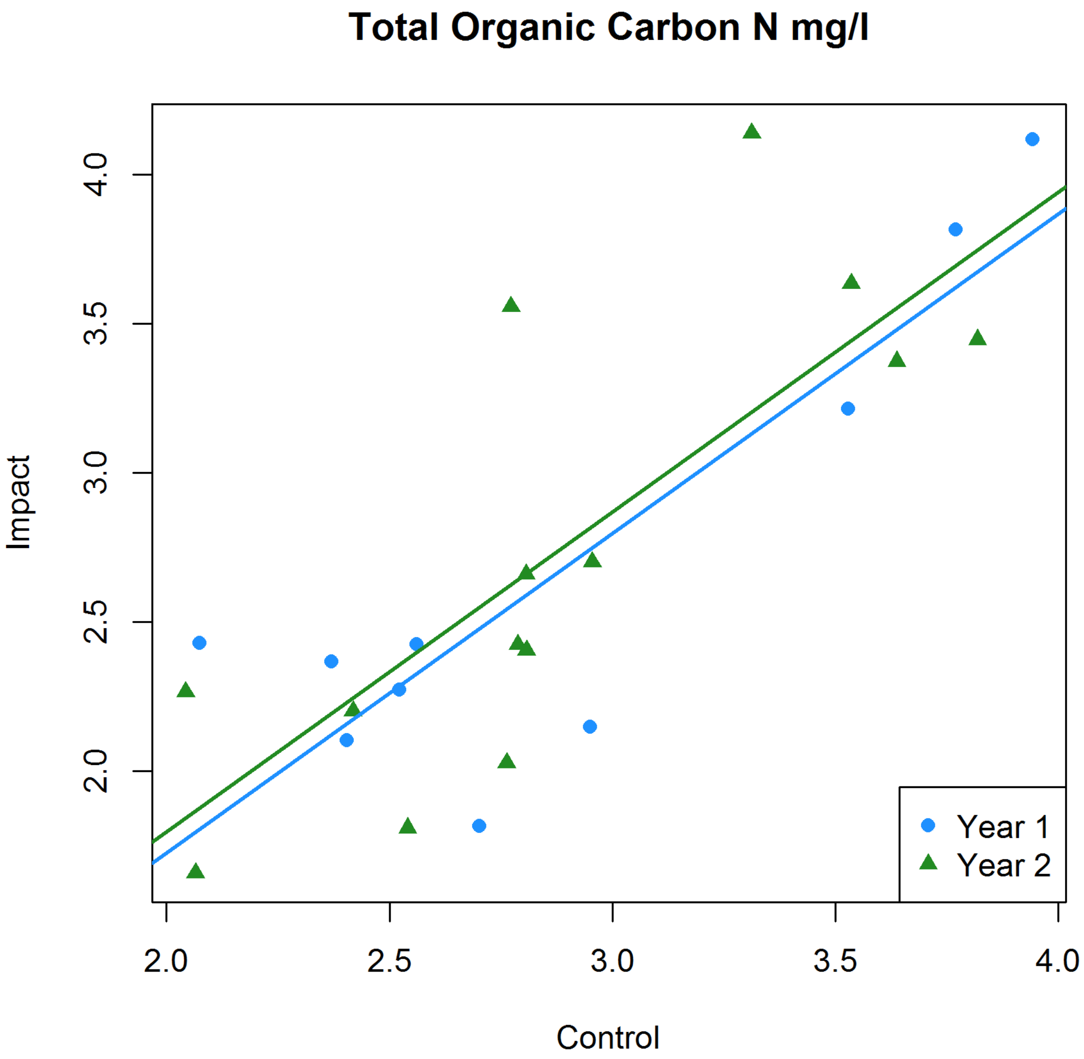
Sediment Conc. 500 to 250 um N mg/l
Impact
Control
1
2
3
4
5
6
Year 1
Year 2

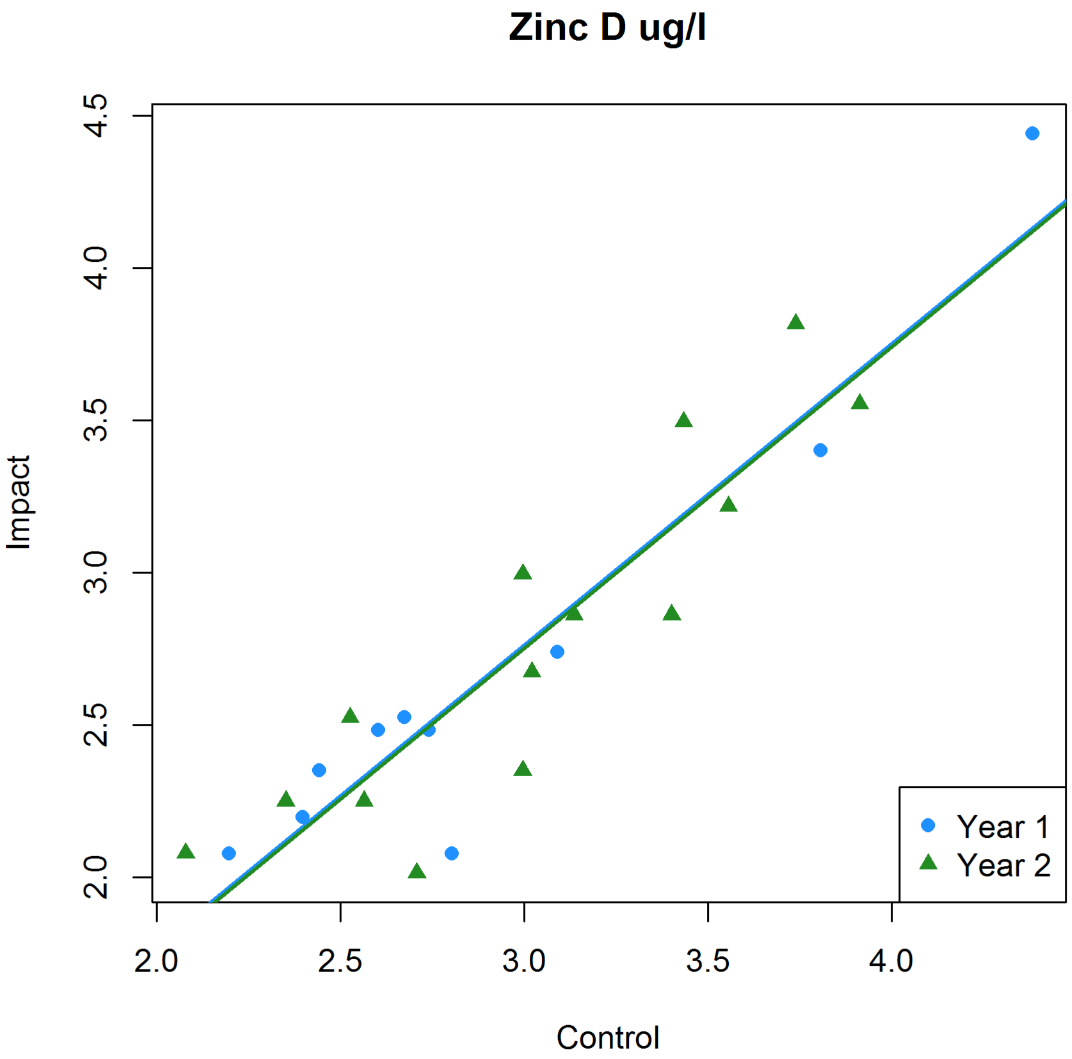


Sediment Conc. Total N mg/l
Impact
7
6
5
4
4.0
4.5
5.0
5.5
6.0
Control
Year 1
Year 2

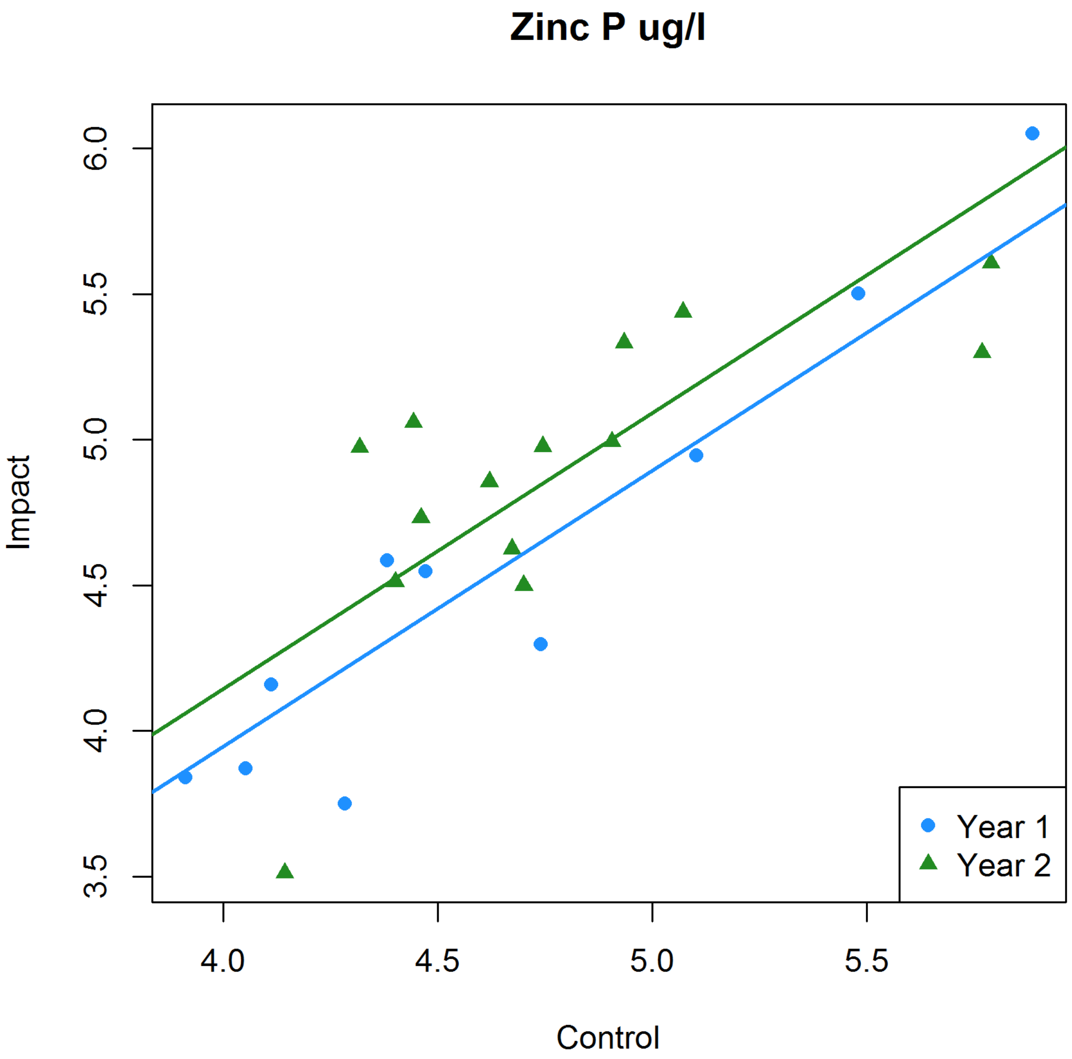


Solids, Total Suspended N mg/l
Impact
Control
6.0
5.5
5.0
4.5
4.0
3.5
4.0
4.5
5.0
5.5
Year 1
Year 2

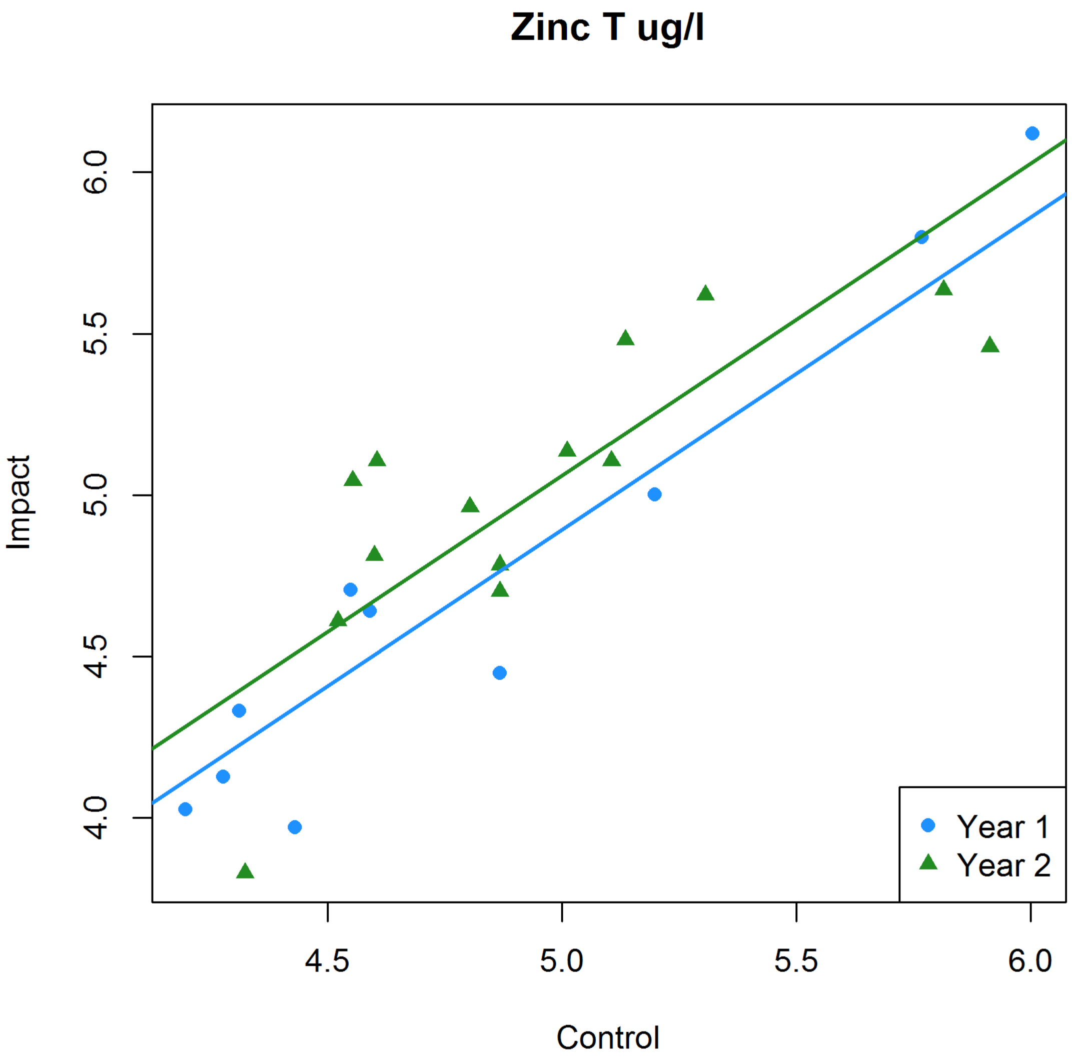

Total Organic Carbon N mg/l
Impact
Control
2.0
2.5
3.0
3.5
4.0
2.0
2.5
3.0
3.5
4.0
Year 1
Year 2



Zinc D ug/l
Impact
Control
2.0
2.5
3.0
3.5
4.0
4.5
Year 1
Year 2



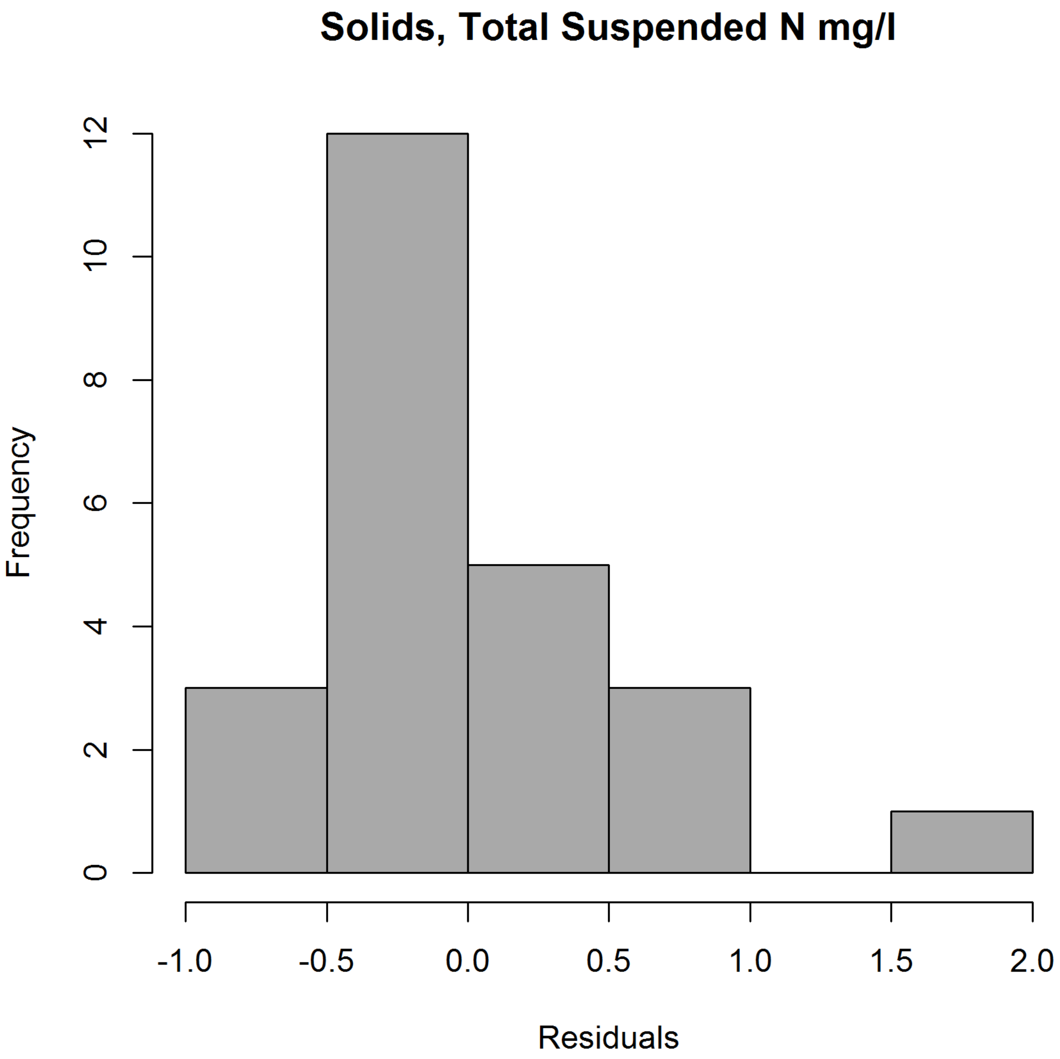
Zinc P ug/l
Impact
6.0
5.5
5.0
4.5
4.0
3.5
4.0
4.5
5.0
5.5
Control
Year 1
Year 2

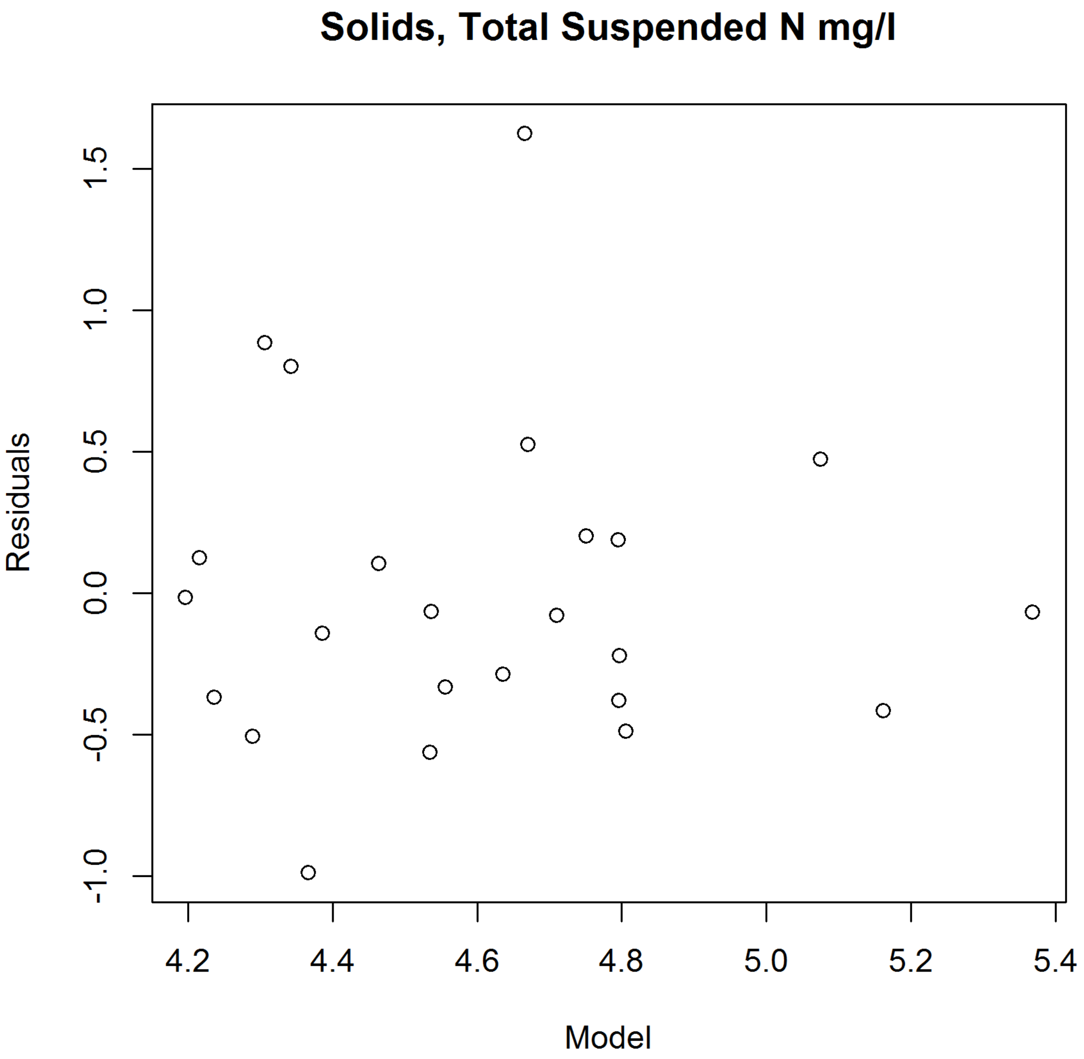


Zinc T ug/l
Impact
6.0
5.5
5.0
4.5
4.0
4.5
5.0
5.5
6.0
Control
Year 1
Year 2

Attachment 4a

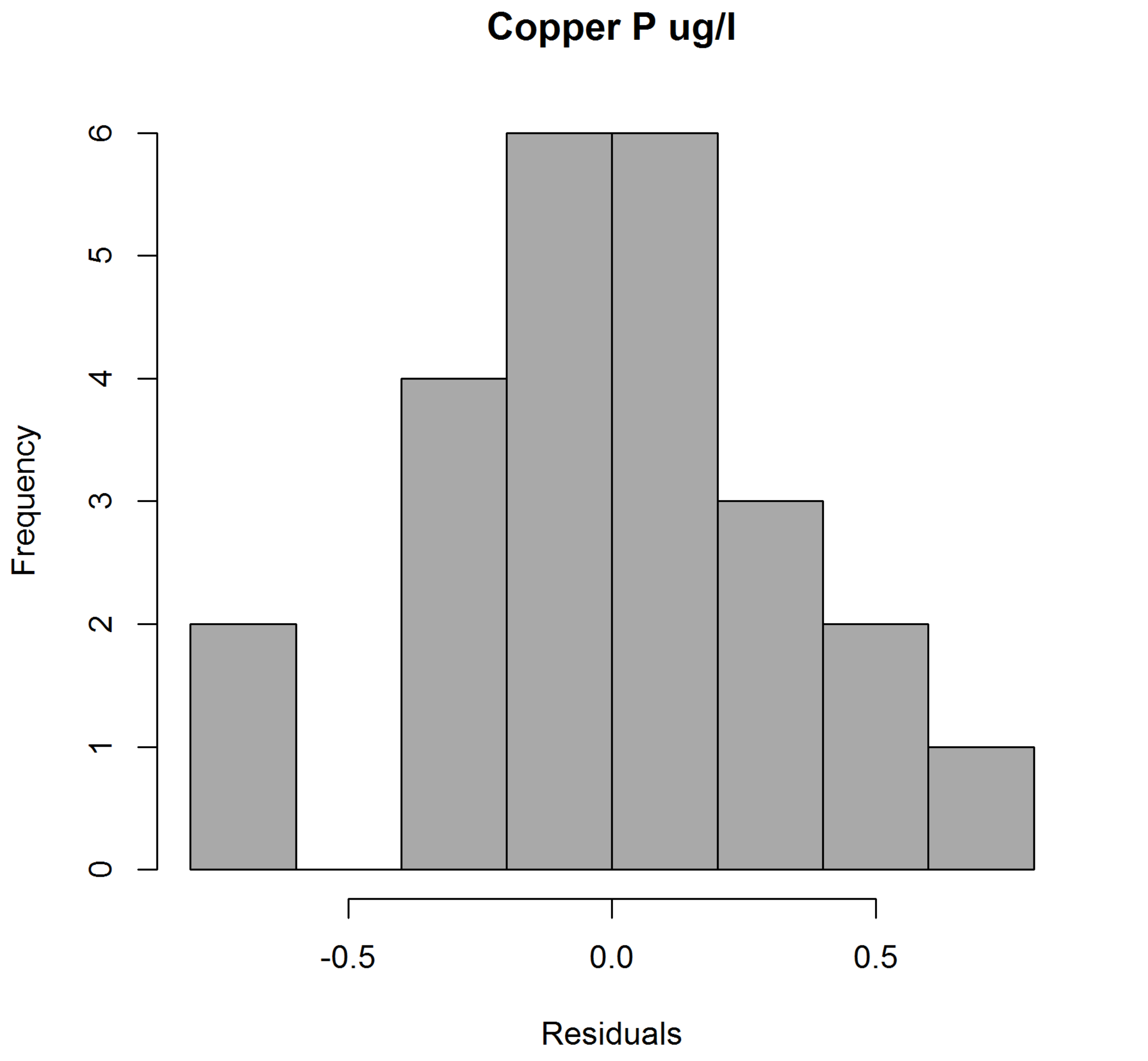
ANCOVA Pooled Impact Assumptions

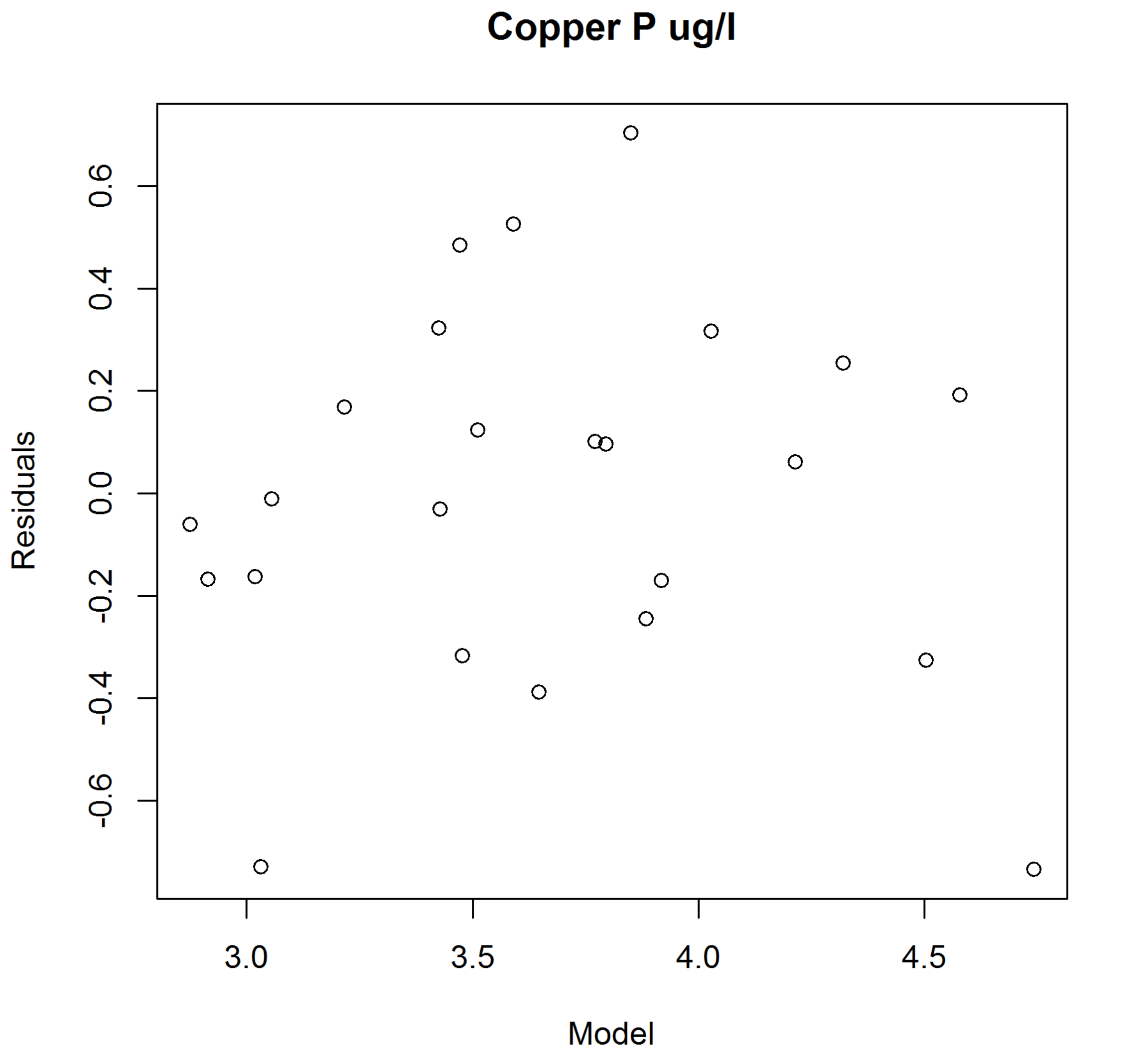

Solids, Total Suspended N mg/l
Frequency
0
2
4
6
8
10
12
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Residuals

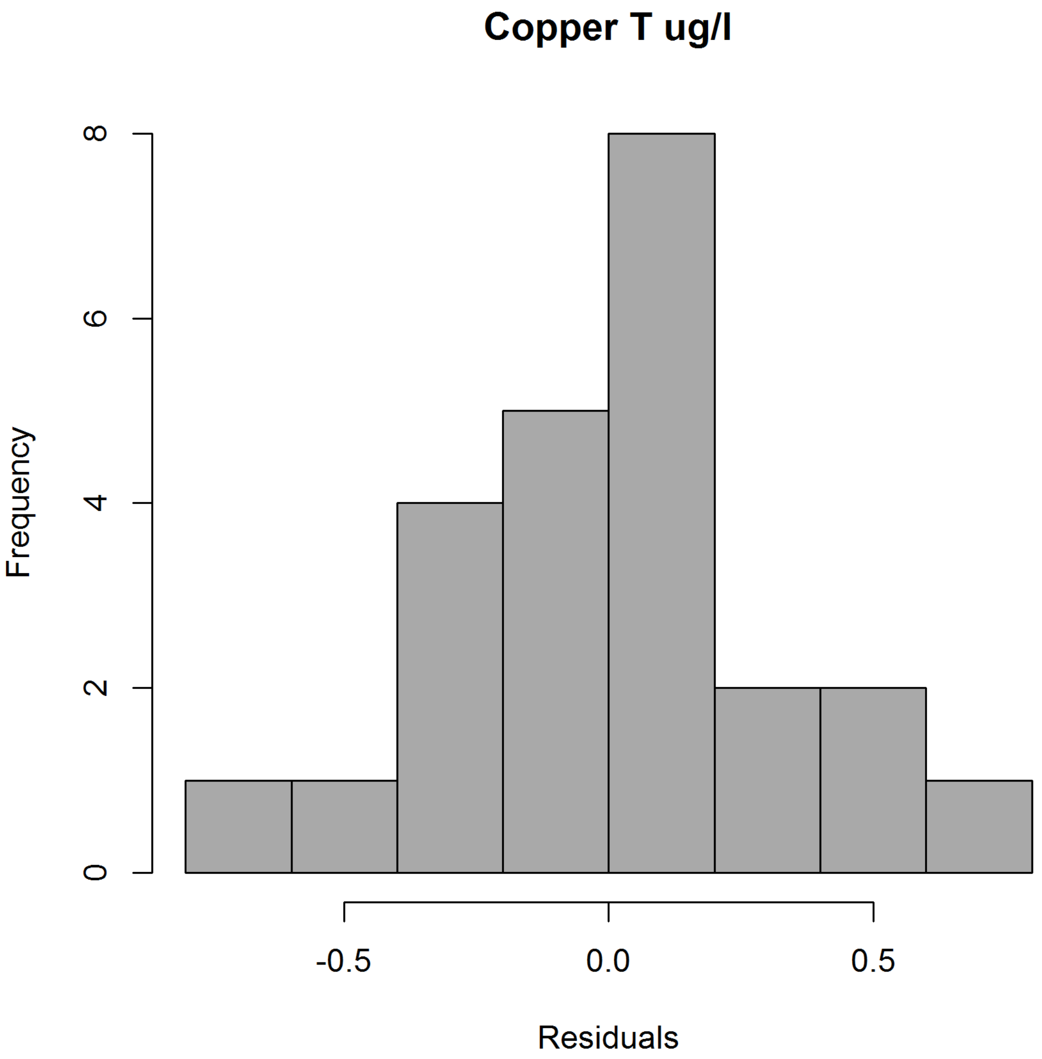

Solids, Total Suspended N mg/l
Residuals
Model
1.5
1.0
0.5
0.0
-0.5
-1.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4

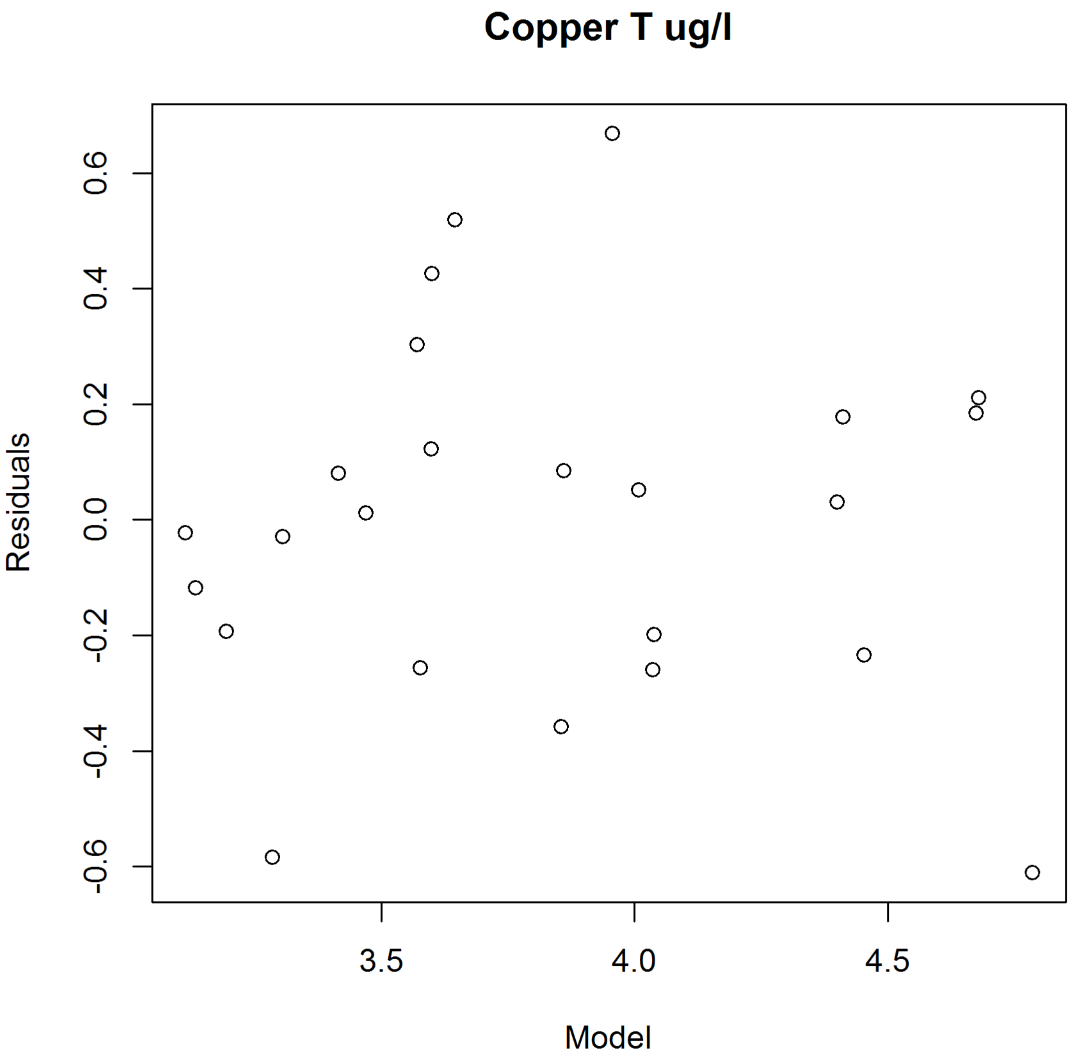
Attachment 4b

ANCOVA SS3 Impact Assumptions

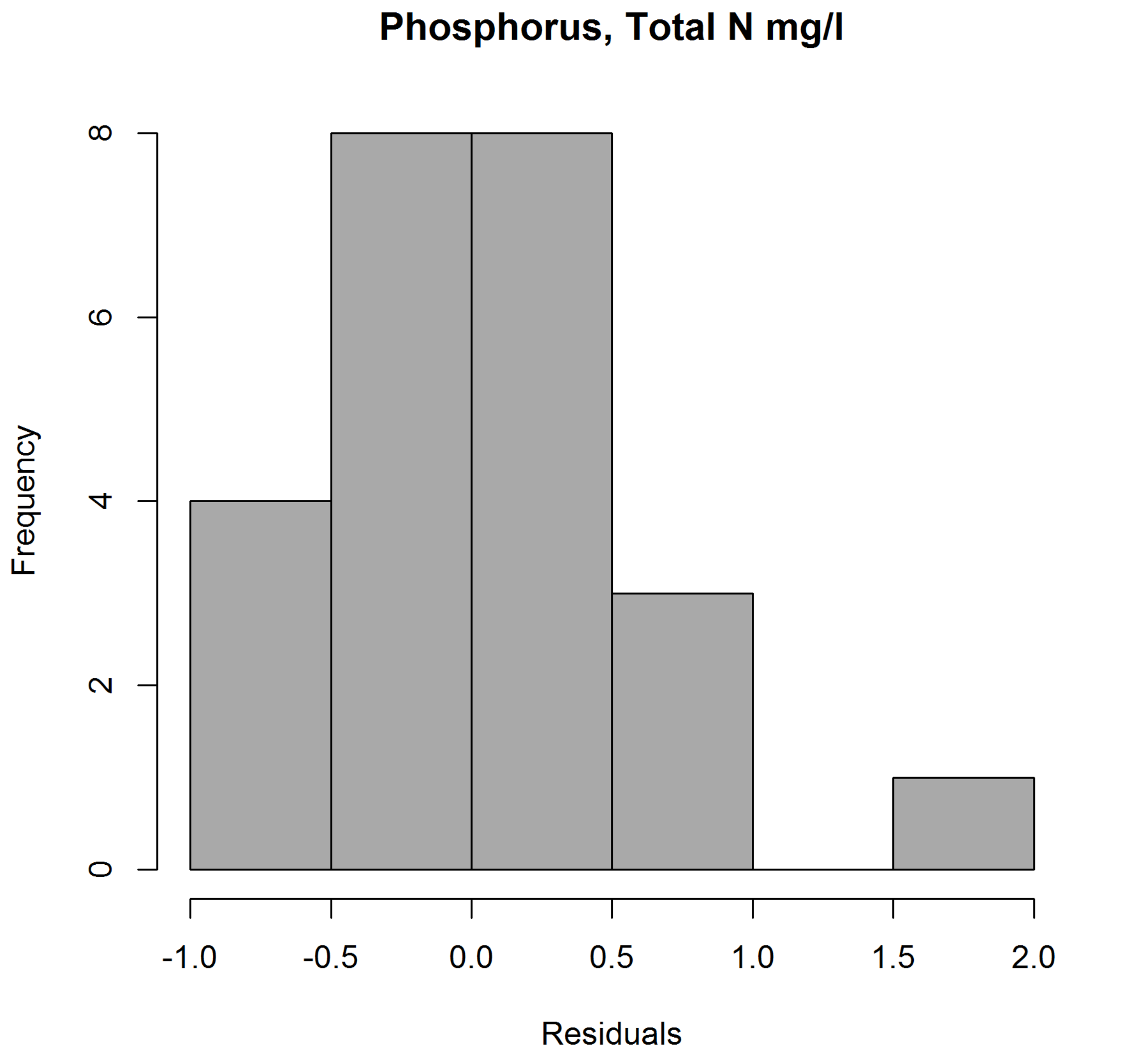

Copper P ug/l
Frequency
0
1
2
3
4
5
6
-0.5
0.0
0.5
Residuals

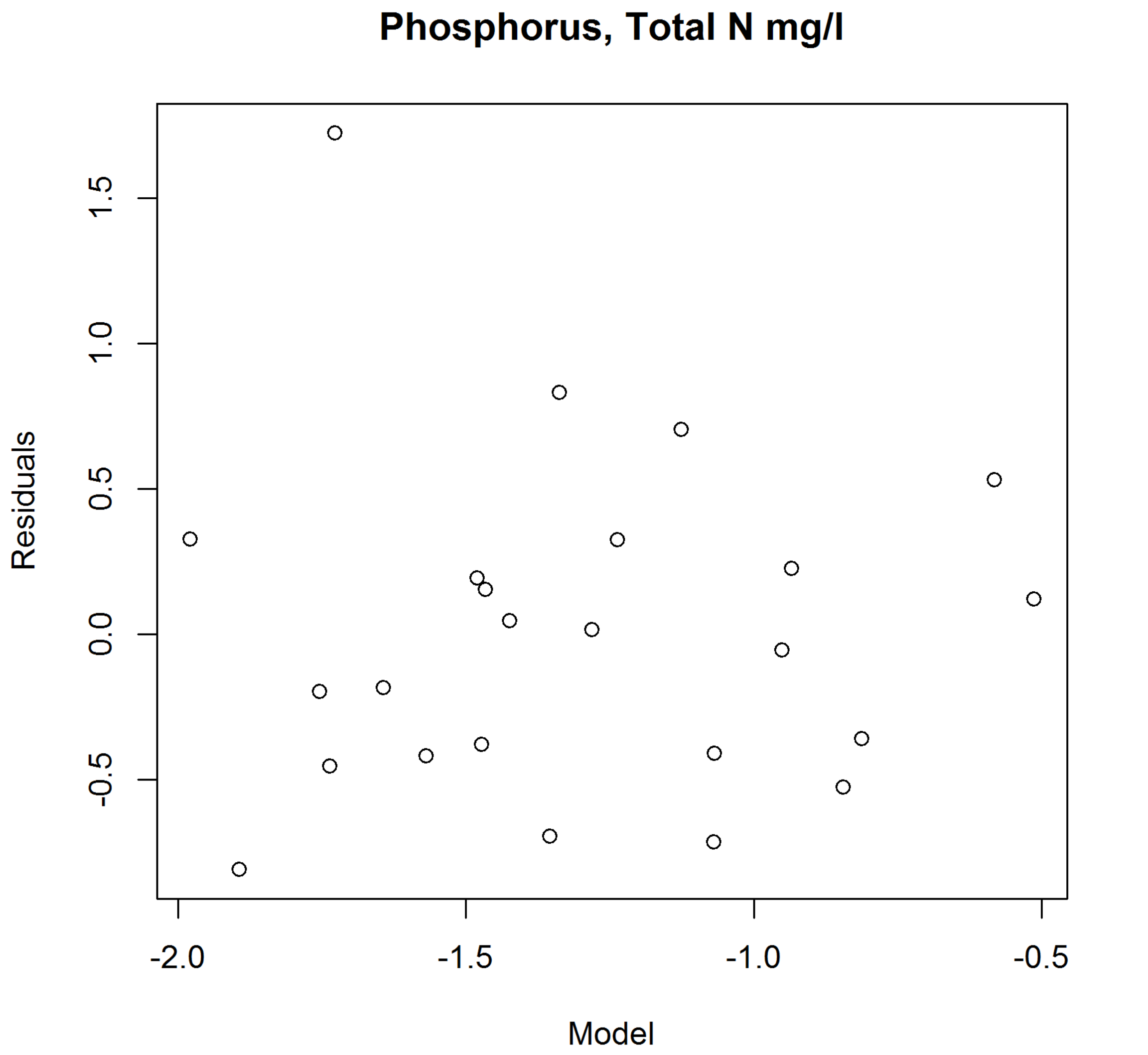

Copper P ug/l
Residuals
Model
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
3.0
3.5
4.0
4.5

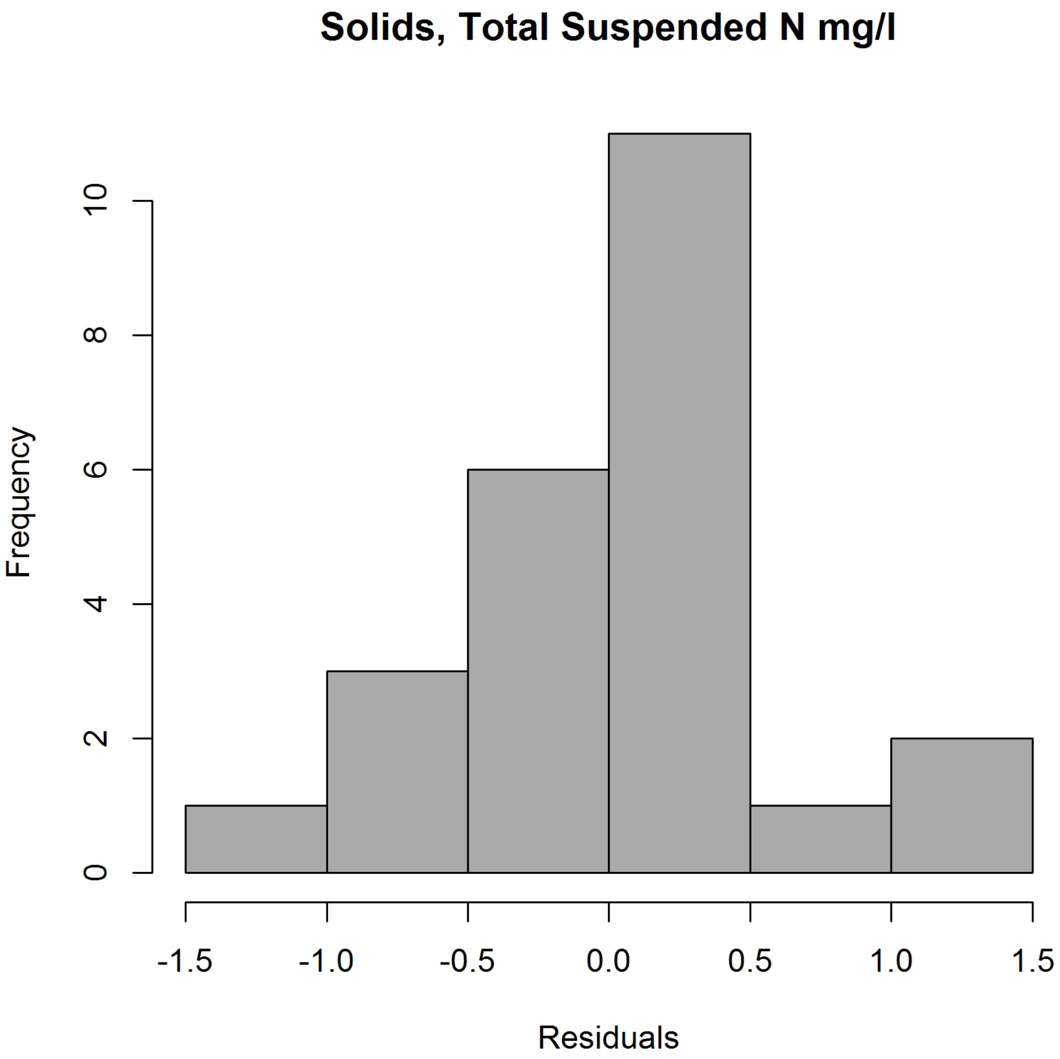

Copper T ug/l
Frequency
0
2
4
6
8
-0.5
0.0
0.5
Residuals



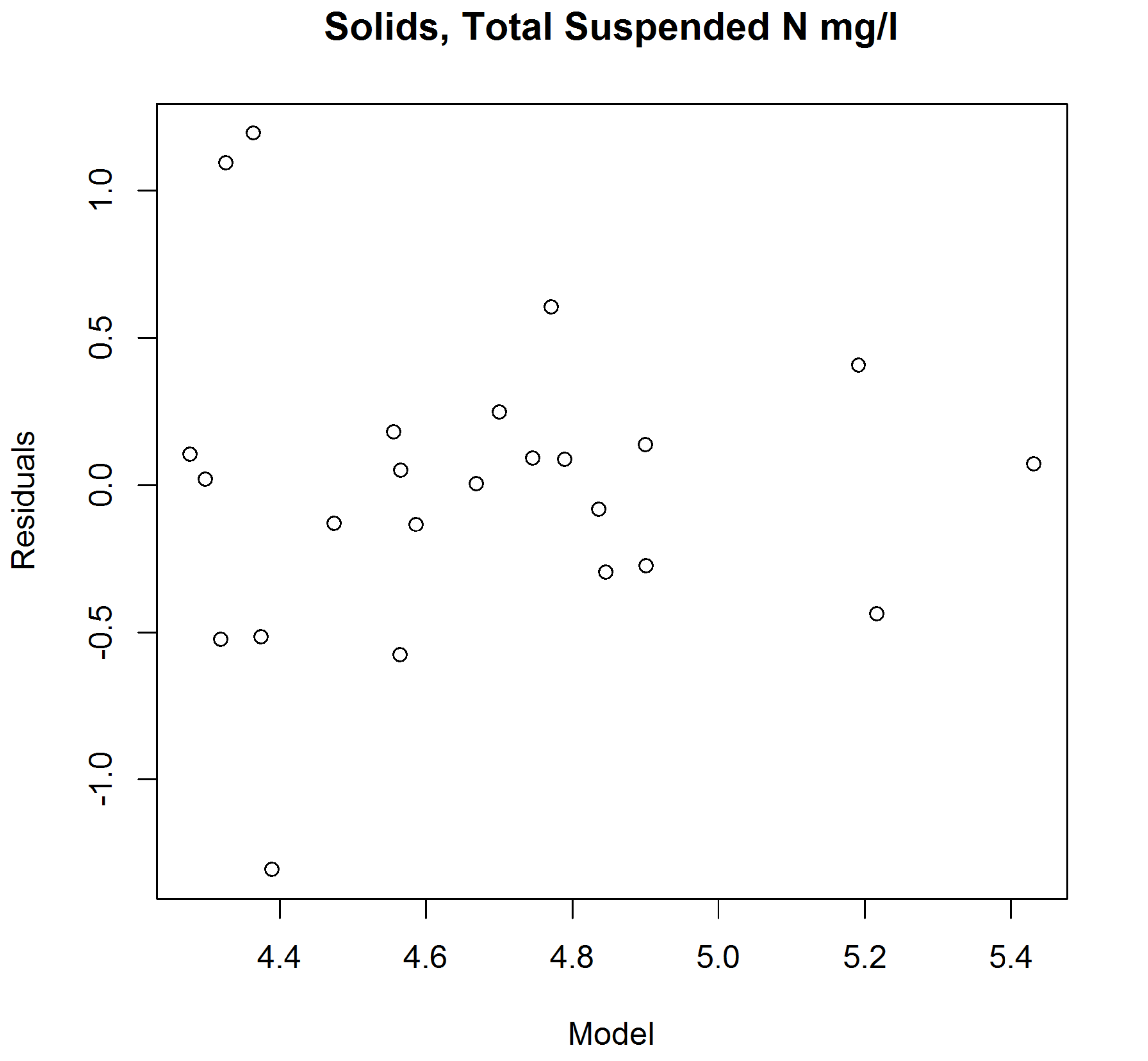
Copper T ug/l
Residuals
Model
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
3.5
4.0
4.5


Phosphorus, Total N mg/l
Frequency
0
2
4
6
8
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Residuals

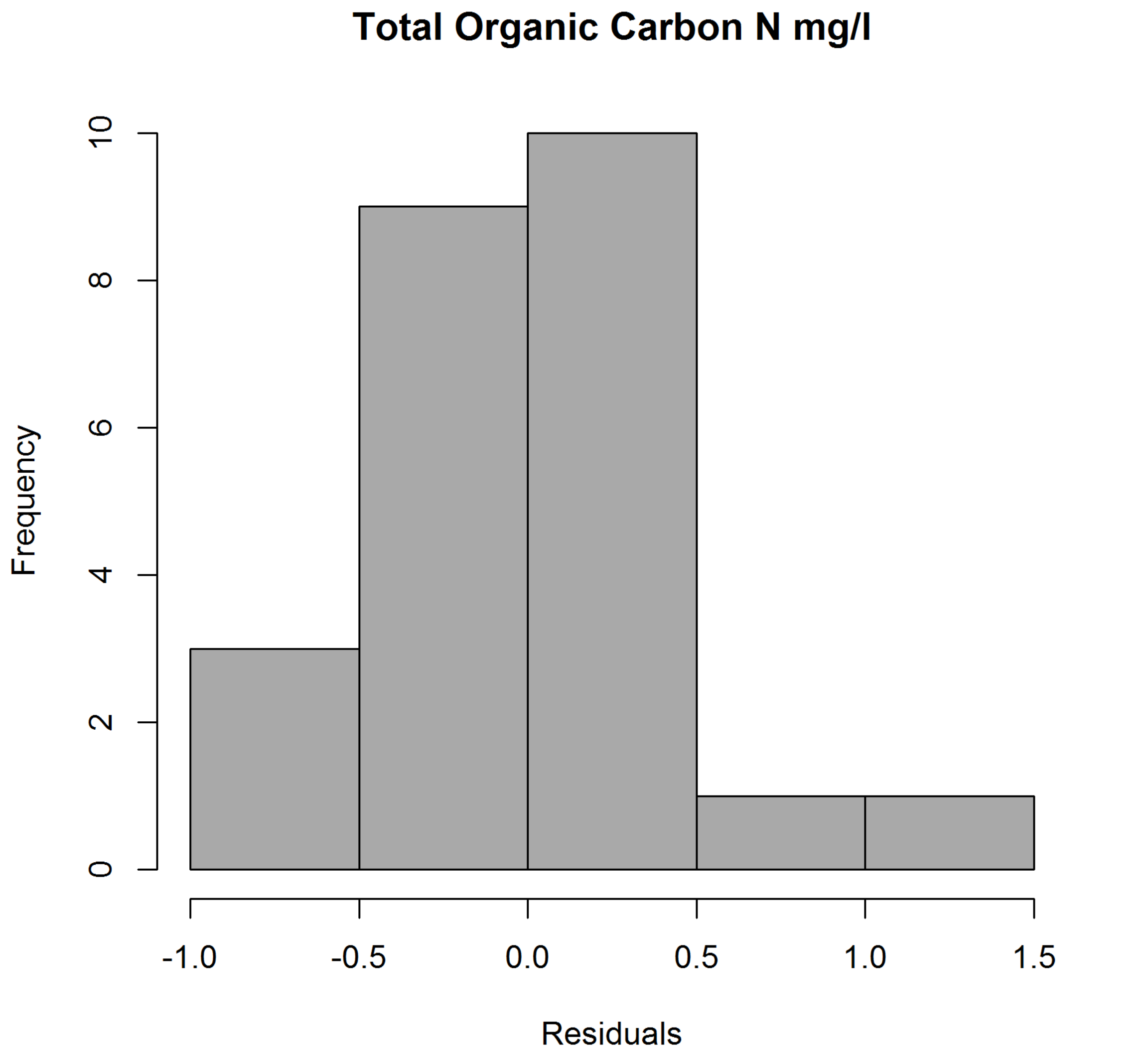

Phosphorus, Total N mg/l
Residuals
1.5
1.0
0.5
0.0
-0.5
-2.0
-1.5
-1.0
-0.5
Model

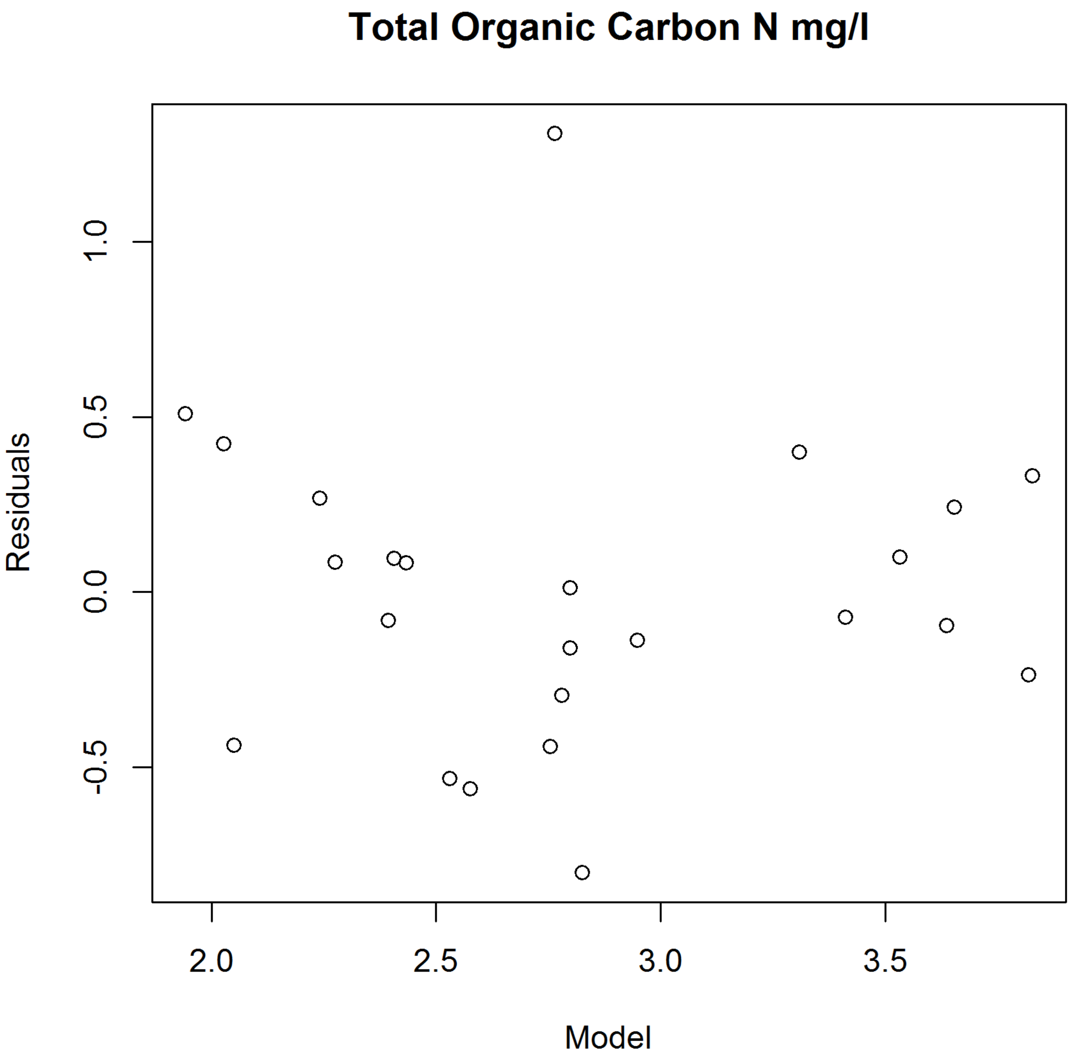


Solids, Total Suspended N mg/l
Frequency
0
2
4
6
8
10
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Residuals

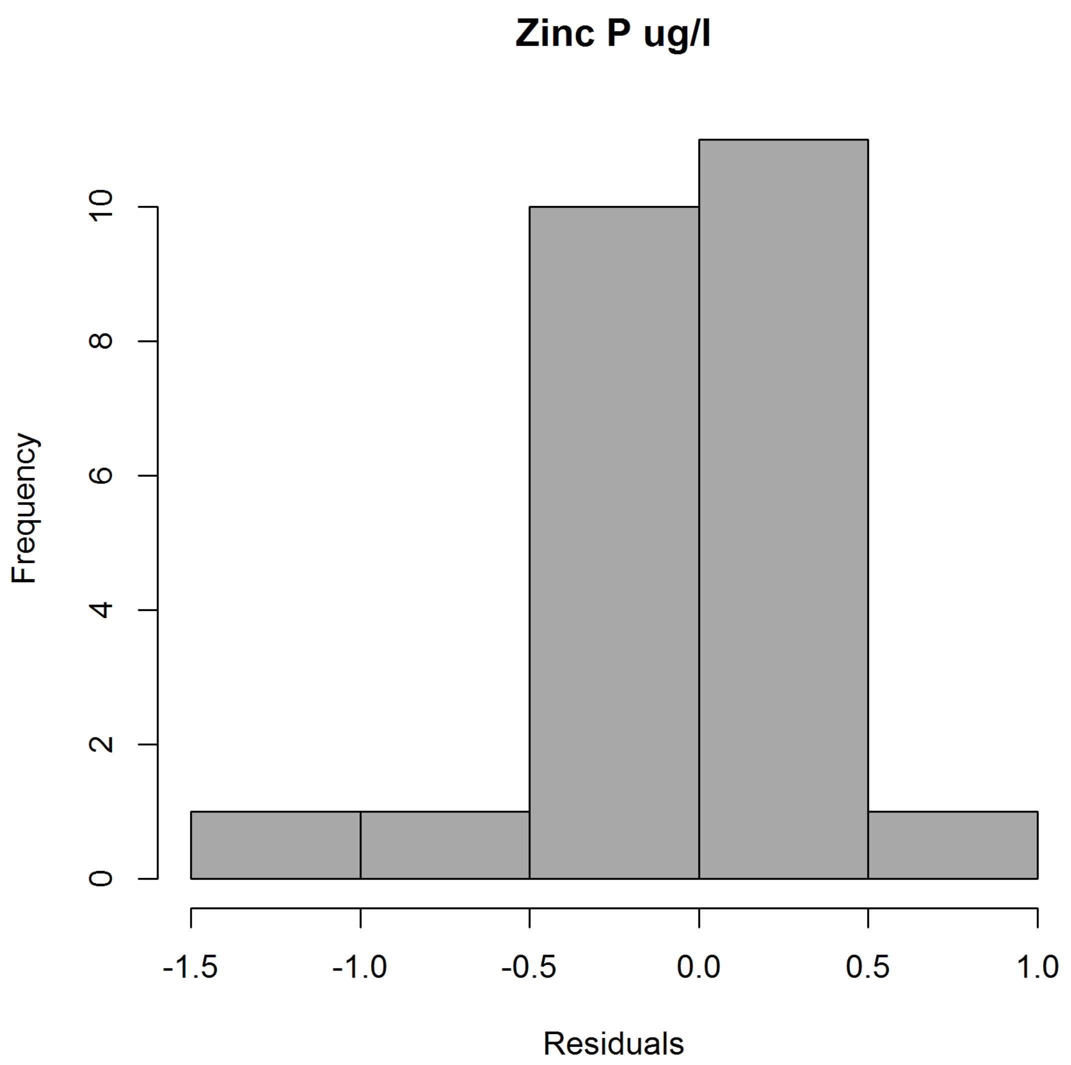


Solids, Total Suspended N mg/l
Residuals
1.0
0.5
0.0
-0.5
-1.0
4.4
4.6
4.8
5.0
5.2
5.4
Model

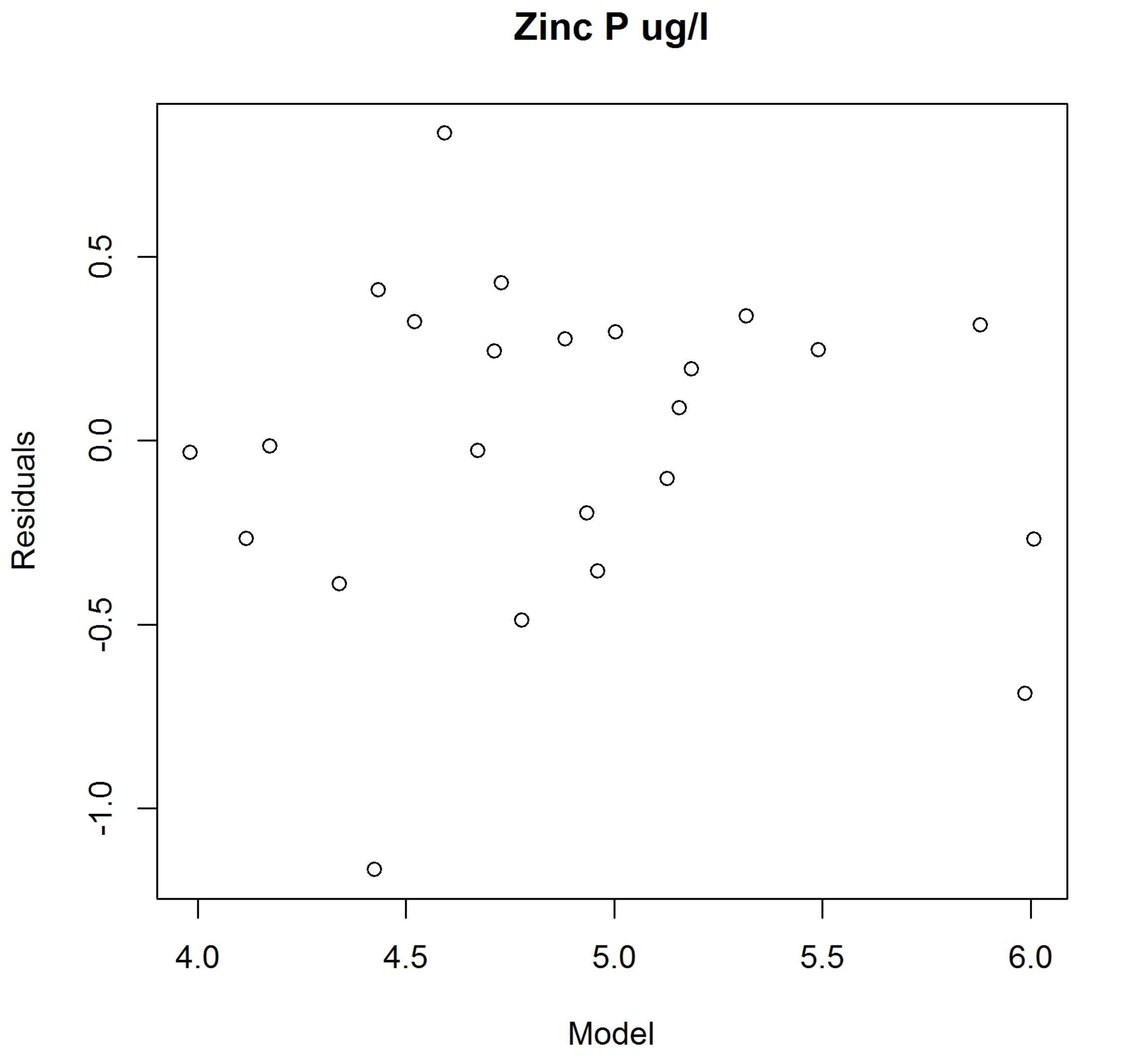

Total Organic Carbon N mg/l
Frequency
0
2
4
6
8
10
-1.0
-0.5
0.0
0.5
1.0
1.5
Residuals

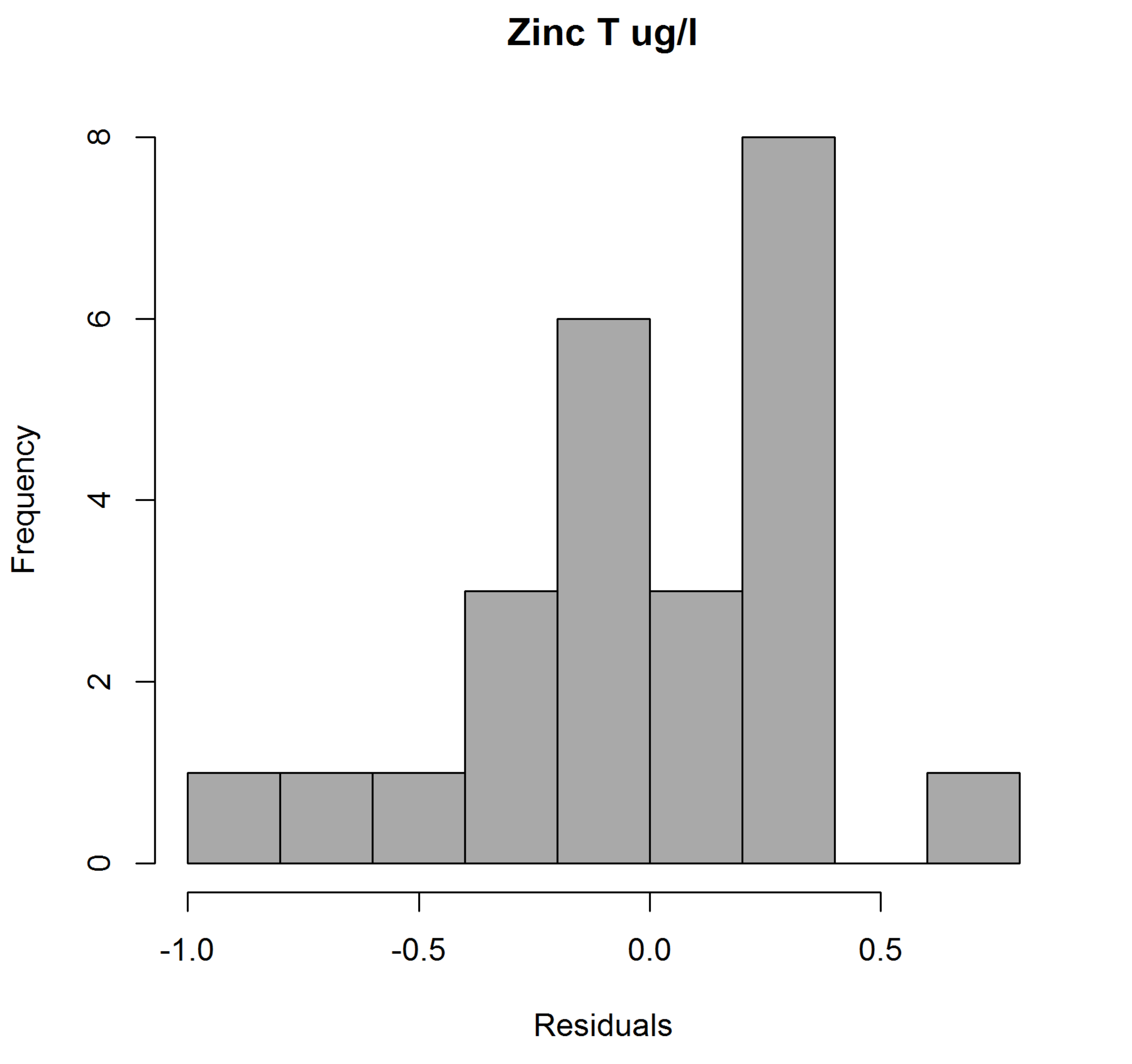


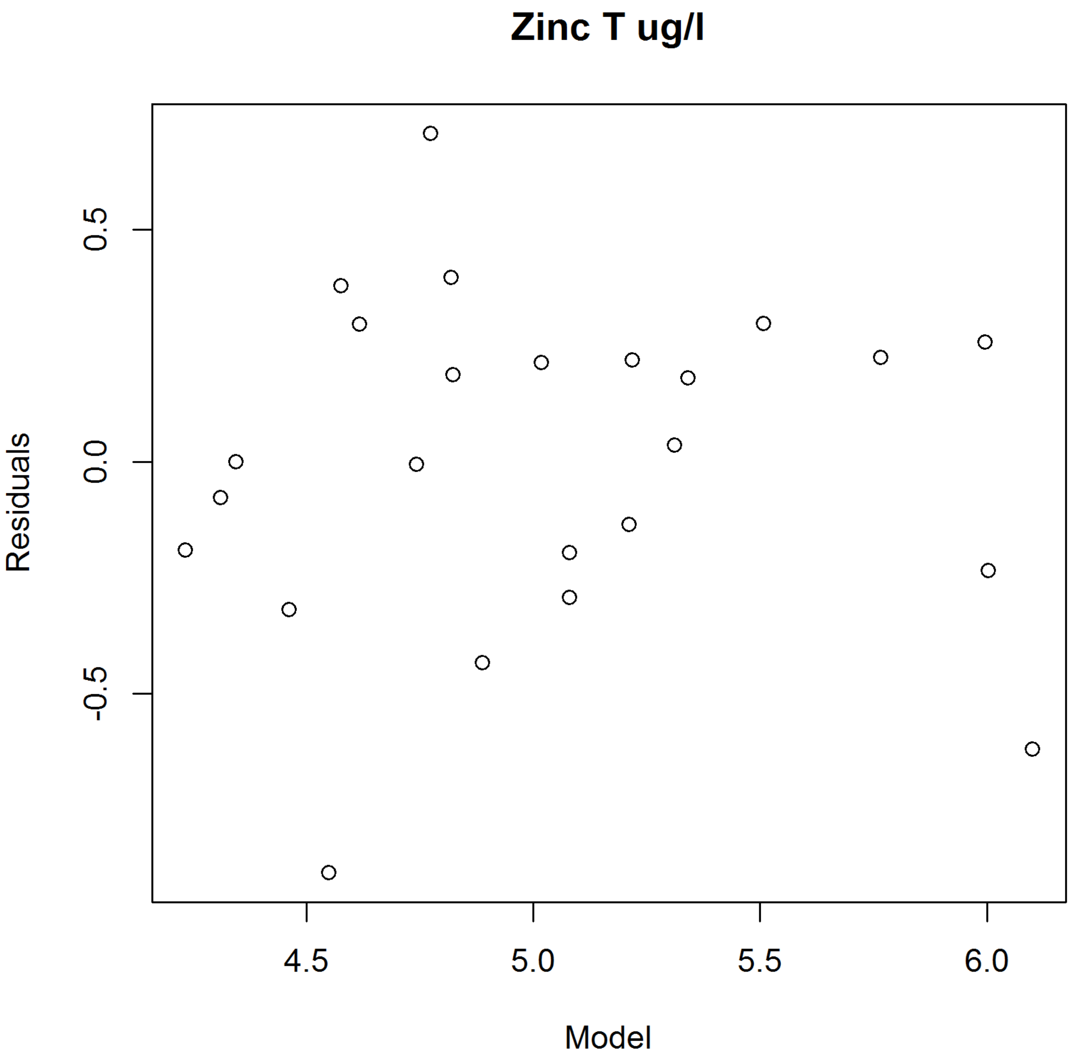
Total Organic Carbon N mg/l
Residuals
Model
-0.5
0.0
0.5
1.0
2.0
2.5
3.0
3.5



Zinc P ug/l
Frequency
0
2
4
6
8
10
-1.5
-1.0
-0.5
0.0
0.5
1.0
Residuals


Zinc P ug/l
Residuals
Model
0.5
0.0
-0.5
-1.0
4.0
4.5
5.0
5.5
6.0


Zinc T ug/l
Frequency
0
2
4
6
8
-1.0
-0.5
0.0
0.5
Residuals


Zinc T ug/l
Residuals
0.5
0.0
-0.5
4.5
5.0
5.5
6.0
Model