CENTER FOR WATERSHED PROTECTION

Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout Programs in the Chesapeake Bay Basin

A report prepared by the Center for Watershed Protection as fulfillment of the U.S. EPA Chesapeake Bay Program grant CB-973222-01

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Project Team

The Center for Watershed Protection (CWP) coordinated the research project team, which included the City of Baltimore Department of Public Works (DPW), Baltimore County Department of Environmental Protection and Resource Management (DEPRM), and the Department of Civil and Environmental Engineering at the University of Maryland-Baltimore County (UMBC). Other partners on the project team include the Center for Urban Environmental Research and Education (CUERE) at UMBC and the U.S. Forest Service Northern Research Station (FS-NRS) as part of the Baltimore Ecosystem Study (BES).

Executive Summary

The research project report provides information to support pollutant removal efficiencies for street sweeping and storm drain cleanout practices for Phase I and II communities in the Chesapeake Bay watershed. Information and data was gathered for this project through a comprehensive literature review, a basin-wide municipal survey of existing street sweeping and storm drain cleanout practices, and an intensive field monitoring program within two study catchments located in Watershed 263 in Baltimore, MD and additional sites in Baltimore County.

Street sweeping and storm drain cleanout practices rank among the oldest practices used by communities for a variety of purposes to provide a clean and healthy environment, and more recently to comply with National Pollutant Discharge Elimination System stormwater permits. The ability for these practices to achieve pollutant reductions is uncertain given current research findings. Only a few street sweeping studies provide sufficient data to statistically determine the impact of street sweeping and storm drain cleanouts on water quality and to quantify their improvements. The ability to quantify pollutant loading reductions from street sweeping is challenging given the range and variability of factors that impact its performance, such as the street sweeping technology, frequency and conditions of operation in addition to catchment characteristics. Fewer studies are available to evaluate the pollutant reduction capabilities due to storm drain inlet or catch basin cleanouts.

A multi-faceted monitoring study was completed to provide locally-derived pollutant removal reductions for street sweeping and storm drain cleanout practices. The monitoring program including water quality and flow, bedload, first flush, precipitation, source area street particulate matter, and storm drain inlet accumulation and chemical characterization. A 'before-and after' study design was used based on the inability to find a suitable control catchment to implement a paired watershed study design. An insufficient number of samples were collected given the conditions experienced during the study period to statistically detect differences in the street sweeping treatment on water quality. Monitoring efforts, however, did reveal key findings to determine factors contributing to the effectiveness of street sweeping and storm drain cleanout practices such as the particle size distribution of the street particulate matter picked-up by sweeping and its chemical composition, along with the significance of leaf litter and other organic material in storm drains and its contributions to pollutant loadings.

To synthesize the diverse research findings from this and other studies, a conceptual model was developed to provide pollutant removal efficiencies for TS, TN and TP for street sweeping and storm drain cleanout practices. The conceptual model is defined by a set of bounding conditions and assumptions that were made based on the literature, survey findings and monitoring data collected as part of the project.

For a given set of assumptions and sweeping frequencies, it is expected that the range in pollutant removal rates from street sweeping for total solids (TS), total phosphorus (TP) and total nitrogen (TN) are: 9 – 31%, 3-8% and 3-7%, respectively. The lower end represents monthly street sweeping by a mechanical street sweeper, while the upper end characterizes the pollutant removal efficiencies using regenerative air/vacuum street sweeper at weekly frequencies.

Pollutant removal efficiencies (%) from street sweeping for TS, TP and TN.				
Frequency	**Technology**	**TS**	**TP**	**TN**
Monthly	Mechanical	9	3	3
	Regenerative Air/Vacuum	22	4	4
Weekly	Mechanical	13	5	6
	Regenerative Air/Vacuum	31	8	7

The conceptual model is also applied to estimate the efficiency with which storm drain inlets trap, or store material to reduce the total pollutant loading at the receiving waters. Data generated from this study and others find that the particle size distribution in storm drains is similar to the street particulate matter and organic material comprised a large fraction of the accumulated material. For a given set of assumptions and cleanout frequencies, it is expected that the range in pollutant removal efficiencies for TS, TP and TN estimated to range from 18-35%, less than 1-2% and 3-6%, respectively.

Pollutant removal rates (%) from catch basin cleanouts for TS, TP and TN.			
Frequency	**TS**	**TP**	**TN**
Annual	18	<1	3
Semi-annual	35	2	6

The compilation and analysis of the data collection from this and other research studies provided valuable information to evaluate the effectiveness of these municipal practices. As a result, the following recommendations are made with respect to street sweeping and storm drain cleanout practices to reduce pollutant loadings to the Chesapeake Bay watershed:

Programmatic

- Adopt the pollutant removal efficiencies presented herein for mechanical and regenerative air or vacuum assist street sweepers used at weekly and monthly frequencies. Based on the municipal practices survey, few communities with the Chesapeake Bay use the more efficient street sweeping technologies or sweep at frequencies to achieve the pollutant removal efficiencies presented in this report.
- Develop street sweeping and storm drain maintenance program efforts to target areas and times during the year in communities that may receive the greatest impact from street sweeping or storm drain cleanouts.
- Implement a downspout disconnection program and/or an urban stormwater retrofit program that redirects and treats stormwater before it reaches the storm drainage system (via parking lots, roads, sidewalks, alleyways) in ultra-urban catchments, such as those in this study.

- Expand MS4 stormwater programs to include a curb-side leaf litter pick-up program that is able to maximize the reduction of leaf litter and prevent it from entering the storm drain. This is important for two reasons, 1) street sweepers avoid leaf piles and this reduces the effectiveness of this practice (sweepers may also emulsify leafy debris and make it more easily entrained by runoff, and 2) the decomposition of leaves and other organic debris in storm drain inlets or catch basins can create an environment suitable for the release of inorganic nitrogen and transport to receiving waters.

Research

- Conduct additional research on the implications of storm drain cleanout practices to include catch basins and chemical analysis of particle size distributions to estimate the pollutant load reductions from the different particle size classes
- Further evaluate stormwater monitoring techniques that can be used to account for the 'missing load' that occurs when using current sampling techniques to reduce potential bias in reported pollutant removal efficiencies.
- Research and develop alternative sampling techniques that can be used to collect more representative stormflow throughout the depth of flow and storm event.
- Adopt whole water sampling as a method to measure sediment in stormwater as an initial step to reduce the bias.
- Quantify bedload contributions to the total stormwater pollutant load. Although it may comprise a small portion of total stormwater load it can have a much larger impact due to the chemical characteristics of the material.

Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout Programs in the Chesapeake Bay Basin

Introduction

The report is organized into six major sections, which are summarized below.

1. **Project Overview and Background** – This section provides an overview of the project purpose and scope. Key findings from the literature review and municipal practices survey are summarized. A description of the conceptual model is presented that is used to estimate pollutant removal efficiencies for street sweeping and storm drain cleanout practices presented in section 5.0.

2. **Study Area** – A description of the study area in Baltimore City for the monitoring component of the project is presented.

3. **Study Design and Sampling Methods** – This section presents a description of the study design used to evaluate the effectiveness of street sweeping and storm drain cleanout practices. The sampling methods are described for monitoring water quality and flow, bedload, first flush, precipitation, source area street particulate matter, and storm drain inlet accumulation and chemical characterization.

4. **Monitoring Results and Analysis** – This section summarizes the data generated on all monitoring components and presents statistical and observational findings of that data. Results between the pretreatment and treatment period are presented along with the particle size and chemical characterization of street particulate matter and material sampled from storm drain inlets. Loading rates (or yields) of street particulate matter are presented.

5. **The Impacts of Street Sweeping and Storm Drain Cleanout Practices on Stormwater Quality –** This section is presented in two major sections that describe the pollutant loading reductions from street sweeping and storm drain cleanout practices and the caveats and issues associated with these values. The conceptual model is applied to estimate pollutant removal efficiencies for these practices.

6. **Conclusions and Recommendations –** Summary concluding remarks on the project findings are provided with a set of nine key recommendations on the future applications of the research project results.

1.0 Project Overview and Background

Street sweeping and storm drain cleanouts rank among the oldest practices used to control storm water pollution; however, very limited and sometimes conflicting data has been published in regard to their performance in removing nutrients and other pollutants from stormwater runoff (Selbig and Bannerman 2007, Breault et al. 2005, Burton and Pitt, 2002, Mineart and Singh, 1994, Sutherland and Jelen, 1997). Despite this uncertainty, many Chesapeake Bay municipalities routinely use one or both practices to comply with their National Pollutant Discharge Elimination System (NPDES) storm water permits. Source control of pollutant loadings from streets can be an important component to a Municipal Separate Storm Sewer System (MS4) stormwater program to achieve needed pollutant reductions. Street sweeping and storm drain cleanouts may be of particular value in reducing pollutants from ultra-urban areas, where few other best management practices (BMPs) are feasible.

The Urban Storm Water Work Group (USWG) of the Chesapeake Bay Program has recognized the importance of defining more accurate pollutant removal efficiencies for street sweeping and storm drain cleanout practices as a top priority for its BMP tracking system. Currently, the Chesapeake Bay Watershed model does not define any removal efficiencies for these practices.

The purpose of this research project is to provide information to gain a better understanding of the impact street sweeping and storm drain cleanouts have on reducing pollutant loadings to surface water. The objectives of the project are to:

1. develop improved estimates of the potential nutrient and sediment reductions achievable through municipal street sweeping and storm drain cleanouts, and

2. provide the Chesapeake Bay Program with a pollutant removal efficiency for nitrogen and phosphorus from street sweeping and storm drain cleanouts.

Information and data was gathered for this research through a comprehensive literature review, a basin-wide municipal survey of existing street sweeping and storm drain cleanout practices, and an intensive field monitoring program within two study catchments located in Watershed 263 in Baltimore, MD and additional sites in Baltimore County. The data derived from the project may be used to provide estimates of pollutant removal efficiencies for street sweeping and storm drain cleanouts for use in the Chesapeake Bay Watershed Model.

Technical Memorandums 1 and 2 (CWP 2006a, CWP 2006b) summarize the findings of the literature review and survey of municipal practices and present interim pollutant removal efficiencies for street sweeping and storm drain cleanout practices using a conceptual model. These reports were submitted to U.S. EPA as fulfillment of the project. An overview of the key findings from these reports is summarized in the next two sections.

1.1 Summary of Past Street Sweeping and Storm Drain Cleanout Research

As part of an extensive literature review, seventy-five monitoring and modeling studies were reviewed from the 1970s to present where fewer than a dozen studies provided sufficient data to quantify a pollutant removal rate for street sweeping. Despite the numerous studies documenting the effectiveness of this practice, the ability to quantify pollutant removal rates based on the literature is challenging given the differences in scope, extent and design of field or modeling studies. The wide range of pollutant removal rates reported for street sweeping, vary based on sweeping frequency, sweeper technology and operation, street conditions, and the chemical and physical characteristics of street dirt. In general, street sweeping studies have been limited to measure the potential water quality improvements despite the research that documents pick-up efficiencies of new street sweeping technology to remove more than 90% of street particulate matter dirt under ideal conditions.

Unlike the street sweeping research, only a handful of monitoring studies evaluate the pollutant reduction due to storm drain or catch basin cleanouts, and the optimal frequencies for cleanouts at a catchment scale. These studies indicate catchment cleanouts can reduce pollutants by 5 to 25% depending on catchment conditions, cleaning frequency and type of pollutant. The pollutant removal capability of catch basins is fundamentally constrained by the design which retains coarse grained sediments but bypass finer grained sediment that typically contains higher concentrations of nutrients and metals.

To synthesize the diverse research findings, a conceptual model was developed to provide interim pollutant removal rates for total solids (TS), total nitrogen (TN) and total phosphorus (TP) for street sweeping and storm drain cleanout practices. The bounding conditions and assumptions were made based on the literature. The conceptual model is defined by four components for both street sweeping and storm drain cleanout (Figure 1). The dashed line indicates the relationship between the two practices, where the street particulate matter (SPaM) that is available to be captured and stored in storm drains or catch basins will be affected by the SPaM remaining after street sweeping.

The *SPaM load* is a model component that represents the input shared by both practices, that is, the material on the street that is available for pick-up by the street sweeper or washed off into the storm drain or catch basin. The street sweeping model components are *treatable load, sweeper effectiveness* and *disposed SPaM*. The treatable load for street sweeping is defined as the SPaM that is available to be 'picked-up' by a street sweeper and is limited to the material on the street at the time of sweeping and within reach of the street sweeping technology (e.g. broom arm extension). It is affected by the street condition and unswept areas that contribute SPaM during storm events. The pick-up efficiency (PUE) of the street sweeper is a function of the frequency of sweeping (greater or less than runoff producing events), technology (mechanical broom, regenerative air, vacuum street sweepers), street condition (e.g., to include condition of pavement as well as obstructions such as parked cars and leaf piles), and street sweeper operation (e.g.

speed of operation). The storm drain cleanout components include *inlet trapping efficiency*, *cleanout effectiveness* and *disposed sediment*. The trapping efficiency is defined by the amount of material that is stored and removed between cleanout events.

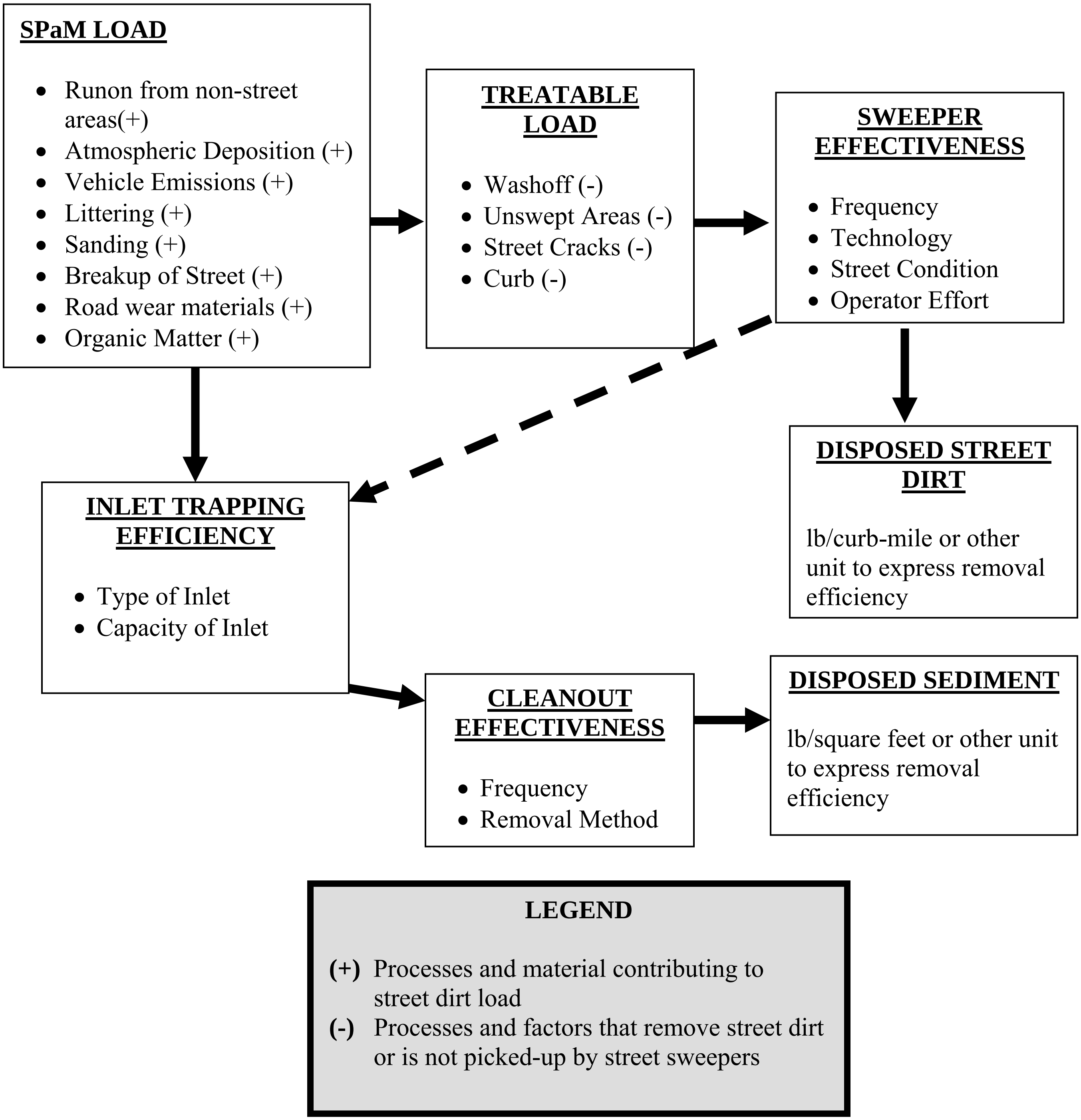


Figure 1. Conceptual model to determine the pollutant removal efficiencies of street sweeping and storm drain cleanout practices.

1.1 Summary of the Municipal Practices Survey for Street Sweeping and Storm Drain Cleanout Program

The Center for Watershed Protection surveyed twenty MS4s in the Chesapeake Bay watershed about their street sweeping and storm drain cleanout practices. Collectively, these communities represent nearly half of the urban population in the Chesapeake Bay watershed. Only one community did not have a street sweeping program. All communities surveyed had a storm drain cleanout program. A summary of key findings are listed below.

- Chesapeake Bay MS4 street sweeping and storm drain cleanout programs are exceedingly diverse in their size and scope. Cumulatively, Chesapeake Bay MS4 programs are spending as much as $13 million/year on these programs.
- Chesapeake Bay communities sweep at least 70% of the public streets in their community on an annual basis, while 85% of communities sweep more frequently than once per year. However, only a small subset of communities are sweeping frequently enough (e.g. biweekly or more) to realize a potential water quality benefit as outlined in CWP (2006a).
- Most Chesapeake Bay communities maintain several thousand miles of streets. Streets located in commercial or central business districts tend to be swept more frequently than local residential streets. Additional street sweeping is commonly scheduled for Spring cleanup of streets from winter de-icing practices.
- Pollutant reduction is not a primary factor driving Chesapeake Bay MS4s to sweep streets or cleanout storm drains, inlets or catchbasins. The purpose of street sweeping and storm drain cleanouts is based on maintaining aesthetics and responding to public demand. Only one community reported that nutrients were a target pollutant for street sweeping. This may reflect that fact that minimal monitoring has been completed within the Bay to determine the effectiveness of these practices with respect to improving stormwater quality.
- Respondents noted several factors that reduce the effectiveness of street sweeping programs, including parked cars and inadequate budgets. Only 27% of the communities use the more efficient street sweeping technology (i.e., regenerative air, vacuum). Conversely, more modern equipment such as vacuum-based technology is used in the majority of the communities to cleanout storm drains.
- Communities that use a stormwater utility fee or other stormwater tax typically have larger street sweeping budgets.
- Storm drains, inlets and catchbasins within the Bay are infrequently cleaned out. 75% percent of Phase I and Phase II communities cleanout their storm drains every two years or less, either as part of a regular cleanout program or based on complaints or clogging
- Assuming this research study is able to confirm the value of street sweeping as a nutrient reduction BMP, most Chesapeake Bay MS4s would need to greatly increase the frequency of sweeping or target specific areas of street dirt accumulation in order to see potential water quality improvements.

2.0 Study Area

The study catchments are located in the City of Baltimore and are referred to as catchments F (Lanvale St.) and O (Baltimore St.). Catchments F and O are part of the Watershed 263 storm drainage area (e.g. sewershed) that conveys runoff to the outlet of the Middle Branch Patapsco River and have areas of 38.4 and 38.7 acres, respectively (Figure 2). These monitoring stations were first established in 2004 by the City of Baltimore and USFS NRS as part of the BES for a longer term monitoring effort to track changes in water quantity and quality from these landscapes over time. Characteristics of the catchments are provided in Table 1 and may be described as being "ultra urban" based on the extensive impervious land area. There is approximately 67% and 77% total impervious cover in catchments F and O, respectively. Land use for each of the catchments is similar with high-density residential land use in the form of row houses being the most predominant. In both catchments, there is redevelopment of a limited set of parcels. Other land uses include commercial, institutional, parks, and vacant lots. There are no natural water features located in either of the catchments, and pervious areas exist largely in the form of small pockets of open space to include vacant lots and a few parks in both catchments. Canopy cover in the catchments is limited to street trees and recent planting efforts on vacant lots.

Table 1. Catchment characteristics.

Characteristics	Catchment F	Catchment O
Total Area (Acres)	38.43	38.70
Impervious Cover (%)	67.8%	76.6%
Pervious Cover (%)	32.2%	23.4%
Streets and Alleys – acres (% of catchment)	10.17 (26.5%)	10.06 (25.6%)
Paved Right of Way [1] acres (% of catchment)	5.79 (15.1%)	5.72 (14.8%)
Rooftop Cover – acres (% of catchment)	9.56 (24.9%)	12.64 (32.2%)
Other Impervious Cover [2] (% of catchment)	0.53 (1.4%)	1.24 (3.2%)
Street and Alley Length (miles)	3.57	3.60
Current Curb Miles Swept Per week [3]	7.69	4.43
Proposed Curb Miles Swept Each week	4.15	11.14
Sweeping Treatment	Restricted	Expanded
Number of catch-basins [4]	92	74

Notes:
[1] Sidewalks from edge of street to rooftop
[2] Parking lots and driveways
[3] Curb miles on each side of street (e.g., 2 times street length)
[4] Estimated from KCI (2004) SWMM Block modeling
Sources: CWP 2005, KCI, Inc 2004, Stack, pers. comm

Figure 2. Catchments F and O and monitoring sites in Watershed 263 (★ is the location of the monitoring station).

Catchment F monitoring station at Lanvale St.

Catchment O monitoring station at Baltimore St.

3.0 Study Design and Sampling Methods

A before and after study design was used in Watershed 263 to evaluate the effectiveness of street sweeping (treatment 1) and the combined effect of street sweeping and storm drain cleanout practices (treatment 2) for two study catchments. A control catchment (no treatment) was unable to be identified for the purposes of the study. Treatment 1 occurred in both study catchments while Treatment 2 was applied to catchment O. Once a sufficient number of storm events were sampled for the single treatment, a second treatment was added that included cleaning the storm drain inlets in catchment O. The level of street sweeping remained the same in both catchments. The monitoring study included additional sampling sites in Baltimore County to characterize the material removed by storm drain cleanout practices. This involved monthly inlet accumulation measurements and chemical analysis of the material sampled on a quarterly basis. Figure 3 illustrates a timeline for these monitoring activities with the level of sampling effort summarized in Table 2. A 15-month pretreatment (baseline) period generated event mean concentrations (EMCs) for the two study catchments based on existing street sweeping practices (9/05 – 12/06). During the pretreatment period, most, but not all streets within each of the study catchments were swept 1 to 2 times a week (Table 3). To evaluate the impact of street sweeping on water quality, the street sweeping frequency was changed beginning January 2006 (e.g. treatment 1) The street sweeping frequency was increased to twice a week on all streets in catchment O, with a concurrent decrease in effort of once per week in catchment F (Table 3). This translated to a 48% increase in the number of curb miles swept in catchment O and an 85% decrease in curb miles swept in catchment F. To inform the public about the new street sweeping schedule, new street signs were installed by the City of Baltimore in addition to door hangers that were distributed to households in the study area. A portion of a street (block) was used as a control street within catchment O (Fairmount St) where this street block was not swept. The street sweeping schedule is included in Appendix A. A description of sampling methods for water quality and flow, street particulate matter (SPaM) and inlet material accumulation and characterization follows.

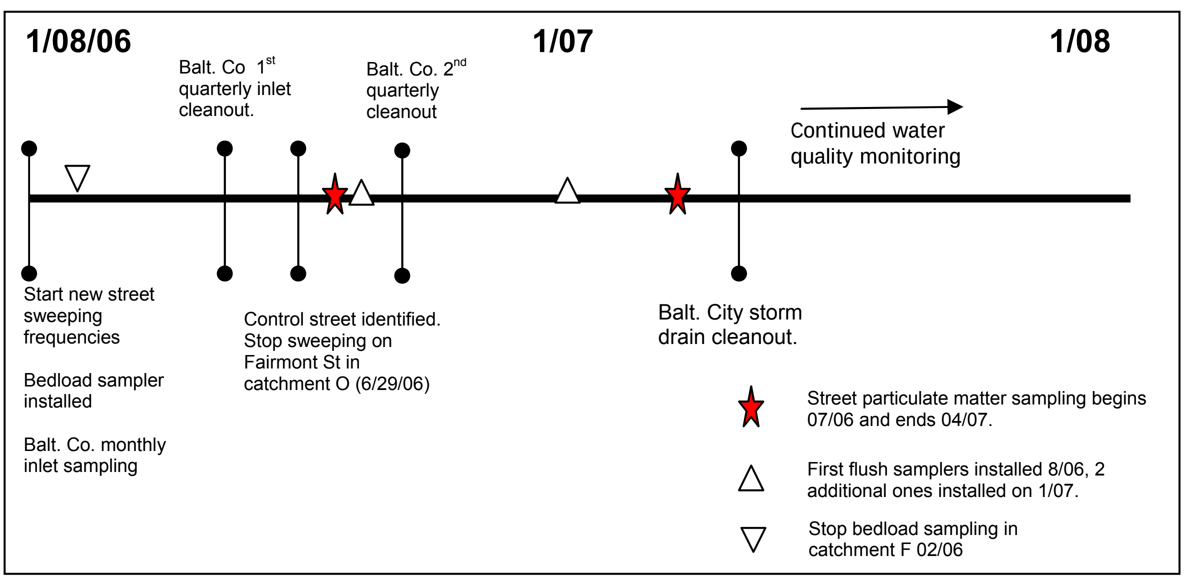


Figure 3. Timeline for monitoring activities.

Table 2. Summary of monitoring effort for the pretreatment and treatment period (street sweeping only).

		Pretreatment		Treatment	
Monitoring Task	**Catchment**	**# of samples**	**Sampling period**	**# of samples**	**Sampling period**
Storm event water quality	Catchment O	17	12/1/2004 - 11/16/2005	11	1/11/2006 – 6/29/2007
	Catchment F	15	12/1/2004 - 10/25/2005	7	1/11/2006 – 4/12/2007
First Flush	Catchment O			41	8/8/2006 - 6/29/2007
Bedload	Catchment O			8	2/14/2006 - 2/2/2007
	Catchment F			2	2/14/2006 – 2/28/2006
Baltimore City storm drain cleanout	Catchment O			Single event	7/15/2007 - 8/1/2007
Baltimore County inlet accumulation				Monthly	1/1/2006 – 12/31/2006
Baltimore County inlet material chemical characterization				Quarterly	Apr. 2006; Sept/Oct 2006

Table 3. Description of street sweeping treatment periods in Catchments F and O.

Treatment Period	Catchment F	Catchment O
Pretreatment Period (Sept. 2004 – Dec. 2005) Curb Miles Swept Per week [1]	7.69	4.43
Treatment Period (Jan. 2006 – July 2007) Curb Miles Swept Each week	4.15 (46% decrease)	11.14 (151% increase)
[1] Curb miles on each side of street (e.g., 2 times street length)		

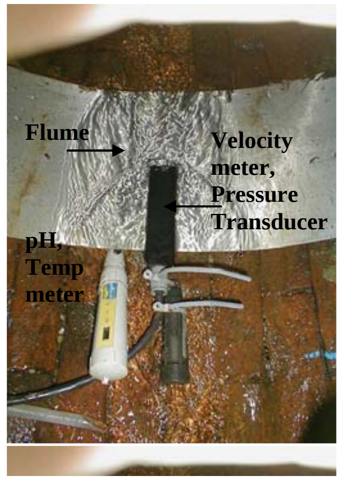
3.1 Water Quality Monitoring

Monitoring in catchments F and O included two permanent water quality stations with additional bedload and first flush sampling. Flow-paced composite stormflow samples were collected using an ISCO 6712 automated water sampler located in 36–inch and 43-inch storm drain pipes in catchment F and catchment O, respectively. The equipment set-up is shown in Figure 4, where the intake sampler for the water quality sampler is secured to the bottom of the storm drain pipe. The automated samples were collected within a single composite bottle. Samples were taken at equal flow intervals (using real time flow computation from the flow meter) to provide event mean concentrations (EMCs). Annual pollutant loads estimates were not computed for the pretreatment and treatment periods using the EMC and flow data given the challenges of equipment reliability. Sensitivity analyses, however, showed that these potential inaccuracies in flow do not affect the automated flow weighted compositing process and so do not impinge greatly on the accuracy of the EMC measurements.

Figure 4. Water sampling set-up, a) automated water sampler (ISCO 6712) lowered into storm drain, and b) monitoring equipment in storm drain.

a)

b)



Weekly baseflow samples were reduced to biweekly beginning January 2006. Statistical analyses showed that there was no significant effect in the water quality measurements by reducing the sampling frequency.

The initial set-up included an ISCO 750 area velocity flow module. Due to repeated damage during high flow events, the velocity flow meter was replaced with a bubbler sampler on September 29, 2007. Operational issues persisted during high flow events. As a result, the gaps in flow data from these equipment problems generated a lack of reliable flow measurements throughout the study period. Flow estimates representing a range of storm events were estimated by deriving runoff coefficients (Belt and Runyan 2008). Briefly, discharge estimates derived using Manning's equation were regressed against selected storm events in 2005 to estimate storm event runoff coefficients for each of the study catchments. Estimated discharge measurements were compared to other USGS monitoring stations in the Gwynns Falls watershed in Balimore City and County (e.g. Gwynns Run, Maidens Choice and Dead Run) to provide rainfall-runoff estimates. The runoff ratios were compared to published research values for small urban catchments and model simulations using TR-55. The runoff ratio computed for catchment O was reasonable, whereas the value estimated for catchment F was considered unreasonably low and was not used.

The sites were accessed weekly to check equipment operation, change batteries and bottles, draw dry weather flow samples and evaluate flow and flow obstructions. A Quality Management Plan and Protocols provided procedures for proper instrumentation, measurement and QA/QC of data collection (Belt and Taylorson 2005).

3.2 Bedload

Bedload is material in a stream or storm drain that moves along the bottom of the channel or pipe. Based on the size of bedload particles (e.g. coarse particles > 250µm), these and other materials in stormwater are not effectively sampled (or missed entirely) by standard automated sampling equipment. A bedload trap with organic filter bags was designed, constructed and installed by the Baltimore City Department of Public Works in catchments F and O (Figure 5). The sampler was installed downslope of the ISCO automated sampler to collect its bypassed load (i.e., bedload). Samples were collected approximately every two weeks from February 2006 through March 2007. Due to confined space entry safety issues, bedload samples were not continued at catchment F after February 2006. The samples were submitted to Baltimore County DPW to be weighed and analyzed for nitrate, kjeldahl N, dissolved P, total P, sulfate, and trace metals (copper, zinc and lead).

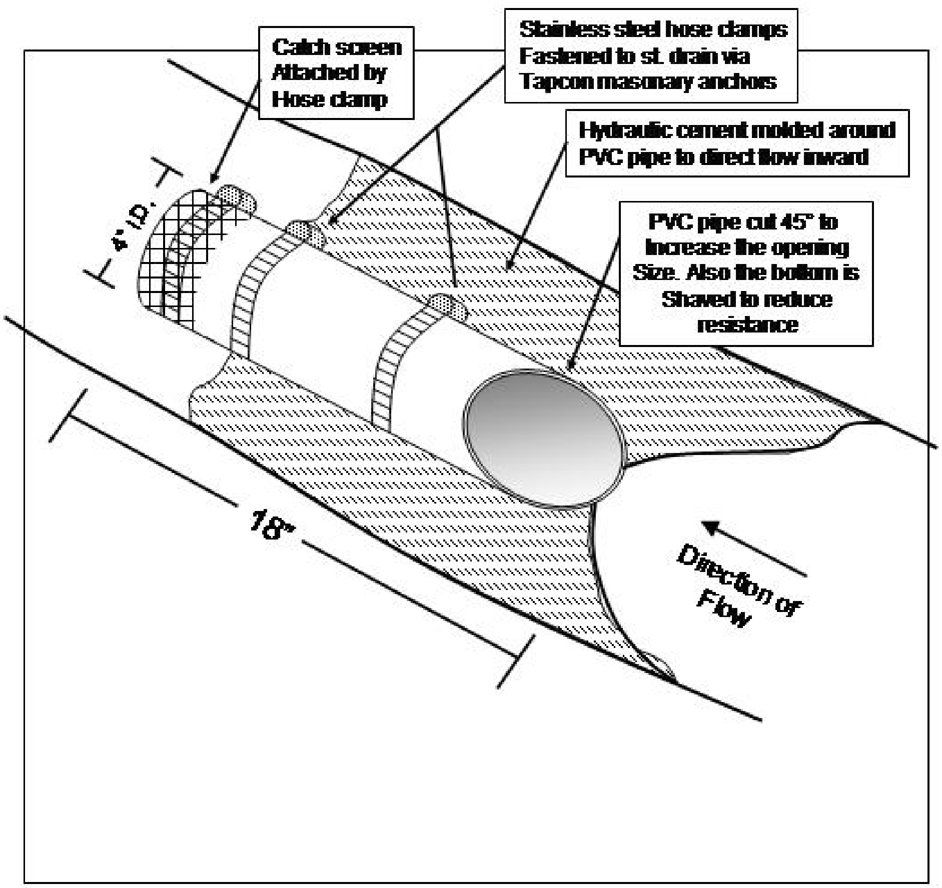


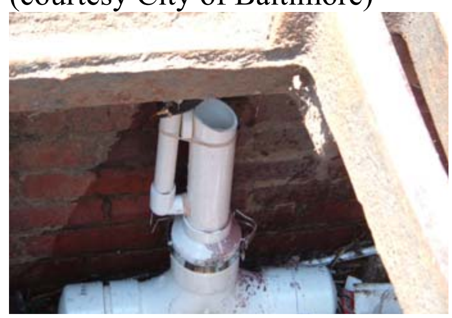
Figure 5. Bedload sampler design.

3.3 First Flush

First flush samples represent the first fraction of stormwater runoff that typically have elevated concentrations compared to storm EMC for some, but not all pollutants. A total of 41 first flush samples were collected at four stations over a10 month period during Treatment 1 for the two study catchments (08/08/06 through 6/29/07). The data generated was used to determine if differences in street sweeping treatment between the two study catchment would have an effect on first flush concentrations. The median first flush pollutant concentrations for each inlet were calculated. Two samplers were located in inlets on Baltimore and Lanvale streets, with additional samplers on the 200 block of Mount Street in catchment O and the control street on the 1800 block of Fairmount in catchment O. The equipment included a single wide-mouth 3L polyethylene sample bottle that was suspended inside the stormwater inlets (Figure 6) and retrieved after storm events.

3.4 Precipitation

Figure 6. Example of inlet sampler to collect first flush samples (courtesy City of Baltimore)



A tipping bucket rain gage was installed at the Harlem Park Elementary School adjacent to the catchment F water quality monitoring site. The equipment was destroyed and was not replaced due to the high risk of repeated vandalism at this open site. Alternative sites were explored through cooperative efforts with the DPW and BES but a suitable location could not be identified nor were there available funds to purchase new equipment. Total annual precipitation was compiled using data from the Sterling National Weather Station and the Maryland Science Center in Baltimore Inner Harbor.

3.5 Street Sweeping

An Elgin Whirlwind © MV 4 Wheel Vacuum Air Sweeper was used to sweep streets in both of the catchments. Appendix B provides a detailed description of the street sweeper.

Street particulate matter sampling (SPaM)

Street particulate matter (SPaM) sampling equipment and methods followed those developed by Pitt (1979) and are described in (CWP 2006c) (DiBlasi 2008) (Figure 7). Samples were collected beginning July 2006 through April 2007 on three streets that were swept within catchment O (Mount, Fayette, Lexington) and one control street that was not swept (Fairmount). These streets were selected due to their characteristics representative of the streets within catchment O and for safety considerations due to hazards presented by traffic. Appendix C provides a description of these monitoring sites.

Samples were collected by vacuuming 10-20 strips from the curb to the crown of the street at 10 ft (3m) intervals along the length of the street. For safety reasons, the entire street width was not sampled. The number of strips varied depending on the total street length, number of cars on the street and the loading of the particulate matter on the street surface. A random starting point was selected within the first third of the street length being sampled. However, parked cars were often located within this street length, and an alternate starting point was selected. Material that was too large to collect using the vacuum was manually picked up and placed in a plastic bag and weighed and characterized at UMBC.

Figure 7. Collection of street particulate matter.

A total of 26 SPaM samples were collected to include:

- 10 before street sweeping, or accumulation (A) samples collected 24 hours after sweeping or a rain event,
- 10 after-sweeping samples (S) collected within one to three hours after the street has been swept, and
- 6 control (C) samples collected.

Approximately 250-400 g of SPaM was collected and sent to the Baltimore County Baltimore County Department of Environment and Resource Management (DEPRM) and Department of Public Works laboratories for chemical and particle size analysis into the following categories:

- <0.063 mm
- 0.063-0.125 mm
- 0.125-0.25 mm
- 0.25-0.5 mm
- 0.5-1.0 mm
- 1.0-2.0 mm
- 2.0-4.0 mm
- >4.0 mm
- >4.0 mm (organic)

Six samples (2 -A, 2-S and 2-C) were sent to Martel Laboratories for inter-laboratory comparison. DiBlasi (2008) provides a detailed description of sample preparation and analytical methods. Table 4 lists the parameters and the analytical methods used to characterize the SPaM.

Table 4. Analytical parameters for street surface particulate samples.

Parameter	Code	Method	Reporting Limit	Holding Time
Total Suspended Solids (liquid samples only)	TSS	EPA 160.2	1 mg/L	7 days
Total Solids	TS	EPA 160.3	1 mg/L	7 days
Total Kjeldahl Nitrogen	TKN	EPA 351.3	0.1 mg/L	28 days
Nitrate-Nitrite	NO_2-NO_3	EPA 300.0	0.02 mg/L	28 days
Total Phosphorus	TP	EPA 365.3	0.05 mg/L	28 days
Orthophosphorus	OP	EPA 300.0	0.01 mg/L	48 hours
Biochemical Oxygen Demand	BOD	EPA 405.1	2 mg/L	48 hours
Chemical Oxygen Demand	COD	EPA 410.4	5 mg/L	28 days
Total Copper	Cu	EPA 220.1	0.01 mg/L	6 months
Total Lead	Pb	EPA 239.2	0.005 mg/L	6 months
Total Zinc	Zn	EPA 289.1	0.01 mg/L	6 months
Total Cadmium	Cd	EPA 213.2	0.01 mg/L	6 months

3.6 Storm Drain Inlet Cleaning

The purpose of this monitoring element was to measure accumulation rates and chemical composition of materials retained in the storm drain system. The monitoring sites were located in Baltimore County. The storm drain inlets were designed without a ‘sump’ and are considered a flow-through or ‘self cleaning’ system. The effect of land use and physiographic province on both accumulation rate and chemical composition of the trapped material was investigated. Using the Baltimore County database on storm drain cleanouts and Geographic Information Systems (GIS) information on the storm drainage system, inlets were selected in both the Gwynns Falls watershed (Piedmont) and in the Baltimore Harbor direct drainage watershed (Coastal Plain) for monitoring.

Inlet selection

A total of 100 inlets were selected in the Physiographic and Coastal Plain areas for two different land use types (Table 5). Inlets within residential land uses (low, medium and high density) and commercial industrial land uses were randomly selected using Baltimore County GIS data layers. Each storm drain inlet was initially inspected in the field to determine if it can be sampled safely and if there were other factors, such as structural conditions, that would preclude sampling. Inlets that were rejected were replaced by other randomly selected inlets in the same category.

Table 5. Accumulation Rate Sample Design (P = Piedmont, C = Coastal, R = Residential, C/I = Commercial/Industrial)

	Residential		**Commercial/Industrial**	
	# Inlets	Code	# Inlets	Code
Gwynns Falls (Piedmont)	25	P-R	25	P-C/I
Baltimore Harbor (Coastal Plain)	25	C-R	25	C-C/I

Of the total194 inlets, 91 were rejected as unsuitable sites. Most were rejected because of their location on busy streets, primarily in travel lanes, depth (greater than 72”), or because they were not found at the indicated location. Additional inlets were randomly selected for inclusion in the study when any of the original randomly selected inlets were deemed unacceptable to sample to keep the total sample number at 100. A subset of four inlets from each class of inlet for a total of sixteen inlets was sampled to determine the rate of accumulation and chemical characterization.

Rate of accumulation

The rate of accumulation was based on material removed from 16 of the inlets on a quarterly basis. Although monthly accumulation measurements were also taken using all 100 inlets, these measurements were considered inaccurate and did not effectively characterize the volume of material. Observations during the monthly sampling efforts are provided in the report for characterization purposes.

Two separate rounds of inlet sampling were conducted in 2006 during the spring (April) and fall (September/October). It should be noted that the fall sampling for chemistry was early and did not capture ‘leaf fall’, however, the spring sample included compacted, decomposed leaf fall material. Accumulation measurements are based on the time period between the spring and fall cleanout. A two-way ANOVA was used to determine the effects of land use and physiographic province on accumulation rates.

The material was removed by hand using a trowel and dustpan and the volume of material removed was determined. Depth measurements were taken before cleaning and after cleaning and recorded on a standard data sheet. Each component, sediment, leaves and trash, were weighed separately in containers of known volume. This permitted a separate calculation of volume of material in the inlet. The combined weight was used to assess bulk density based on the cubic feet of material collected in the inlet. Percent sediment, organic matter, and trash were also determined based on weight of material removed. The sediment sample collected from each inlet was split into two. One sample was used to analyze for particle size distribution, while the second sample was used to analyze for pollutant concentrations expressed as mg/kg. A sample of the organic matter was collected and sent to the laboratory for a separate analysis of pollutant concentration. Each sample was placed in a plastic bucket or sediment bag and labeled with the date, assigned inlet identifier, sampling crew, and whether the sample was a chemical analysis sample or a particle size analysis sample. Trash collected from the inlet was not kept for analysis.

Particle size and pollutant characterization

The particle size analysis was conducted at the Baltimore County DEPRM laboratory for the same particle size classes as the SPaM. CWP (2006c) describes the analytical procedures used.

The chemical composition of the samples obtained from the inlets was analyzed by the Baltimore County Department of Public Works. Each sediment and organic matter sample was analyzed for the parameters listed in Table 6 using standard analytical techniques. A description of sample preparation and methods are provided in CWP (2006c).

The sample analytical results were compared to an agronomic soil from the North American Proficiency Testing Program run by the Soil Science Society of America. This soil was run for every soil test as part of the quality control program along with duplicates and spikes.

The results were reported in mg/kg and were entered into an Excel database by DEPRM. The Quality Control, including double entry, outlier analysis, and out of range analysis, was conducted by the Quality Control Officer prior to analysis.

Table 6. Analytical parameters for storm drain inlet material characterization.

Parameter	Code	Method	Reporting Limit	Holding Time
Total Solids	TS	EPA 160.3	1 mg/kg	7 days
Total Kjeldahl Nitrogen	TKN	EPA 351.3	0.1 mg/kg	28 days
Nitrate-Nitrite	NO_2-NO_3	EPA 353.2	0.02 mg/kg	28 days
Total Phosphorus	TP	EPA 365.3	0.05 mg/kg	28 days
Orthophosphorus	OP	EPA 365.3	0.01 mg/kg	48 hours
Biochemical Oxygen Demand	BOD	EPA 405.1	2 mg/kg	48 hours
Chemical Oxygen Demand	COD	EPA 410.4	5 mg/kg	28 days
Total Copper	Cu	EPA 200.7	0.01 mg/kg	6 months
Total Lead	Pb	EPA 239.2	0.005 mg/kg	6 months
Total Zinc	Zn	EPA 200.7	0.01 mg/kg	6 months
Total Cadmium	Cd	EPA 213.2	0.01 mg/kg	6 months

4.0 Monitoring Results and Analysis

Precipitation conditions were similar between the pretreatment and treatment study periods. Daily and monthly precipitation records from the National Weather Service Maryland Science Center NOAA weather station and other sources were used to complete the data record provided in Table 7. Total rainfall during the pretreatment study period was 58.4 inches and 60.5 inches during the treatment period. Approximately 55% and 58% of the total daily rainfall were categorized as runoff generating, having rainfall greater than 0.1″ with an average of 5 to nearly 7 days between these events.

Table 7. Comparison of pretreatment and treatment rainfall patterns.

Pretreatment	Precip (in)	Average monthly (in)	% rain events > 0.1 in.	Annual precipitation (in) for each of the study periods
9/01/04 - 12/31/05	58.41	3.9	55%	**2005 – 49.13 in**
Treatment				**2006 – 43.23 in**
1/1/06 - 7/14/07*	60.54	3.3	58%	**2007 – 34.97**

4.1 Water Quality Data

An insufficient number of samples were collected to sufficiently characterize the patterns in water quality pre and post-treatment, while an even greater number of samples were needed for paired sample comparisons (e.g. catchments F and O pre and post treatment). For example, using methods described by Burton and Pitt (2002), an estimated 87 samples would be needed to characterize the stormwater EMCs in either catchment with statistical confidence level of 95% and power of 80% using the coefficient of variation from initial samples collected during the treatment phase, as well as the pre-treatment phase. A total of eleven storm event samples were collected in catchment O and seven in catchment F during the single treatment study period (see Table 2). Due to only one additional storm event sample collected during the treatment 2 period (not shown), results are only presented for treatment 1 period.

A summary of median EMCs for storm event samples is provided in Table 8 for the pretreatment period and treatment period for street sweeping only. The values are compared to the median National Stormwater Quality Database (Pitt and Maestre 2004). A summary of all samples is provided in Appendix D from DiBlasi (2008).

Overall, no positive changes in storm event water quality were observed from the pretreatment and treatment period as summarized in Table 8 and illustrated in Figures 8a – d for selected parameters. All storm event samples for both study periods had higher or similar concentrations compared to national values. The only statistically significant difference observed between the pretreatment and treatment period stormflow concentrations were for total suspended sediment and hardness in catchment O (p-value < 0.05) (DiBlasi 2008). These concentrations were higher in the treatment period, rather than lower as might be expected with increased street sweeping frequency. The presence of baseflow in such small catchments, and high fluoride and ammonia levels (not shown) suggest that baseflow may be augmented by drinking water, illicit discharges or sewage discharges and contributing to the elevated baseflow concentrations. Such conditions can mask any potential difference in EMCs that may be observed during the treatment period, although considering the flashy nature of urban stormwater flows, in general, this masking effective may be minimal.

Table 8. Pretreatment and treatment storm event median EMCs for the study catchments (DiBlasi 2008).

Catchment O (Baltimore Street)				
Parameter	**Units**	**Storm Pretreatment**	**Storm Treatment**	National Median[1]
n =	Number	**17**	**11**	3765
BOD5	mg/L	21.0	22.0	8.6
DisCu	µg/L	19.0	16.0	8.0
DisPb	µg/L	4.77	1.94	3.0
DisZn	µg/L	60.0	74.0	52.0
E. coli	MPN/100 ml	30000	30000	1750
Fec. Col.	MPN/100 ml	35000	50000	5091
Hardness	mg/L	100	170	38.0
NO2-NO3	mg/L	1.70	1.10	0.6
SS	mg/L	52.0	100	58.0
TKN	mg/L	1.70	2.40	1.4
TP	mg/L	0.34	0.45	0.27
TotCu	µg/L	41.0	40.0	16.0
TotPb	µg/L	50.0	110	16.0
TotZn	µg/L	120	150	116
Catchment F (Lanvale Street)				
Parameter	**Units**	**Storm Pretreatment**	**Storm Treatment**	National Median[1]
n =	Number	**15**	**7**	3765
BOD5	mg/L	19.0	15.0	8.6
DisCu	µg/L	5.50	5.90	8.0
DisPb	µg/L	2.09	*100% <5*	3.0
DisZn	µg/L	62.0	58.0	52.0
E. coli	MPN/100 ml	17000	17000	1750
Fec. Col.	MPN/100 ml	30000	30000	5091
Hardness	mg/L	62.0	140	38.0
NO2-NO3	mg/L	0.77	0.58	0.6
SS	mg/L	59.0	38.0	58.0
TKN	mg/L	1.60	1.10	1.4
TP	mg/L	0.31	0.27	0.27
TotCu	µg/L	13.0	18.0	16.0
TotPb	µg/L	46.0	49.0	16.0
TotZn	µg/L	100	91.0	116

[1] from Pitt et al. 2004, National stormwater quality database (NSQD).

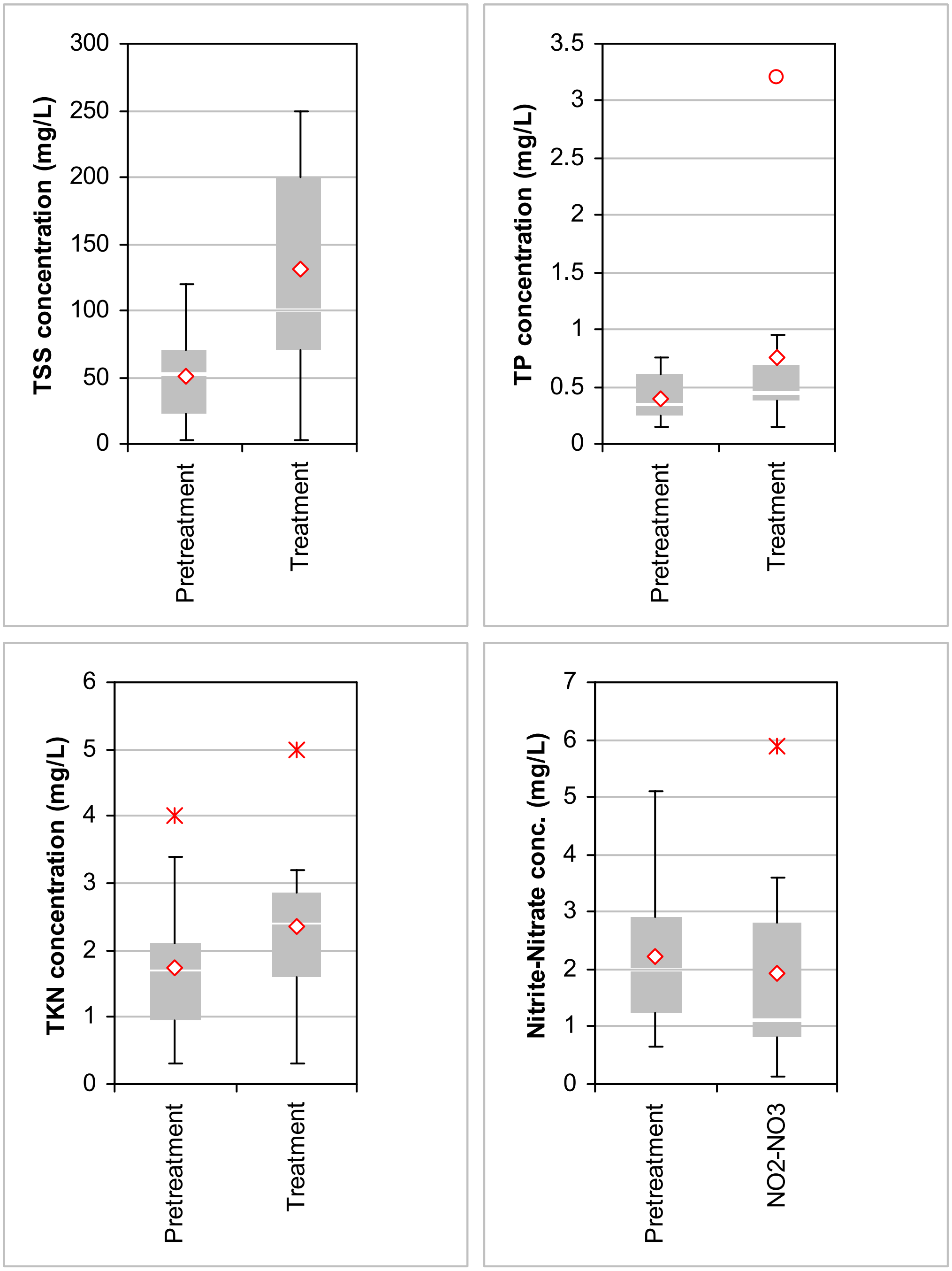


Figure 8. A comparison of pretreatment and treatment storm event median EMCs a) TSS (mg/L), b) TP (mg/L), c) TKN and d)NO2-NO3 (mg/L) .

4.2 First flush samples

A total of 41 first flush samples were collected during the Treatment 1 period of the study between 08/08/2006 - 6/29/07 at four inlets. The 3L sample container collected a very small fraction of the first flush event for the contributing drainage areas (e.g. less than 1/1000″). The median first flush concentrations are summarized in Table 9. Overall, the median first flush concentrations for many pollutants are an order of magnitude greater than the stormflow EMCs (BOD-5, dissolved Pb, bacteria, TSS, TKN, TP, total Cu). There is large variability in the data where in some instances stormflow EMCs were higher when compared to first flush concentrations on a storm event basis. For example, DiBlasi (2008) found the median EMCs for E.coli and hardness in catchment F to be greater than the first flush samples collected at the Lanvale inlet in this catchment. An inconsistent pattern amongst the three treatment inlets and the control was also observed. It may be expected that the first flush samples collected at the inlets along the treatment streets would be lower than the control street. It was found that the median first flush dissolved metal concentrations at the Baltimore inlet were higher, and for the Mount St inlet lower compared to the control, Fairmont St. inlet.

Although the City of Baltimore has made progress to address the illicit discharges into the storm drainage system, elevated bacteria levels observed for both first flush and stormflow EMCs illustrate a continued problem. The highly developed and connected drainage network within the study catchments (e.g. downspouts) along with the potential storage of material in the storm drain system itself create a system for multiple source areas to contribute pollutants during storm events, in addition to illicit discharges. Examples of some of the potential contributing source areas include compacted pervious areas and rooftops that may provide elevated concentrations of bacteria, nutrients and metals as found in other source area monitoring studies (e.g. Steuer et al. 1997, Bannerman et al. 1993). In addition, elevated lead concentrations found in Baltimore soils (e.g., 289 mg/kg) (Pouyat et al. 2007) may contribute to the lead concentrations in stormwater.

Table 9. Median concentrations of first flush samples collected at 4 monitoring stations in catchment O (Baltimore, Mount, Fairmount) and catchment F (Lanvale) (from DiBlasi 2008).

Parameter	Units	Baltimore St. (Catchment O)	Mount St. (Catchment O)	Lanvale St. (Catchment F)	Fairmount St. (control)
Sample (n)	Number	8	15	8	10
BOD-5	mg/L	210	81	140	110
Dis Cu	µg/L	18	4.3	28	6
Dis Pb	µg/L	16	3.5	40.5	7.95
Dis Zn	µg/L	225	33	255	69
E. coli	MPN/100 ml	60000	1100000	13500	24000
Fec. Col.	MPN/100 ml	30000	1100000	28500	27000
Hardness	mg/L	400	400	350	210

NO2-NO3	mg/L	1.35	1.15	3.15	1.11
TSS	mg/L	1450	1400	515	740
TKN	mg/L	12.85	4.2	7.65	5.15
TP	mg/L	3.05	4.80	1.70	1.90
Tot Cu	µg/L	135	77	72.5	63
Tot Pb	µg/L	210	240	255	265
Tot Zn	µg/L	635	550	520	530

4.3 Bedload

A total of eight bedload samples were collected from the Baltimore sampling station in catchment O. The average mass of bedload collected was 225g (standard deviation of 114g) per sample, which typically represented material accumulated over a 1-2 week period. Figure 9 illustrates the wide variability in the type of material collected. The monitoring set-up did not function as expected. Large debris (glass bottles, bricks) often blocked the intake of the bedload sampler and bedload material would bypass the sampler and was not collected, or the mesh screen designed to collect the bedload material would be shredded due to the glass present in the storm drain. Consequently, the amount of bedload material collected is an underestimation of the total contribution.

Despite these shortcomings of the bedload sampling equipment, inferences may be drawn from the bedload that was collected along with observations during the study period and other recent street sweeping studies to assess the significance of the bedload material to stormflow pollutant loadings. The small quantity of bedload material collected is in part attributed to the observation made during the Treatment 1 period that the storm drain inlets were filled with trash and other debris, effectively preventing any additional material from entering (Figure 10). However, data collected during SPaM monitoring provides some indication of the proportion of gross pollutants available to be entrained by runoff. For example, gross pollutants picked up during SPaM sampling comprised approximately 3% of the total sample weight of the SPaM collected. Further, as will be presented in the following section, the majority of the SPaM may be classified as bedload based on its particle size distribution. Estimates of the proportion of bedload from other studies range from 5-10% (Selbig, 2007, unpublished, Burton and Pitt 2002).

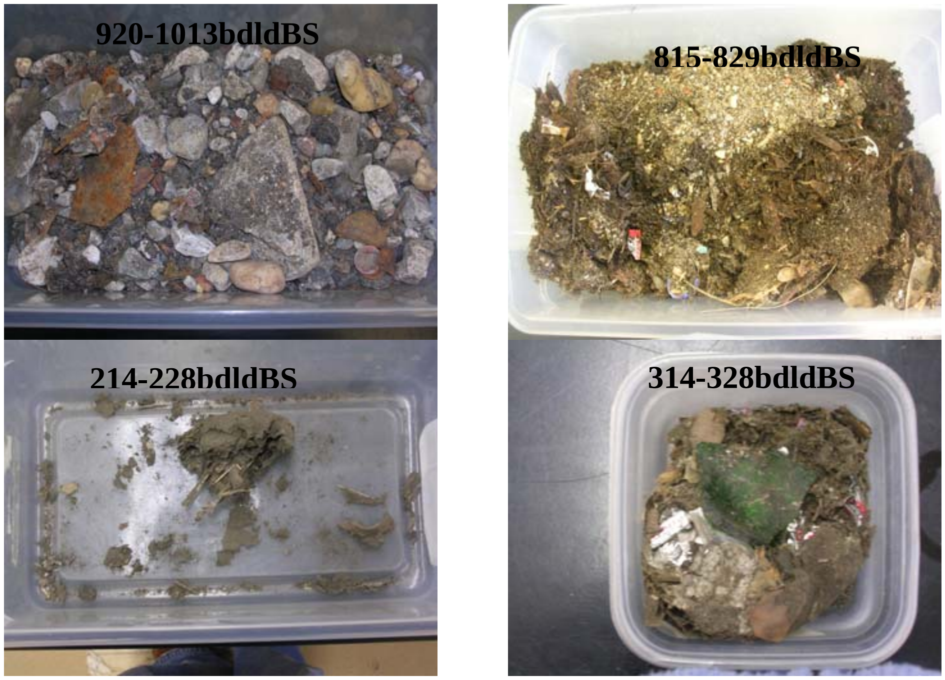


Figure 9. Examples of bedload material collected in catchment O.

Figure 10. Example of material blocking storm drain inlet in catchment O.

4.4 Source Area Monitoring: Street Particulate Matter (SPaM) sampling

SPaM Loading

SPaM loadings were calculated by taking the total sample weight (g) and dividing it by the area of street surface vacuumed (m^2). The average loading (expressed as g/m^2) is shown in Figure 10 and was relatively constant throughout the study period. Analysis of Variance (ANOVA) found significant differences in the SPaM loading between the control (C) and before (A) and after sweeping (S) loading. There were no significant differences between the A and S samples (DiBlasi 2008). The SPaM loading in Figure 11 excludes the trash and other debris that was collected from the sampling streets and weighed separately and presented above as bedload.

The SPaM loading was extrapolated to lbs/ curb mile for comparison to other studies. The loading (Table 10) are comparably low to other studies that report typical street loading range from 887 to 1,064 lbs/curb mile (Sartor and Gabory 1984). However, Selbig and Bannerman (2007) estimated less than 500 lbs/curb mile for weekly SPaM loadings in the Madison, WI residential street sweeping study (Selbig and Bannerman 2007). The low SPaM loading in the current study may be explained by intense storm events prior to source area monitoring where 5.18 inches of rain occurred from June 23 through 29, 2006, with another 2.3 inches of rain from July 5 to 6, 2006. These conditions would have been very effective to 'wash-off' material from the streets. For example, Pitt and Amy (1979) found that 90% of SPaM was washed-off by rain exceeding 0.39 inches (10mm) of rain.

Figure 11. Average street particulate matter loadings (g/m2) for the three sample types (A – before sweeping, S – after sweeping, C – control, no sweeping) in catchment O.

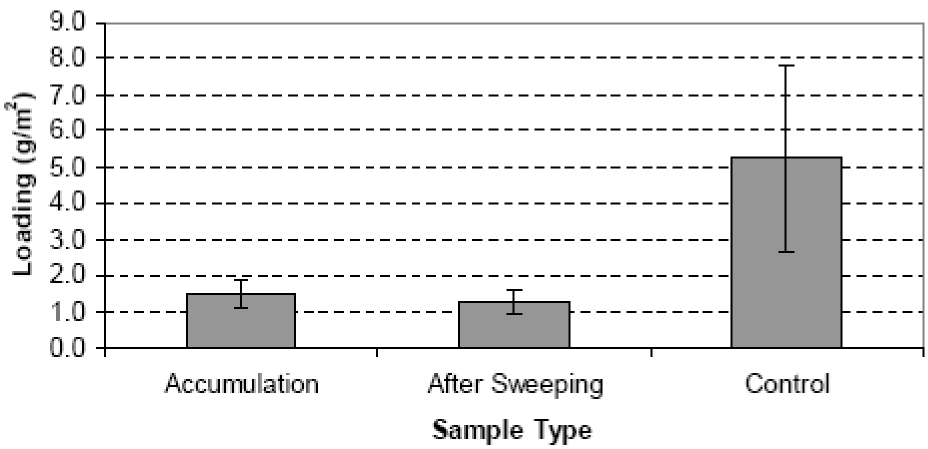


Table 10. Average SPaM loading for the before (A) and (S) after street sweeping and control (C) samples.

		Loading		
Sample type	n	g/m2	lbs/curb mile*	lbs/street acres**
A	10	1.47	645.2	245
S	7	1.26	553.3	153
C	4	4.62	1,100.8	304

* two times the street length (e.g. both sides of the street)
** includes impervious area of both streets and alleys

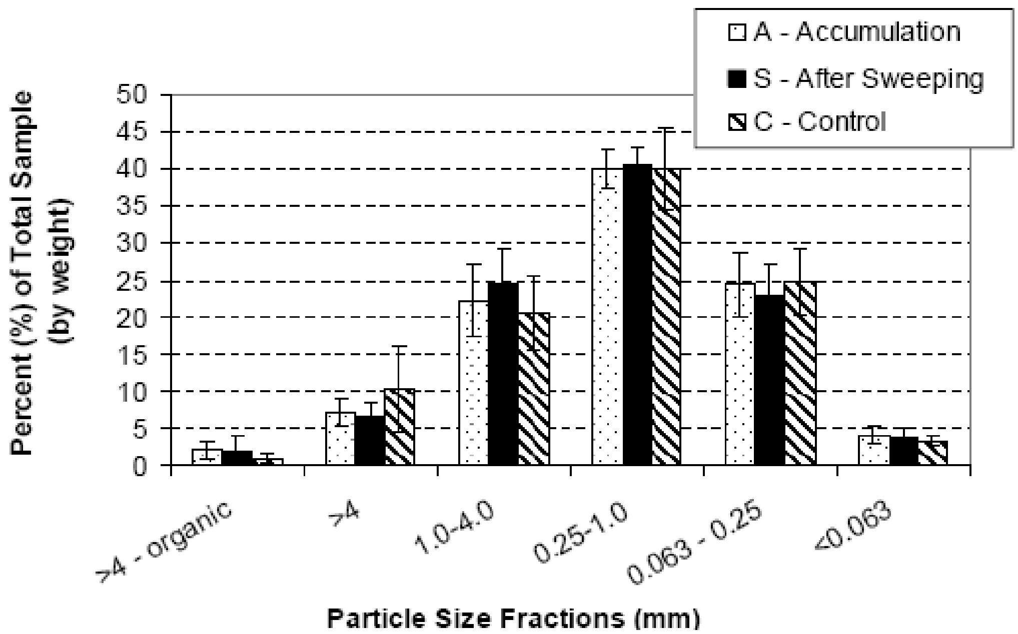
Particle Size Analysis

The average percent (by weight) of the SPaM was combined into six particle size fractions and calculated for the three sample types. The sand/silt split for sediment is 63 µm (0.63mm), with particles less than 63µm classified as silt, and particles less than 45µm considered dissolved (See Box 1 for a description of particle sizes). Particle size distributions were generally similar across all sample types and were not affected by street sweeping (Figure 12). This is consistent with Selbig and Bannerman (2007), who found that the particle size distribution of SPaM was similar during the pretreatment and treatment study periods. However, other field studies found that the median particle size of SPaM is lower following street sweeping (Pitt 1979, Bender and Terstriep 1984, Pitt and Bissonnette 1984) based on the ability of street sweepers to more effectively pick-up coarser sized particles. The only significant difference amongst sample type and particle size classes for this study was found for the "> 4mm organic size fraction" that was significantly greater for accumulation compared to control samples at the 95% confidence level. This may be attributed to the street trees present along the treatment streets but is inconclusive given the small amount of this particle size and contribution to total SPaM weight (1-2%) (DiBlasi 2008).

Box 1. A description of particle size distributions (from Breault et al. 2005).	
Gravel	Larger than 2,000µm (2.0 mm)
Coarse sand	Smaller than 2,000µm, larger than or equal to 250µm (0.25mm)
Find sand	Smaller than 250µm, larger than or equal to 125 µm (0.125mm)
Very fine sand	Smaller than 125µm, larger than or equal to 63µm (0.63mm)
Silt and clay	Smaller than 63µm, larger than or equal to 45 µm (0.45mm)
Dissolved particles	Smaller than 45 µm

The majority (40%) of the SPaM particles were associated with the 250µm to 1,000 µm size class. Similar to other recent studies, the majority of particles in SPaM have particles equal to or greater than 250µm that comprise approximately 70% of the total street dirt load sampled. Only a small fraction of the SPaM had particles less than or equal to 63µm. In a previous study, Sartor and Boyd (1972) found that about half of the SPaM was greater than 250µm for their Baltimore study site.

Figure 12. Average percent by weight of each sample type by particle size fractions. Error bars represent 1 standard deviation of the mean. (from DiBlasi 2008)



Chemical Composition

SPaM was analyzed for nutrients and metals but many censored values (below detection values or 'less-than" values) precluded a comprehensive statistical analysis of the SPaM chemistry. The average concentrations reported as "mg/kg" are presented in Figure 13 where the metal concentrations represent elemental metals (bioavailable fraction) and not total metals. The average concentrations are similar across all sample types with the exception of lead and total phosphorus. Lead concentrations and total phosphorus concentrations were significantly higher (at the 95% level) in the control samples compared to both the A and S samples (DiBlasi 2008). Overall TKN and TP have the highest concentrations ranging from 1,477 to 3,067 mg/kg and 1,033 to 3,309 mg/kg for all sample types, respectively.

The majority of the pollutants analyzed were associated with particle sizes greater than 250µm, similar to the particle size distribution of the SPaM (Figure 14). Although comparable to other studies, the percent contribution of pollutants for particles greater than 250µm is greater for TP and TKN (70% for TKN compared to 40-50% as reported by Shaheen 1984, and Sartor and Boyd 1972). This is likely due to the inclusion of leaf material in the sample analyses and is consistent with Waschbusch et al. (1999) where TP contribution increased from 50% to 80% for particles greater than or equal to 250µm when leaves were added to the SPaM. These results strongly indicate the significant contribution of leaf litter to SPaM and potential pollutant loadings to receiving waters, The metals concentrations in this study are not comparable to other studies that report total metals.

Figure 13. Chemical characterization of street particulate matter, E = elemental (from DiBlasi 2008).

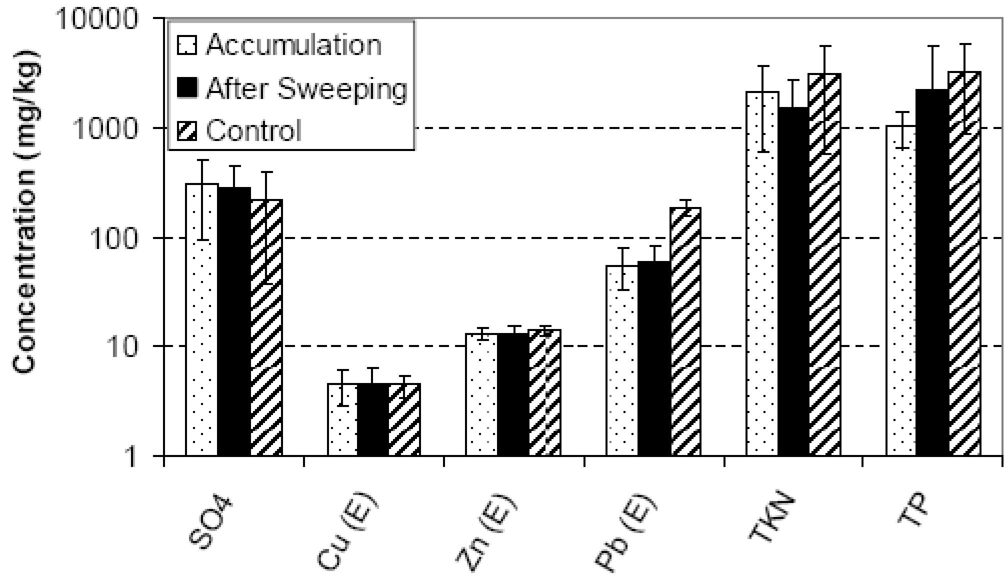
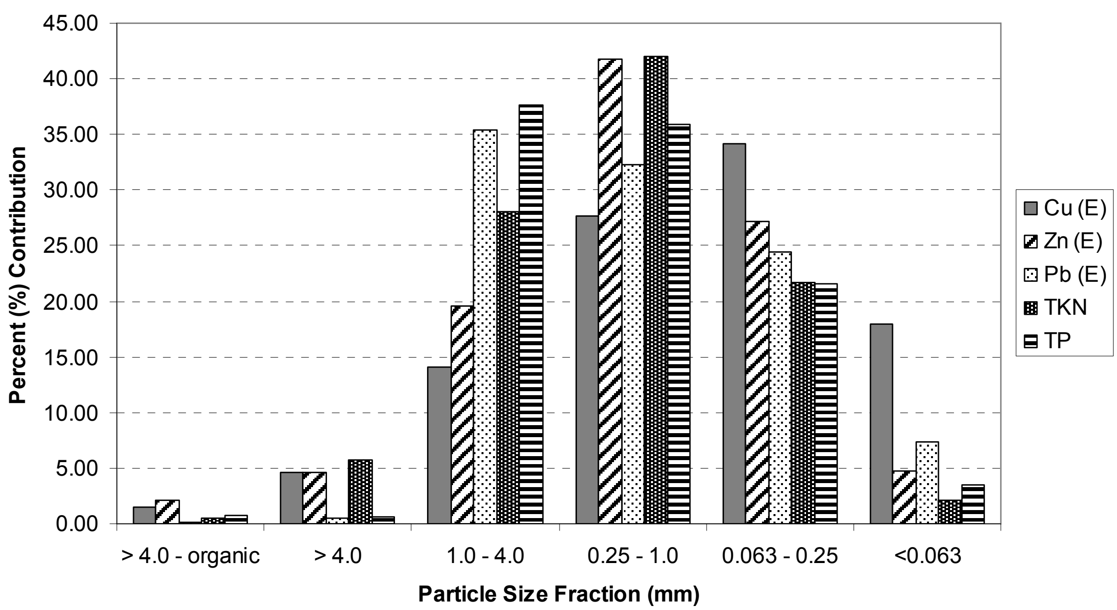


Figure 14. Percent contribution by particle size fraction to total pollutant load type in type S sample (from DiBlasi 2008)



4.5 Storm Drain Inlet Behavior

Storm Drain Inlet Material Accumulation

Different land uses resulted in significantly different accumulation rates, with commercial/industrial land uses having higher accumulation rates (Table 11). There were no significant differences between the Coastal Plain and Piedmont provinces for the accumulation rates. Annual accumulation rates (lbs/yr) were estimated using an overall estimated mean bulk density of 331 pounds/cubic yard of 13.4 lb/yr for residential land uses and 53.7 lbs/yr for commercial/industrial land uses. Inlet annual accumulation rates in the Coastal Plain were 1.5 times greater compared to the Piedmont area at 40.3 lbs/yr compared to 26.9 lbs/yr, respectively. Drainage areas were not estimated during this monitoring effort to provide unit aerial loadings rates. Table 12 provides unit area loading rates based on data from Pitt and Bissonnette (1984). The higher accumulation rates in the catch basins reflects the function of the sump that has the greater capacity to store material compared to inlets without a sump.

Material removed from the inlets consisted largely of sediment and leaves where, on average 52% of the material accumulated was leaves (Table 13). During the monthly site visits, the presence of large pieces of wood and other material, such as a scooter, was found and acted like a 'dam' storing material behind it. Net losses were also observed on a monthly basis during the winter and spring where wet conditions provided a suitable environment for degradation of organic matter as noted by the decomposed leaf material.

Table 11. Daily Accumulation Rate Based on Sampled Inlets (Cubic feet/day)

	Residential	Commercial/Industrial	**Physiographic Province Means**
Coastal Plain	0.005	0.013	**0.009**
Piedmont	0.001	0.011	**0.006**
Land Use Means*	**0.003**	**0.012**	

*Was found to be significant with ANOVA analysis

Table 12. Annual accumulation rates for catch basins and inlets (from Pitt and Bissonnette 1984).

	Total Solids	TKN	TP
	Lbs/acre/yr	Lbs/acre/yr	Lbs/acre/yr
Catch basins	13	0.01	0.02
Inlets	5.9	0.01	0.01

Table 13.Composition of Material Removed from Inlets.			
	% Sediment	% Leaves	% Trash
C-C/I	43.1	52.0	4.9
C-R	17.1	67.5	15.4
P-C/I	42.5	40.8	16.7
P-R	29.7	45.0	0.3
Mean	**39.0**	**52.1**	**8.9**

Particle Size Analysis

Particle size-distribution for the inlet material was found to be similar to the distribution for the SPaM (Table 14), similar to findings by Pitt and Bissonnette (1984). Analysis indicates that statistical differences exist amongst the four inlet types for some particle size classes. The Piedmont inlets had significantly higher means in the 2mm-4mm particle class. The Piedmont-residential land use had a lower mean particle size for the four smallest size fractions. This indicates that Piedmont inlets, particularly residential inlets, are enriched in coarser material relative to the finer material. This may be due to the greater topographic slope in the Piedmont physiographic province providing greater energy to flush out the finer material.

Table 14. Particle Size Analysis (% Distribution by Size Class)

Sample Type	N	Particle Size Faction (mm)									
		>4 Organic	>4	2.0-4.0	1.0-2.0	0.5-1.0	0.25-0.5	0.125-0.25	0.063-0.125	0.038-0.063	<.038
C-C/I	7										
Mean		0.8	13.9	11.2	15.8	19.4	21.9	10.9	4.1	1.3	0.6
Std.Dev		0.7	10.9	6.0	4.0	2.9	5.5	3.5	1.5	0.6	0.2
C-R	4										
Mean		1.7	4.2	12.9	19.8	22.0	25.8	10.9	3.1	0.8	0.3
Std.Dev		2.4	1.4	6.7	8.2	9.2	9.8	4.6	1.2	0.4	0.2
P-C/I	8										
Mean		1.9	9.2	15.6	19.9	20.4	19.4	9.1	3.1	0.9	0.3
Std.Dev		3.2	7.0	5.2	4.6	2.6	5.8	3.4	1.9	0.7	0.3
P-R	5										
Mean		3.1	10.8	23.7	21.4	20.0	15.8	4.8	1.0	0.2	.02
Std.Dev		4.3	5.9	10.8	5.0	5.9	6.4	2.9	0.7	0.1	.02
Mean		**1.8**	**10.1**	**15.6**	**19.0**	**20.3**	**20.5**	**9.0**	**3.0**	**0.9**	**0.4**

Storm Drain Inlet Matter Chemical Characterization

Seven (NO3, TKN, TN, PO4, TP, Cu, and Zn) of the nine pollutant parameters were found to be significantly different between sediment and leaves. The sediment exhibited higher concentrations of the nitrogen components (NO3, TKN, and TN) compared to the leaves. Total phosphorus concentrations also had higher concentrations in the sediment in comparison with the leaves. Conversely, ortho-phosphorus had higher concentrations in the leaves than in the sediment, as did copper and zinc. Terrestrial systems are typically nitrogen limited with the result that much of the nitrogen is withdrawn from the leaves prior to leaf fall. This could account for the higher concentrations in the sediment in relation to the leaves. For example, the wet, decaying, large mass of leafy material collected in the spring cleanout provided conditions for dentrification. The results for nitrite, nitrate, TKN, ortho-phosphorus and total phosphorus are displayed in Figures 15-19, respectively.

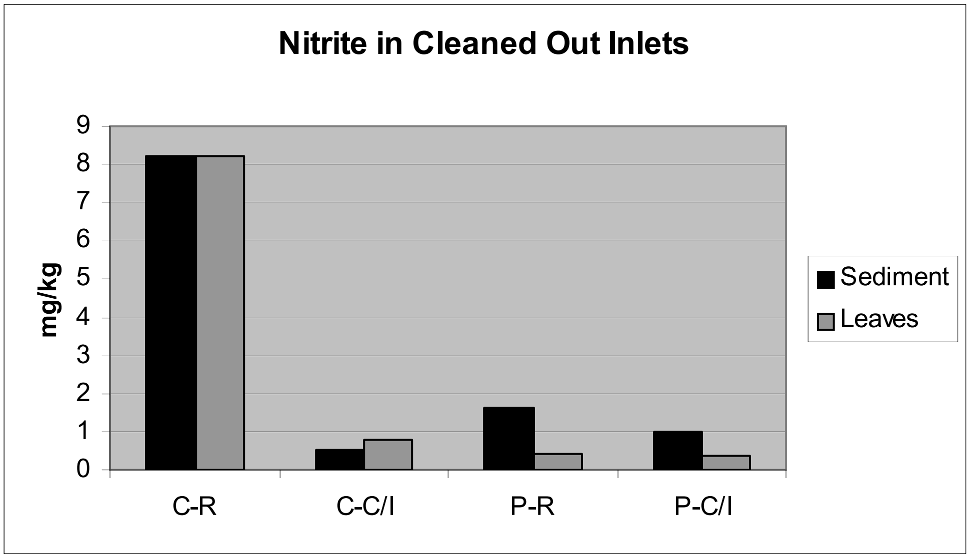


Figure 15. Nitrite concentrations in sediment and leaves by land use and physiographic province.

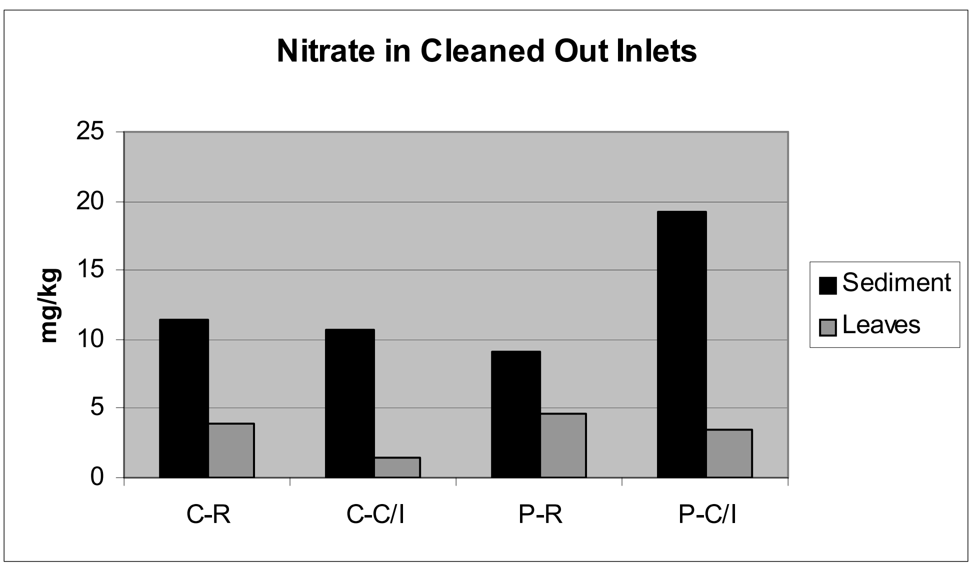


Figure 16. Nitrate concentrations in sediment and leaves by land use and physiographic province.

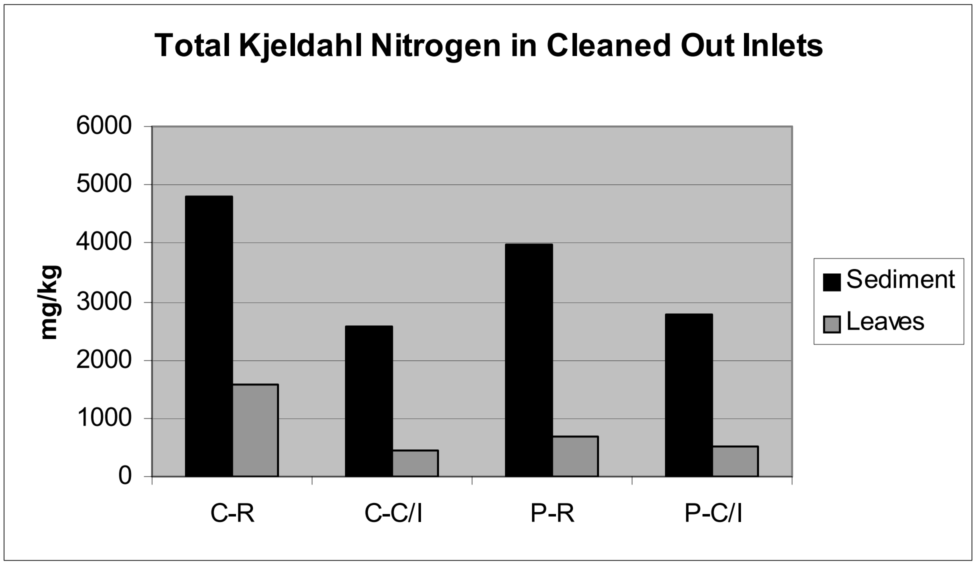


Figure 17. Total Kjeldahl nitrogen concentrations in sediment and leaves by land use and physiographic province.

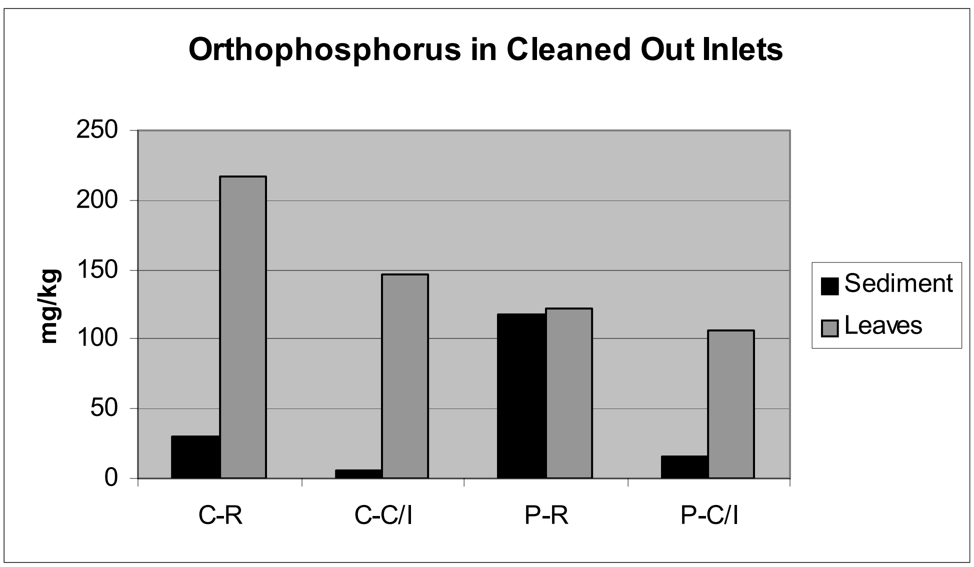


Figure 18. Ortho-phosphorus concentrations in sediment and leaves by land use and physiographic province.

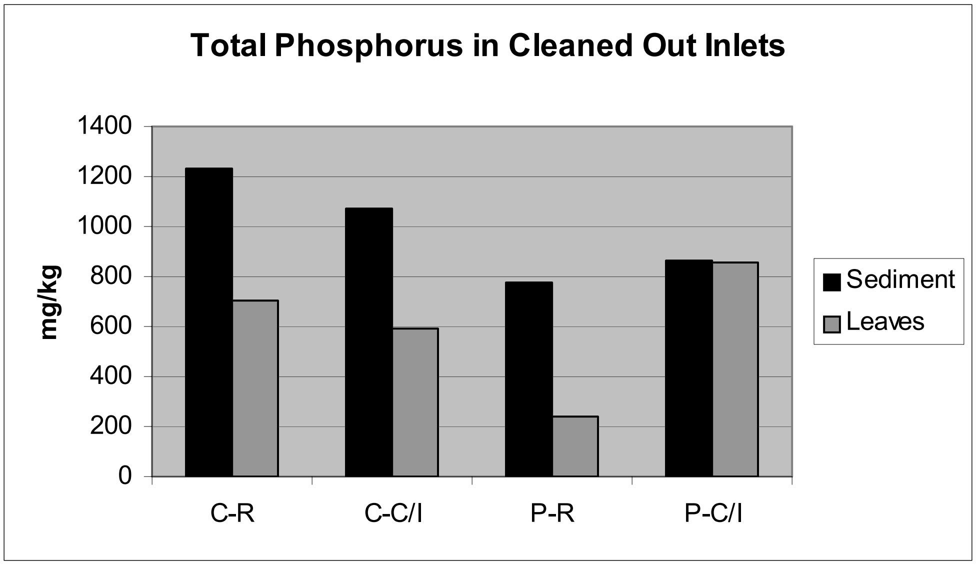


Figure 19. Total phosphorus concentrations in sediment and leaves by land use and physiographic province.

5.0 The Impact of Street Sweeping and Storm Drain Cleanout on Stormwater Quality

This section of the report presents information on the impact that street sweeping and storm drain cleanouts can have on water quality. The compilation of information and data generated from the literature review, municipal practices survey and monitoring, along with recent findings from other street sweeping research studies were used to determine the impact street sweeping and storm drain cleanout practices are expected to have on water quality. Although the intent of the monitoring study was to evaluate the combined effects of street sweeping and storm drain cleanout practices, insufficient data was collected (due to monitoring equipment problems) to allow for this evaluation. As a result, the effectiveness of street sweeping and storm drain cleanout practices are evaluated separately.

5.1 Pollutant Loading Reductions from Street Sweeping and Storm Drain Cleanout

Street Sweeping

The effectiveness of street sweeping in reducing pollutant loadings can be defined in two ways: 1) "pick-up efficiency" (PUE) that quantifies the difference between the SPaM on the street before and after sweeping and 2) quantifying the load reduction at an outfall.

The PUE of street sweeping is based on the difference between the before (A) and after (S) street sweeping loading rates. The PUE is a measure of SPaM removal from the street surface and is not equated to pollutant removal at the outfall or receiving waters. For the current study, the PUE is estimated to be 14% using values presented in Table 10. This value is very low compared to published PUE for the regenerative air and vacuum assisted technology, which range from 60-92% (Breault 2005, Sutherland and Jelen 1997). Selbig and Bannerman (2007), however, report an average PUE of 25-30% for regenerative air and vacuum street sweepers, with a range of -3% to 52%. The lower PUE estimated from the monitoring study may be due to the streets being 'too clean' given the street sweeping frequency of twice per week and the storm events that preceded sample collection and effectively washed off SPaM. For example, the National Urban Runoff Program (e.g. Bannerman et al. 1984) suggest that, on average, streets need to have 1,000 lbs/curb mile of SPaM for sweepers to effectively reduce the SPaM loading.

Studies have consistently documented the increased effectiveness of street sweeping with increasing particle size. Typically, 69-91% of the total mass picked up by street sweepers (mechanical, regenerative air and vacuum assist) have particles greater than or equal to 250μm in diameter. Street sweepers are less effective at picking up smaller sized particles (e.g., Selbig and Bannerman 2007, Sutherland and Jelen 1997).

Despite, the high PUEs reported in other studies, it has been a challenge to demonstrate that street sweeping provides significant pollutant load reductions in paired catchment or modeling studies (Pitt and Bissonnette, 1984, Zariello et al. 2002, Selbig and Bannerman 2007). This has been attributed to several factors, other than street sweeping technology and frequency that contribute to the variability of street sweeping in reducing stormwater pollutant loads to include:

- The SPaM loading on the street (e.g. the dirtier the street the more efficient the street sweeper) and its particle size distribution
- Contribution from other source areas that vary from storm event to storm event, due to storm intensity and antecedent moisture conditions, in addition to seasonal variability and catchment characteristics
- Lag effect of sediment transport for individual storm events such that the loads measured on a storm event basis reflect in part, past storm event pollutant loads
- Sampling bias of suspended solids given a fixed location of automated sampling equipment in the invert of the storm drain

The predominance of the coarse sediment picked up by street sweepers and standard monitoring study designs for street sweeping have implications for measuring the effectiveness of street sweeping. In general, the particles that are most effectively removed by street sweepers are less effectively captured (or sampled) by automated samplers. For example, research has reported the potential bias of automated samplers that may not accurately characterize the presence of particles as small as 75 μm in stormwater (ASCE 2007) and can 'miss' an increasing proportion of sediment in stormwater with increasing particle size (Selbig 2008). Burton and Pitt (2002) summarize the percentage of total sediment load that may be lost based on the size of the particle and sampler intake velocity. The specifications for the ISCO 6712 automated sampler used in this study has a maximum intake velocity of 90cm/s. Using information in Table 15, it may be conservatively estimated that the sampler may have missed 25% of the particles in stormwater up to 3 mm (or 3,000 μm) in size. This issue is further compounded by the analytical methods used to determine sediment concentrations (e.g. total suspended solids versus suspended sediment concentrations) (Gray et al. 2000, Lenhart 2007, Selbig 2008). As a consequence, the usefulness of standard monitoring protocols to determine the effectiveness of street sweeping by comparing pretreatment and treatment stormwater pollutant loads is questionable.

Table 15. Losses of Particles in Sampling Lines (from Burton and Pitt 2002)

	30 cm/sec flow rate		100 cm/sec flow rate	
	Critical settling rate (cm/sec)	**Size range (μm, for ρ = 1.5 to 2.65 g/cm^3)**	**Critical settling rate (cm/sec)**	**Size range (μm, for ρ = 1.5 to 2.65 g/cm^3)**
100% loss	30	2,000 - 5,000	100	8,000 - 25,000
50% loss	15	800 - 1,500	50	3,000 - 10,000
25% loss	7.5	300 - 800	25	1,500 - 3,000
10% loss	3.7	200 - 300	10	350 – 900
1% loss	0.37	50 - 150	1	100 – 200

Storm Drain Inlet Cleaning

The data generated from the storm drain cleanout sampling (material concentrations, accumulation rates and density of materials) provide limited information to estimate the total amount of pollution removed by storm drain cleanout in Baltimore County. The monitoring program did illustrate the predominance of organic material accumulated in the storm drains and may likely be a potential source for nutrient transport to receiving waters. Although the total mass removed by storm drain cleanout for watersheds in Baltimore County is less than 1% of the total pollutant load at the watershed scale, it is estimated that 290 lbs of TN and 112 lbs of TP are removed annually from Baltimore County watersheds (DEPRM 2008). The characterization of the material accumulating in the storm drains (leaves and sediment) suggest that municipal pollution prevention/good housekeeping practices can play a critical role in reducing the amount of material that accumulates in inlets. For example, a municipal curb-side leaf litter pick-up program can prevent leaves from entering the storm drain system and when combined with street sweeping, these practices can be effective to reduce organic matter and sediment from entering the storm drains, especially at more critical times during the year (e.g. after leaf fall or in early spring as a result of winter de-icing practices).

5.2 Pollutant Removal Efficiencies using the Conceptual Model

To estimate the TSS, TN and TP pollutant removal rates for street sweeping and catch basin cleanouts within a particular subwatershed, the conceptual model presented in Figure 1 is used. To put the conceptual model into practice, a set of bounding conditions and assumptions were applied based on the literature review, survey findings and monitoring efforts and are described below.

The conceptual model identifies a list of factors that affect the removal or addition of SPaM. A list of discount factors is defined in Table 16. These factors reduce the effectiveness of street sweeping and storm drain cleanout practices. In some cases, assumptions had to be made in the absence of data or the lack of agreement among research findings to associate a value with these discount factors. As one example, estimation of sediment trapping efficiency by cleanout method and type of inlet were not available. The application of the conceptual model produces conservative estimates for pollutant load reductions that may be achieved by street sweeping and storm drain cleanout practices. The estimated percent removal efficiencies are considered to be representative of general urban characteristics, while best attempts have been made to reconcile the large variability presented in the literature and monitoring efforts. The values reported in italics in Tables 17- 22 represent best professional judgment as the literature review and monitoring efforts are limited for some model parameters. Overall, the estimated pollutant removal efficiencies are within estimates of other studies.

Table 16. Discount factors that reduce the effectiveness of SPaM for street sweeping and storm drain cleanouts.

STREET SWEEPING	**CATCH BASIN or STORM DRAIN INLET CLEANOUT**
• Removal of particulate-phase pollutants • Washoff • Fugitive dust loss[1] • Non-street area sources (e.g. runon)[2] • Frequency of sweeping (e.g., less than weekly)[3] • Equipment used/technology [3] • Street conditions (e.g., good or poor condition, residual dirt load)[1] • Access to curb (e.g., parked cars)[4]	• Coarse vs fine-grain sediment • Cleanout frequency[5] • % Catch basin/Inlet full (>50%) • Cleanout method

[1] Pitt (1979)
[2] Bannerman et al. 1993, Waschbusch et al. 1999, Pitt and Bissonnette 1984)
[3] See CWP (2006a) for a summary pick-up efficiencies for a range of street sweeping technology and frequencies
[4] APWA (1978) and Pitt (1979)
[5] Lager et al. (1979) and Pitt and Bissonnette (1984)

Street Sweeping Pollutant Removal Efficiencies

A hypothetical amount of 100 units of a type of pollutant is used to illustrate the application of the conceptual model to estimate the potential pollutant removal efficiencies associated with street sweeping. The treatable load is first estimated. It is the amount of pollutant that is available to be picked up by a street sweeper. The treatable load is initially determined by applying the discount factors to determine the treatable load. The particulate fraction of pollutants, such as total phosphorus or total nitrogen (e.g. TKN) needs to be determined. The particulate fraction of TP and TN were estimated based on the median stormwater concentrations for Chesapeake Bay communities found in the National Stormwater Quality Database (NSQD).

Factors that reduce the amount of material that is available to be picked up by the street sweeper, discount factors, to include fugitive dust loss and non-street area contributions. The fugitive dust loss is the dust created during street sweeping activities and is a constant for the examples given estimated at 10 percent. The treatable load is also affected by non-street areas that contribute to pollutant loadings but are not affected (or accessible) by street sweepers to include for example, rooftops, pervious areas, parking lots. Non-street area contributions would further discount the effectiveness of street sweeping. In this study, streets and alley represented 25.6% of the total catchment area in catchment O. Alleys and street areas that are not swept represent additional pollution source areas that contribute to pollutant loadings that are not affected by street sweeping. Source areas other than public streets and roadways may contribute between 10-45% of the total solids and up to two-thirds of TP (e.g. Waschbusch et al. 1999, Pitt and Bissonnette 1984) load. The discount factors for non-street area contributions are parameter specific where data is available. Although washoff may be considered an additional discount factor it is considered to be reflected in the reduced pick-up efficiencies for weekly and monthly street sweeping.

Once the treatable load is determined for each pollutant by applying the discount factors, the pick-up efficiency of the street sweeper is defined by the frequency of street sweeping, technology and obstructions during operation. To maximize the effectiveness of street sweeping, research suggest that the street sweeping frequency should be defined based on local rainfall statistics, where the optimal frequency is about twice the interim storm period. During the pretreatment and treatment periods for the current study, runoff producing rain events (greater than 0.1") occurred on average every 5-7 days. This agrees with findings of a number of studies completed over the past twenty years, which indicate that weekly street sweeping for residential and some commercial streets is needed to maximize pick-up of the street dirt load (Sartor and Gaboury 1984, Bender and Terstriep 1984, Sutherland and Jelen 1997, Brinkmann and Tobin 2001). Less frequent sweeping increases the probability that the street dirt load would likely be washed-off into the storm drains by rain and snowmelt. However, recent studies find that a weekly street sweeping frequency throughout a community, throughout the year may not be warranted based on daily SPaM loading rate for streets. Rather, targeted street sweeping during periods and areas when SPaM accumulation rates are high (e.g. early spring following winter deicing practices) is recommended.

Two technologies are presented in the conceptual model and represent the street sweeping technologies most commonly used in the Chesapeake Bay (CWP 2006b). Nearly three-quarters (73%) of Phase I and II communities use mechanical brush street sweepers while 27% rely on more modern street sweeping technology (regenerative air or vacuum). Monthly and weekly street sweeping frequencies are used in the conceptual model to provide a range of pollutant removal efficiencies given available data published in the literature. Given the treatable load that is available on the street, the PUE at the given frequency and technology is applied. However, the PUE may be reduced by the condition of the street and access to curb due to parked cars further reducing the treatable load and varies by pollutant type. For this example, the street condition is assumed to be in good condition with moderate parking where the sweeper moves around parked cars as needed. There is also the base residual street dirt that remains and is not washed during most rain events or even picked up by the most efficient street sweeper. The base residual may only be mobilized during the most extreme or intense rainfall event. Zariello et al. (2002) assigned an availability factor of eighty percent, indicating that twenty percent of the street dirt load would not be available for sweeping. However, the base residual would be a constant value for a street, rather than relative and would be very site specific and it is not applied to these example calculations. Particle size distribution will also affect street sweeper efficiency where larger particles will have a higher removal rate than smaller particles. For example, research, including the current study finds on average that 70% of the street sweepers load is comprised of particles greater than 250μm.

Table 17-19 provide pollutant removal efficiencies for TS, TP and TN using the conceptual model for street sweeping and values from the literature and other monitoring studies as reported in Table 16. The conceptual model is limited to two sweeping technologies (mechanical broom and regenerative air/vacuum) operating at two frequencies, monthly and weekly. These bounding conditions are based on survey findings reported in CWP (2006b) to reflect technologies currently being used in the Chesapeake Bay, but also to reflect street sweeping program characteristics needed to achieve some level of pollutant load reductions (e.g. vacuum or regenerative air technologies).

Using the conceptual model, it is expected that the range in pollutant removal rates from street sweeping for TS, TP, and TN are: 9 – 31%, 3-8% and 3-7%, respectively. The lower end represents mechanical, monthly street sweeping while the upper end characterizes the pollutant removal efficiencies for regenerative air/vacuum technologies at weekly frequencies.

The estimated pollutant removal efficiencies based on this model may be applied to communities where the amount of material removed by street sweeping is not known. In some communities, the SPaM collected by street sweepers is measured (CWP 2006b). Otherwise, the removal efficiency for street sweeping may be estimated by first estimating the SPaM loading on local streets using the values presented in Table 10 applied to local community characteristics (e.g. total street area, curb miles swept). Based on the street sweeping frequency the removal efficiency would be applied to the estimated total SPaM loading.

Table 17. An estimate of expected average pollutant removal rate for total solids (TS) using street sweeping.

Discount factor	Percent	Amount of available SPaM
Total street pollutant		100 units
Fugitive dust loss	10	90
Non-street area contributions	20	72
Treatable Load		
90% of street dirt within 12 inches of curb		64.8
	Percent Reduction	**Amount of material removed**
Pick-up Efficiency		
Monthly, Mechanical	18	12
Monthly, Reg Air/Vacuum	42	27
Weekly, Mechanical	25	16
Weekly, Reg/Air/Vacuum	60	39
Reduced effectiveness due to obstructions	20	
Monthly, Mechanical		9
Monthly, Reg. Air/Vac		22
Weekly, Mechanical		13
Weekly, Reg. Air/Vac		31

Table 18. An estimate of expected average pollutant removal rate for total phosphorus (TP) using street sweeping.

Discount factor	Percent	Amount of available SPaM
Total street pollutant		100 units
TP as particulate	54	54
Fugitive dust loss	10	49
Non-street area contributions	25	36
Treatable Load		
90% of street dirt within 12 inches of curb		33
	Percent Reduction	**Amount of material removed**
Pick-up Efficiency		
Monthly, Mechanical	*10*	3
Monthly, Reg Air/Vacuum	*15*	5
Weekly, Mechanical	20	7
Weekly, Reg/Air/Vacuum	30	10
Reduced effectiveness due to obstructions	20	
Monthly, Mechanical		3
Monthly, Reg. Air/Vac		4
Weekly, Mechanical		5
Weekly, Reg. Air/Vac		8

Table 19. An estimate of expected average pollutant removal rate for total nitrogen (TN) using street sweeping.

Discount factor	Percent	Amount of available SPaM
Total street pollutant		100 units
TP as particulate	33	33
Fugitive dust loss	10	30
Non-street area contributions	25	22
Treatable Load		
90% of street dirt within 12 inches of curb		20
	Percent Reduction	**Amount of material removed**
Pick-up Efficiency		
Monthly, Mechanical	*15*	3
Monthly, Reg Air/Vacuum	*20*	4
Weekly, Mechanical	35	7
Weekly, Reg/Air/Vacuum	*45*	9
Reduced effectiveness due to obstructions	20	
Monthly, Mechanical		3
Monthly, Reg. Air/Vac		4
Weekly, Mechanical		6
Weekly, Reg. Air/Vac		7

Storm Drain Cleanout Pollutant Removal Efficiencies

The ability to estimate pollutant removal efficiencies for storm drain cleanout (inlet or catch basin) is limited by the small amount of data obtained from the monitoring study. However, the monitoring study did provide an estimated accumulation rate between cleanout events (see Table 11). These and data from other studies (e.g. Pitt and Bissonette 1984) illustrate that inlets and catch basins accumulate a small proportion of total solids and, once removed, represent a small fraction of the total pollutant load. Information generated from the literature review, municipal practices survey, and monitoring study is used to define pollutant removal efficiencies using the conceptual model.

Annual and semi-annual cleanout frequencies can be used to estimate the potential pollutant removal efficiencies that may be provided by catch basin cleanouts. However, similar to street sweeping, the effectiveness is in part, driven by targeting the storm drains with high accumulation rates (e.g. the dirtiest of the bunch). Not all inlets or catch basins accumulate material in a uniform matter (if at all) and efforts to target these inlets or catch basins may be an efficient way to implement this practice

The conceptual model can be applied to estimate the efficiency with which storm drain inlets trap, or store material, and with which catch basin cleanouts reduce the total pollutant loading within watershed. Data generated from the monitoring study and Pitt and Bissonnette (1984) find that the particle size distribution in storm drains is similar to the SPaM, where 70% of the material is greater than or equal to 250µm. A weighted average of the material found in storm drains is used such that 55% of particles less than 250µm is retained and that all sediment greater than 250µm is retained, or settled out . For example, using the values from Table 20 the weighted average is determined by,

$$70 + (.55 * 30) = 93.$$

Tables 20-22 summarize pollutant removal efficiencies for TS, TP and TN estimated to range from 18-35%, less than 1-2% and 3-6%, respectively. The pollutant removal rate for TS and TN (expressed as TKN) is within the range reported by Pitt and Bisonnette (1984) at 25% and 5-10%, respectively.

Table 20. An estimate of expected average pollutant removal rate for total solids (TS) using storm drain cleanout practices .

Discount factor	Percent	Amount of sediment
Total amount of material		100 units
Sediment fraction < 250µm	30	
Sediment fraction > 250µm	70	
Percent fine particles retained	55	93
	Percent Reduction	**Amount of material removed**
Cleanout frequency		
Annual	39	36
Semi-annual	75	70
Reduced effectiveness due to reduced capacity	50	
Annual		18
Semi-annual		35

Table 21. An estimate of expected average pollutant removal rate for total phosphorus (TP) using storm drain cleanout practices .

Discount factor	Percent	Amount of sediment
Total amount of material		100 units
TP as particulate fraction	54	54
Sediment fraction < 250µm	46	
Sediment fraction > 250µm	54	
Percent fine particles retained	55	43
	Percent Reduction	**Amount of material removed**
Cleanout frequency		
Annual	3	1
Semi-annual	6	3
Reduced effectiveness due to reduced capacity	50	
Annual		< 1
Semi-annual		2

Table 22. An estimate of expected average pollutant removal rate for total nitrogen (TN) using storm drain cleanout practices .		
Discount factor	**Percent**	**Amount of sediment**
Total amount of material		100 units
TN as particulate fraction TKN	33	3
Sediment fraction < 250μm	29	
Sediment fraction > 250μm	71	
Percent fine particles retained	55	43
	Percent Reduction	**Amount of material removed**
Cleanout frequency		
Annual	14	6
Semi-annual	27	12
Reduced effectiveness due to reduced capacity	50	
Annual		3
Semi-annual		6

6.0 Conclusions and Recommendations

This report provides information on two municipal pollution prevention/good housekeeping practices – street sweeping and catch basin cleanouts – that can be used by communities to improve water quality in the Chesapeake Bay watershed. The results of this project provide information to support the estimation of the pollutant load removal provided by these practices in the Chesapeake Bay watershed. The pollutant removal efficiencies presented in this report are considered conservative and compare well with results from other studies, despite the gaps in the data collected from the monitoring study and the need to resolve key monitoring /sampling issues. These practices are most applicable in ultra-urban catchments where space limitations preclude the use of other more traditional BMPs.

The information used to estimate the pollutant removal efficiencies presented in this report included a literature review, a survey of street sweeping and storm drain cleanout practices in the Chesapeake Bay and data generated from the multi-faceted monitoring study. The data generated from the monitoring study reflects the conditions experienced by municipalities that may use these practices rather than the conditions experienced in controlled laboratory or field experiments. Quantifying the pollutant removal rates of these practices is challenging given the many factors that affect the ability to determine practice effectiveness in addition to the differences in scope, extent and design of other field studies. To make use of the wide range of pollutant removal rates reported for street sweeping a conceptual model was developed to provide pollutant removal efficiencies for

TS, TN and TP. The bounding conditions and assumptions for the conceptual model were based on the results of the monitoring study and data from the literature.

Despite the high pick up efficiencies of newer street sweeping technologies such as regenerative air or vacuum assist street sweepers, current monitoring protocols are challenged to detect significant differences in sediment and nutrient pollutant loading reductions that may be achieved from street sweeping. Additional pollutant contributions from areas other than public streets and roadways provide additional pollutant loadings that are unaffected by street sweeping reducing the effectiveness of this practice, in general. Similar conclusions have been made by other researchers conducting street sweeping studies where there are many sources of variability in such field-based studies that make any potential impact from street sweeping undetectable (e.g., Selbig and Bannerman 2007).

Although street sweeping is largely used to maintain aesthetics and to keep material out of the storm drain system (CWP 2006b), MS4 communities would like to use this practice as part of their larger efforts to reduce the amount of stormwater pollution that enters receiving waters and the Chesapeake Bay. Selbig and Bannerman (2007) and Breault et al. (2005) demonstrate much lower PUE and resultant pollutant loadings from mechanical sweepers compared to regenerative air and vacuum-based street sweepers. However, mechanical sweepers represent 25% of the street sweeping fleet in the Chesapeake Bay MS4 communities, increased to nearly 75% for mechanical sweepers with vacuum assist technologies (CWP 2006b). Only about one-quarter of Chesapeake Bay MS4 communities use the newer, more effective technologies and at a frequency (weekly) sufficient to achieve the pollutant loadings estimated by this study.

The storm drain inlet monitoring data revealed significant findings in terms of the composition of material accumulating within storm drains and their associated pollutant loadings. The particle size distribution of coarser material is similar to the distribution of SPaM. This is due to the ‘flow through system’ of storm drains without sumps or catch basins that comprise the majority of inlets in Baltimore County. The material composition provides insight into the type of source control practices that may be the most beneficial to reduce accumulation in storm drains. Such programs may include a curb side leaf pick-up program, given that leaves represented a majority of material that accumulated in catch basins between the fall and spring cleanouts. Sediment was nearly equal in mass to leaves in the storm drain inlets and suggests the continued need for street sweeping. To be most effective, however, street sweeping should target areas or times of year when SPaM loadings are high (e.g. 1,000 lbs/curb mile or more) such as after the winter de-icing practices have ended and before the heavy spring rain (Fries, 2008).
As a result of the monitoring study and a literature review, the following recommendations are made with respect to street sweeping and storm drain cleanout practices to reduce pollutant loadings to the Chesapeake Bay watershed:

Programmatic

- Adopt the pollutant removal efficiencies presented herein for mechanical and regenerative air or vacuum assist street sweepers used at weekly and monthly frequencies. Based on the municipal practices survey, few communities with the Chesapeake Bay use the more efficient street sweeping technologies or sweep at frequencies to achieve the pollutant removal efficiencies presented in this report.

- Develop street sweeping and storm drain maintenance program efforts to target areas and times during the year in communities that may receive the greatest impact from street sweeping or storm drain cleanouts.
- Implement a downspout disconnection program and/or an urban stormwater retrofit program that redirects and treats stormwater before it reaches the storm drainage system (via parking lots, roads, sidewalks, alleyways) in ultra-urban catchments, such as those in this study.
- Expand MS4 stormwater programs to include a curb-side leaf litter pick-up program that is able to maximize the reduction of leaf litter and prevent it from entering the storm drain. This is important for two reasons, 1) street sweepers avoid leaf piles and this reduces the effectiveness of this practice (sweepers may also emulsify leafy debris and make it more easily entrained by runoff, and 2) the decomposition of leaves and other organic debris in storm drain inlets or catch basins can create an environment suitable for the release of inorganic nitrogen and transport to receiving waters.

Research

- Conduct additional research on the implications of storm drain cleanout practices to include catch basins and chemical analysis of particle size distributions to estimate the pollutant load reductions from the different particle size classes
- Further evaluate stormwater monitoring techniques that can be used to account for the 'missing load' that occurs when using current sampling techniques to reduce potential bias in reported pollutant removal efficiencies.
- Research and develop alternative sampling techniques that can be used to collect more representative stormflow throughout the depth of flow and storm event.
- Adopt whole water sampling as a method to measure sediment in stormwater as an initial step to reduce the bias.
- Quantify bedload contributions to the total stormwater pollutant load. Although it may comprise a small portion of total stormwater load it can have a much larger impact due to the chemical characteristics of the material.

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Appendix A. Street Sweeping Schedule

FROM	
NAME & TITLE	Joseph A. Kolodziejski, Bureau Head
AGENCY NAME & ADDRESS	Bureau of Solid Waste 1000 Abel Wolman Municipal Building
SUBJECT	MECHANICAL STREET SWEEPING SIGNS

CITY of BALTIMORE

MEMO

DATE: October 27, 2005

TO

Mr. Frank Murphy
417 E. Fayette Street
5th Floor/Room 539

– MON

The purpose of this memorandum is to respectfully request you produce and post Mechanical Street Sweeping signs for West Baltimore, as follows:

N. VINCENT STREET

UNIT BLOCK	EVEN SIDE	MONDAY AND THURSDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY AND FRIDAY	7:30AM TO 11:30AM

N. BRUCE STREET

UNIT BLOCK	EVEN SIDE	MONDAY AND THURSDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY AND FRIDAY	7:30AM TO 11:30AM
100 BLK	EVEN SIDE	MONDAY AND THURSDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY AND FRIDAY	7:30AM TO 11:30AM
200 BLK	EVEN SIDE	MONDAY AND THURSDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY AND FRIDAY	7:30AM TO 11:30AM

FULTON AVENUE

UNIT BLOCK S.	EVEN SIDE	MONDAY AND THURSDAY	8:00AM TO 11:00AM
	ODD SIDE	TUESDAY AND FRIDAY	8:00AM TO 11:00AM
UNIT BLOCK N.	EVEN SIDE	MONDAY AND THURSDAY	8:00AM TO 11:00AM
	ODD SIDE	TUESDAY AND FRIDAY	8:00AM TO 11:00AM
100 BLOCK N.	EVEN SIDE	MONDAY AND THURSDAY	8:00AM TO 11:00AM
	ODD SIDE	TUESDAY AND FRIDAY	8:00AM TO 11:00AM
200 BLOCK N.	EVEN SIDE	MONDAY AND THURSDAY	8:00AM TO 11:00AM
	ODD SIDE	TUESDAY AND FRIDAY	8:00AM TO 11:00AM

N. MONROE STREET

UNIT BLOCK	EVEN SIDE	MONDAY AND THURSDAY	9:00AM TO 11:00AM
	ODD SIDE	TUESDAY AND FRIDAY	9:00AM TO 11:00AM
100 BLOCK	EVEN SIDE	MONDAY AND THURSDAY	9:00AM TO 11:00AM
	ODD SIDE	TUESDAY AND FRIDAY	9:00AM TO 11:00AM

N ADDISON STREET

UNIT BLOCK	EVEN SIDE	MONDAY AND THURSDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY AND FRIDAY	7:30AM TO 11:30AM

N. PAYSON STREET

UNIT BLOCK	EVEN SIDE	TUESDAY AND ~~THURSDAY~~ FRIDAY	7:30AM TO 11:30AM
	ODD SIDE	~~TUESDAY~~ MONDAY AND ~~FRIDAY~~ THURSDAY	7:30AM TO 11:30AM

W. BALTIMORE STREET

1600 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1700 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1800 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1900 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM

W. FAIRMOUNT AVENUE

1800 BLK	EVEN SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
1900 BLK	EVEN SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM

VINE STREET

1800 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1900 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM

N. MOUNT STREET

600 BLK	EVEN SIDE	MONDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY	7:30AM TO 11:30AM

N. MOUNT STREET

700 BLK	EVEN SIDE	MONDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY	7:30AM TO 11:30AM
800 BLK	EVEN SIDE	MONDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY	7:30AM TO 11:30AM

N. GILMOR STREET

600 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM
700 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM
800 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM

N. STRICKER STREET

800 BLK	EVEN SIDE	MONDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY	7:30AM TO 11:30AM

N. FULTON AVEUE

600 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM
700 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM
800 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM
900 BLK	EVEN SIDE	TUESDAY	7:30AM TO 11:30AM
	ODD SIDE	MONDAY	7:30AM TO 11:30AM

W. LAFAYETTE STREET

1500 BLK	EVEN SIDE	MONDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY	11:30AM TO 3:30PM
1600 BLK	EVEN SIDE	MONDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY	11:30AM TO 3:30PM
1700 BLK	EVEN SIDE	MONDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY	11:30AM TO 3:30PM

N ADDISON STREET

UNIT BLOCK	EVEN SIDE	MONDAY AND THURSDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY AND FRIDAY	7:30AM TO 11:30AM

N. PAYSON STREET

UNIT BLOCK	EVEN SIDE	TUESDAY AND ~~THURSDAY~~ FRIDAY	7:30AM TO 11:30AM
	ODD SIDE	~~TUESDAY~~ MONDAY AND ~~FRIDAY~~ THURSDAY	7:30AM TO 11:30AM

W. BALTIMORE STREET

1600 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1700 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1800 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1900 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM

W. FAIRMOUNT AVENUE

1800 BLK	EVEN SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
1900 BLK	EVEN SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
	ODD SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM

VINE STREET

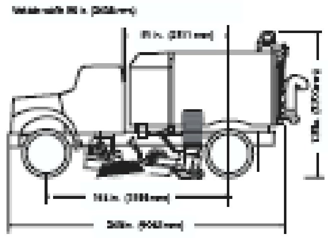
1800 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM
1900 BLK	EVEN SIDE	TUESDAY AND FRIDAY	11:30AM TO 3:30PM
	ODD SIDE	MONDAY AND THURSDAY	11:30AM TO 3:30PM

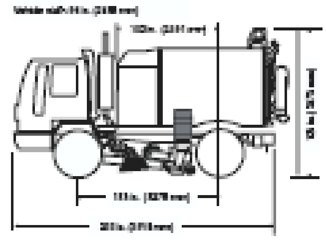
N. MOUNT STREET

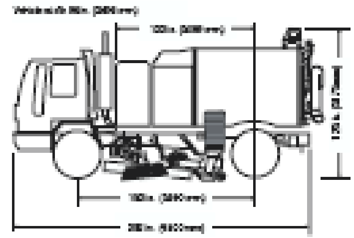
600 BLK	EVEN SIDE	MONDAY	7:30AM TO 11:30AM
	ODD SIDE	TUESDAY	7:30AM TO 11:30AM

Appendix B. Description of Elgin street sweeper.

Whirlwind MV







Sweep System–Components

General Specifications

Measured sweeping path (with 36" side broom):
- Suction nozzle only
  - 35 in. (890 mm)
- Suction nozzle and one side broom
  - 52 in. (1320 mm)
- Suction nozzle and extension broom
  - 78 in. (1981 mm)
- Suction nozzle, extension, and one side broom
  - 95 in. (2413 mm)
- Dual suction nozzles, side brooms and extension broom 144 in. (3658 mm)

Blower

Drive Fluid coupler and 5-groove banded power belt with adjustable idler pulley
Speed 3400 RPM
Blower Rating 20,000 CFM (562 m^3/min.) @4000 RPM
Blower Construction Abrasion resistant steel
Blower Housing 10 gauge (3.4 mm) steel, liners lined for extended wear

Vacuum Nozzle and Hoses

Nozzle Width 30 in. (762 mm)
Pickup Area 174 in^2 (1119 cm^2)
Construction Abrasion resistant steel components
Hose Connection Quick disconnect type at lower area near vacuum nozzle
Hose Construction Flexible rubber, steel reinforced
Hose 11 in. (280 mm) inside diameter

Side Broom

Diameter
- 28 in (711 mm) on 133" WB Sterling SC8000
- 36 in (914 mm) on 152" WB Sterling SC8000
- 36 in (914 mm) on 164" WB Freightliner FL70

Disc Construction Steel plate
Speed Constant
Drive Hydraulic motor, protected by relief valve
Mounting Free floating trailing arm
Motion Pneumatically inward/outward, raised/lowered
Tilt Adjustment Inward/outward, forward/backward
Digging Pressure/Wear Control Pneumatic in cab
Type Segment set disposable
Material Oil tempered steel wire

Extension Broom

Diameter 16 in. (406 mm)
Length 54 in. (1372 mm)
Speed Constant
Drive Hydraulic motor, protected by relief valve
Digging Pressure/Wear Control Pneumatic outside cab

Lift Control Pneumatic from control panel
Type Polypropylene prefab, disposable
Location Center of sweeper

Debris Hopper

Volumetric Capacity 8.0 yds^3 (6.0 m^3)
Floor Angle 10°
Dump Angle 50°
Construction 10 gauge (3.4 mm) steel sides and top, 1/4" gauge (6.4 mm) steel floor
Lifting Double acting hydraulic cylinder
Hopper Dump Door Hydraulic open/close and lock/unlock
Full Load Indicator Weight actuated with in-cab warning light
Hopper Screens Hinged, quick release, steel
Safety Prop Steel bar under body and inside rear door
Hopper Dumping Controls Hydraulic levers on right side of unit

Spray Water System

Water Tank Construction Dual polyethylene, removable
Water System Capacity 335 gal. (1268 L) standard
Pump Type Twin diaphragm with run-dry capability
System Flow 8 GPM (30 LPM) (2 - 4 GPM Pumps)
System Pressure 40 PSI (2.8 bar)
Spray Nozzles (Quick Disconnect Type)
- 7 inside each suction nozzle
- 4 at extension broom
- 2 at each side broom

Controls On/off at control panel
Filter 100 mesh, cleanable
Anti-Siphon Fill Standard
Hydrant Fill Hose 16 ft. 8 in. (5080 mm) with coupling

Hydraulic System

Purpose: Powers hydraulic motors on side broom, extension broom, and hopper cycle
Hydraulic Pump Capacity 8.3 GPM (31 LPM) @ 2500 RPM, each section (16.6 GPM Total)
Hydraulic Pump Direct gear driven, tandem type
Reservoir Capacity 23 gal. (87 L)
Filter 10 micron, spin-on type with in-cab restriction indicator

Sweep System–Power

Engine

Make John Deere 4045 TF275
- **Type** 4 cylinder Turbocharged Diesel
- **Displacement** 276 in^3 (4.5 L)
- **Horsepower** 115 (86 kW) @ 2500 RPM

Fuel Tank Capacity 50 gal (189 L)
Air Cleaner Two stage, dry type
Oil Filter Spin-on, full flow

Electrical System

Alternator 95 amperes
Battery 12 volt, 925 CCA
Lights Side broom, rear clearance, rear identification
Reversing Safety Electric back-up alarm, sweep components raise automatically
Circuit Breakers Manual reset
Wiring Harnesses Color coded, function stamped and labeled every 4 in (100mm)

Major Options

- Extra 280 Gallon Water For total of 615 gal
- High Volume 13 inch Leaf Suction Hose(s)
- Wandering Hose
- Side Broom Tilt
- Front Spray Bar
- Stainless Steel Hopper Floor, Sides & Rear Door
- Life Last Hopper Liner
- Inspection Doors
- Rear Flood Light(s)
- Rotating Beacon Light
- Automatic Lubrication System
- Variable Broom Speed
- PM-10 Compliant

ELGIN
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(847) 741-5370 Phone
(847) 741-3035 Fax
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P/N 0703163

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Appendix C. Characterization of streets in Catchment O for street particulate sampling.

Section 3: Lexington from Fulton to Mount
Section 7: Fayette Fulton to Mount
Section 8: Fayette from Monroe to Fulton
Section 9: Mount from Saratoga to Lexington

Street Section[1]	Condition[2]	Parking	LULC	Pictures
Lexington from Fulton to Mount	Curbs in fair condition Inlet structurally good	Yes	Residential Canopy on S-side of street	Looking west
Fayette Fulton to Mount	Good condition but curbs and inlet	Yes	Church on SW corner, open space(CG) on NE corner	Looking west
Fayette from Monroe to Fulton	Good curb, fair street condition, inlets good structurally	Yes	Comp LU to #7 (community center and CG lot)	
Mount from Saratoga to Lexington	West side brick gutter, east side looks in good condition	minimal	Few trees	Looking north

[1] All street sections are classified as having moderate traffic volume.
[2] Streets in fair to good condition, no major potholes, patchwork street repair, cracks in pavement

Street Section	Streetscape	Curb & Gutter	Inlet
Lexington from Fulton to Mount			
Fayette Fulton to Mount			
Fayette from Monroe to Fulton			
Mount from Saratoga to Lexington	No photo available	No photo available	

Appendix D ; Baseflow and stormflow water quality data for the pretreatment and treatment 1 periods for Catchment F and O (from DiBlasi 2008).

Baltimore Street Stormwater Before

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
6034	12/1/2004	33	16	<5	60	22000	35000	64	1.1	64	0.57	0.34	34	50	120
6039	12/7/2004	12	12	<5	45	13000	13000	69	1.3	86	2.1	0.27	82	130	160
6158	2/2/2005	36	36	8.8	59	1700	5000	77	2.5	22	1.7	0.64	46	22	60
6287	3/23/2005	21	28	11	88	200	3000	68	2.6	52	3.4	0.54	41	50	140
6289	3/23/2005	4.5	<2	<5	52	1300	8000	28	0.68	49	1.7	0.21	14	54	89
6361	5/24/2005	13	19	<5	80	30000	30000	61	1.7	33	1.3	0.2	33	29	100
6532	6/30/2005	14	20	<5	51	50000	220000	120	4.1	3	1.2	0.34	36	11	70
6533	7/5/2005	23	16	<5	76	170000	260000	82	1.7	120	1.8	0.65	48	110	210
6537	7/8/2005	8.4	9.8	<5	56	50000	90000	38	0.66	40	0.32	0.25	19	34	78
6626	8/9/2005	10	17	<5	58	140000	270000	110	1	7.5	0.94	0.26	21	8.5	54
6630	8/16/2005	28	47	6.1	150	80000	130000	120	5.1	58	2.9	0.6	82	76	240
6641	9/15/2005	51	28	12	150	110000	110000	160	3	61	1.4	0.15	63	87	210
6688	10/6/2005	38	23	8.9	130	500000	1300000	180	1.3	97	2.7	0.75	47	86	230
6860	10/21/2005	78	41	11	120	30000	30000	160	2.9	70	4	0.7	93	44	210
6865	10/25/2005	19	9.1	<5	53	24000	24000	120	3.9	13	0.78	0.16	16	9.7	45
6868	10/26/2005	9.1	12	<5	51	11000	22000	130	2.3	9.5	0.85	0.26	22	8.9	54
6917	11/16/2005	48	25	9.1	96	30000	90000	100	<0.05	87	2	0.42	100	78	170

Baltimore Street Stormwater After

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
7056	1/11/2006	19	7.8	<5	95	90000	90000	130	1.1	190	2.5	0.95	45	150	290
7114	2/16/2006	13	30	<5	66	13000	3000	170	3.4	37	0.77	0.32	140	34	92
7288	4/26/2006	30	15	<5	88	130000	300000	220	5.9	20	3.2	0.45	29	18	98
7328	5/11/2006	22	16	7.5	230	17000	30000	120	0.91	240	2.1	0.61	63	180	330
8239	11/16/2006	11	7.2	<5	74	90000	90000	130	0.64	100	5	0.34	21	110	140
8352	3/2/2007	21	16	5.9	32	30000	90000	160	2.2	250	2.2	0.5	76	160	250
8438	3/16/2007	25	11	<5	76	50000	50000	200	0.15	87	0.89	3.2	27	65	150
8483	4/12/2007	7.3	8.2	<5	53	13000	13000	190	0.7	100	1.1	0.39	40	210	220
8488	4/27/2007	36	17	<5	72	30000	30000	210	3.6	53	2.4	0.37	23	21	97
8537	5/17/2007	31	21	15	71	30000	30000	160	1.6	150	2.8	0.77	21	18	84
8627	6/29/2007	23	18	5.1	76	30000	50000	190	1.1	210	2.9	0.38	71	190	260

Baltimore Grab Before Data

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
5918	10/5/2004	<2	25	<5	28	<2000	<2000	220	6.9	<2.5	0.78	0.49	33	<5	28
6008	10/19/2004	5.5	14	5.7	33	>16000	>16000	180	8.2	<1	0.79	0.26	16	6.3	31
6010	10/26/2004	<2	11	<5	24	1700	1700	160	8.7	4.5	0.42	0.26	14	<5	<20
6012	11/9/2004	<2	14	<5	23	500	400	130	3.5	2.8	0.5	0.45	24	5.8	29
6030	11/16/2004	2.2	7.6	<5	21	30	110	140	4.4	3.2	0.59	0.54	11	<5	22
6037	12/7/2004	16	13	<5	66	3000	16000	100	3.8	17	2.6	0.29	23	18	89
6091	12/14/2004	<2	6.2	<5	<20	130	1600	140	7.7	1.8	0.5	0.14	12	<5	<20
6093	12/21/2004	4	35	<5	49	2300	2300	140	6.7	4.4	0.81	0.5	45	<5	48
6095	12/28/2004	<2	14	<5	<20	1600	50	130	5.4	1.8	0.67	0.1	22	<5	<20
6097	1/4/2005	3.5	19	<5	45	300	500	130	3.4	22	0.82	0.7	28	8	51
6098	1/11/2005	<2	18	<5	<20	17	30	170	5.8	<2.5	0.47	0.7	28	<5	<20
6154	1/25/2005	38	170	5	87	24000	24000	250	3.5	48	2.7	0.31	160	36	120
6156	2/1/2005	41	28	6.1	39	5000	8000	89	21	670	1.7	0.53	35	33	70
6159	2/3/2005	23	40	11	61	1600	24000	85	2.6	24	1.9	0.4	45	26	63
6160	2/8/2005	5.5	43	<5	37	1000	1000	220	5.7	1	1.7	0.26	54	<5	27
6187	2/15/2005	4	21	<5	38	<2	<2	220	11	11	0.26	0.19	23	<5	27
6228	3/1/2005	18	24	40	130	50000	50000	220	0.76	240	0.48	0.36	43	110	230
6230	3/8/2005	18	19	20	91	5000	5000	32	0.74	110	0.4	0.22	36	73	150
6334	4/26/2005	<2	14	48	<20	3000	7000	150	4.9	50	0.1	0.53	28	120	22
6336	5/3/2005	3	12	<5	28	11	50	180	0.94	3.2	0.09	0.23	18	<5	20
6338	5/10/2005	11	9.3	<5	37	400	700	170	5.3	93	0.95	0.24	18	<5	110
6339	5/17/2005	29	18	<5	45	5000	17000	260	4.8	40	2.2	0.36	27	19	62
6359	5/24/2005	5.1	19	<5	55	160000	>160000	140	5.2	3.5	1.4	0.35	28	<5	43
6399	5/31/2005	<2	46	<5	30	23	700	150	7.3	<2.5	0.61	1.2	100	<5	25
6442	6/7/2005	<2	17	<5	29	1300	1300	130	3.5	6	0.45	0.56	35	<5	30
6444	6/14/2005	<2	6	<5	26	110	500	150	26	0.6	0.28	0.21	12	<5	10
6505	6/21/2005	<2	19	<5	45	1700	8000	120	5.6	2.5	1.2	0.71	40	<5	26
6507	6/28/2005	<2	20	<5	41	300	2300	200	7.3	2.5	0.63	0.52	40	<5	29
6535	7/6/2005	<2	20	<5	37	300	3000	140	6.1	<2.5	0.18	0.94	39	<5	31
6615	7/12/2005	2.6	23	<5	40	130	300	140	6.9	1	0.59	0.78	38	<5	34
6619	7/19/2005	<2	16	<5	54	500	500	200	6.5	<2.5	0.17	0.71	29	<5	32
6621	8/2/2005	4.3	18	<5	32	50	80	230	6.8	2	0.6	0.93	30	<5	27
6623	7/26/2005	7.3	12	<5	31	900	900	220	5.7	4.5	0.29	0.62	20	<5	26
6627	8/9/2005	2.5	21	<5	35	13000	24000	380	9.6	1	0.78	1.1	40	<5	50
6629	8/16/2005	9.1	18	<5	70	7000	7000	180	6.6	2	0.78	0.74	27	<5	100

6634	8/23/2005	<2	6.8	<5	29	50000	>160000	170	6	8	1.4	0.34	17	<5	41
6637	8/30/2005	<2	12	<5	10	5000	5000	160	5.4	<2.5	0.62	0.98	23	<5	20
6639	9/13/2005	2.2	5.9	<5	31	500	400	160	6.1	1	0.4	0.15	13	<5	20
6685	10/4/2005	4.1	5.5	<5	27	>1600	90000	140	0.97	49	1.1	0.38	33	28	53
6691	10/12/2005	<2	16	<5	27	1700	3000	130	6.3	2	0.12	0.63	26	<5	39
6693	10/18/2005	9.1	13	<5	22	160000	>160000	200	4.9	6	0.24	0.21	24	<5	20
6870	11/1/2005	3.6	34	<5	85	2200	2700	170	11	5	1.1	1.4	51	<5	82
6911	11/8/2005	<2	33	<5	30	30000	50000	190	4.4	3	0.51	1	42	<5	22
6915	11/15/2005	7.1	38	<5	37	400	2300	180	3.6	9	0.66	0.49	79	5.4	41
7050	12/20/2005	<2	23	<5	23	230	230	180	56	1	<0.1	0.46	36	<5	10

Baltimore Grab After Data

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
7053	1/4/2006	2.6	7.1	<5	20	70	500	130	4.6	5.5	0.43	0.43	14	<5	10
7058	1/18/2006	7.3	6	<5	56	24000	24000	75	0.49	41	0.89	0.2	13	29	82
7110	1/31/2006	9.7	13	5.8	78	160000	230000	160	6	20	1.2	0.48	19	16	71
7112	2/15/2006	14	17	<5	66	500	230	100	2.3	18	1	0.24	40	21	79
7153	2/28/2006	<2	13	<5	33	<20	<20	140	5	7	0.09	0.22	26	6.8	30
7158	3/14/2006	<2	56	<5	48	<20	80	200	5	4	0.16	0.33	220	6.7	66
7242	3/28/2006	<2	9.8	<5	29	<20	<20	180	5.4	13	0.78	0.36	6.9	<5	10
7282	4/11/2006	8.2	3.4	<5	34	<20	40	200	5.8	<2.5	0.08	0.3	4.4	<5	26
7285	4/25/2006	6.7	3.9	<5	42	2400	9000	220	9	4.5	0.05	0.15	5.1	<5	30
7330	5/9/2006	7.4	2.6	<5	36	230	230	240	8.7	28	0.33	0.24	8.4	<5	33
7397	5/23/2006	5.5	21	<5	47	20	130	320	7.7	10	0.43	0.68	25	6.9	41
7400	6/6/2006	2.6	14	<5	44	40	500	200	1.1	2	0.22	0.18	15	5.2	36
7472	6/20/2006	<2	15	<5	63	300	2400	190	1.2	1	0.18	0.17	16	5.2	42
7544	7/5/2006	<2	3.6	<5	28	500	5000	200	1.5	1	0.12	0.12	7.6	<5	20
7589	7/18/2006	<2	25	<5	64	3000	16000	<1	11	<1	0.69	0.9	26	<5	56
7648	8/1/2006	2.8	2	<5	23	2400	16000	200	7.4	<2.5	1.3	0.1	2.4	<5	10
7705	8/15/2006	<2	<2	<5	42	230	1100	200	7.1	15	<0.1	0.16	3.1	<5	30
7910	8/29/2006	<2	2.3	<5	21	2400	30000	180	7.7	10	0.14	0.13	5	<5	20
7943	9/12/2006	<2	36	<5	27	2400	3000	340	1.3	36	1.1	2.1	290	8.4	100
7964	9/26/2006	2.8	4.3	<5	35	9000	16000	210	1.3	12	0.24	0.21	8.5	12	39
8037	10/13/2006	9.2	6.8	<5	45	220	3000	220	17	14	0.53	0.63	13	30	48
8040	10/24/2006	<2	6	<5	29	80	80	180	5.4	0.6	2.3	0.69	7.3	<5	21
8176	11/9/2006	<2	3.9	<5	31	1700	1700	190	6	6	2	0.27	6.4	8.4	20
8196	11/21/2006	<2	5.1	<5	25	40	60	260	5.3	1.4	0.49	0.52	5.2	<5	20
8237	12/5/2006	<2	14	<5	20	<20	20	210	5	7.5	0.28	1.2	34	<5	26
8284	1/18/2007	6.3	14	5.2	37	90	140	190	5.4	7	0.23	0.55	18	8.9	38

8287	1/30/2007	3.3	12	<5	45	20	20	170	5.3	7	0.18	0.4	11	7.6	21
8363	3/13/2007	<2	5.4	<5	<20	<20	<20	200	11	5.8	0.23	0.25	21	<5	22
8444	3/27/2007	<2	2.5	<5	<20	210	210	68	0.72	11	0.14	0.078	5.4	<5	10
8480	4/10/2007	2.3	32	<5	20	<20	<20	200	5.3	3.8	0.15	0.43	40	<5	20
8530	5/8/2007	<2	3.7	<5	<20	230	230	210	3.7	5.6	0.69	0.18	5.3	<5	10
8539	5/22/2007	<2	2.9	<5	10	9000	9000	150	0.33	<2	0.09	0.085	3.5	<5	10
8542	6/5/2007	<2	<2	<5	<20	800	3500	150	3.8	4	0.89	0.022	2	<5	<20
8626	6/19/2007	<2	10	<5	22	40	300	380	5	6.7	0.09	0.42	13	<5	26
8633	7/3/2007	3.3	11	6.5	10	1700	5000	220	3.4	<5	0.5	0.28	13	12	10

Lanvale Street Stormwater Before

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
6035	12/1/2004	7.6	3.7	<5	37	7000	30000	42	0.43	35	0.49	0.18	11	30	86
6038	12/7/2004	32	6.9	8.8	84	13000	30000	62	0.96	59	2.9	0.34	19	70	150
6089	12/10/2004	3.5	3.3	<5	<20	13000	30000	39	0.37	52	1.5	0.21	12	37	89
6157	2/1/2005	29	54	5.1	79	23000	23000	210	1	<1	2.4	0.29	86	45	140
6229	3/8/2005	53	29	40	170	3000	3000	98	1.5	260	0.94	0.52	52	140	290
6286	3/23/2005	12	<2	14	62	2300	3000	70	0.32	220	2.9	0.42	31	180	290
6288	3/23/2005	3.6	<2	7.4	52	3000	3000	31	0.24	81	1.6	0.21	13	57	100
6352	5/20/2005	21	5.5	<5	66	13000	22000	56	0.59	32	1.9	0.22	11	32	81
6439	6/3/2005	27	9.3	<5	100	17000	30000	50	1.2	78	2.1	0.49	23	63	150
6440	6/6/2005	19	5.6	<5	130	90000	90000	60	0.62	220	1.1	0.48	31	190	340
6536	7/8/2005	19	6.4	<5	54	50000	300000	41	0.36	59	0.52	0.31	11	46	94
6624	8/8/2005	7.8	5	<5	61	220000	800000	100	0.87	67	1.4	0.34	13	44	99
6687	10/6/2005	27	11	<5	79	230000	300000	200	0.77	86	2.3	0.59	25	71	180
6864	10/25/2005	60	4.8	<5	46	30000	30000	180	0.8	10	2.1	0.26	8.1	11	46
6867	10/25/2005	5.6	5.1	<5	45	30000	30000	150	0.93	15	0.63	0.12	7.7	11	45

Lanvale Storm After

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
7055	1/11/2006	<2	3	<5	67	<200	<200	170	1.4	33	0.87	0.082	19	49	74
7113	2/15/2006	23	6.7	<5	73	13000	13000	220	0.34	45	1.1	0.27	23	54	110
7327	5/11/2006	22	5.3	<5	58	160000	160000	100	0.58	240	1.5	0.57	29	150	210
7954	10/6/2006	15	6.6	<5	62	14000	50000	140	0.72	35	1.1	0.036	13	26	78
8042	10/17/2006	13	5.1	<5	49	30000	30000	95	0.26	31	0.97	0.21	9.2	20	55
8437	3/16/2007	24	6.5	<5	48	50000	50000	170	0.51	38	0.85	0.94	13	32	91
8482	4/12/2007	7	5.9	<5	46	17000	22000	120	0.64	94	1.7	0.32	18	77	130

Lanvale Grab Before

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
5919	10/12/2004	<2	2	<5	<20	<200	<200	90	1.6	1.2	0.49	<0.01	2.2	<5	<20
6006	10/19/2004	<2	2.6	<5	<20	2400	3000	110	1.8	2.2	0.52	0.023	3.5	<5	<20
6009	10/26/2004	<2	<2	<5	<20	240	240	100	1.8	3	0.56	0.017	3	<5	<20
6011	11/9/2004	<2	8.7	<5	<20	23	80	92	1.8	2.4	0.41	0.012	3.7	<5	<20
6029	11/16/2004	<2	2.1	<5	<20	8	8	150	1.6	1.8	0.5	0.014	2.9	<5	<20
6036	12/7/2004	9.9	7.3	<5	55	50000	50000	69	1.1	14	1.8	0.16	12	21	79
6090	12/14/2004	<2	<2	<5	<20	220	220	320	3.2	<1	0.47	0.017	2.3	<5	<20
6092	12/21/2004	6.8	19	<5	<20	240	300	250	2.7	27	0.59	0.098	31	330	31
6094	12/28/2004	13	<2	<5	<20	13000	13000	270	2.5	95	2.8	0.89	12	50	81
6096	1/4/2005	130	3	<5	26	3000	3000	260	1.9	170	2.1	0.21	18	34	170
6153	1/25/2005	36	46	<5	88	2700	2700	250	2.1	82	3.5	0.36	42	75	140
6155	2/1/2005	28	15	<5	43	24000	24000	150	1	220	2.7	0.24	30	96	160
6161	2/8/2005	<2	3.2	<5	41	1800	1800	440	2.4	14	1.8	0.11	4	7.9	33
6186	2/15/2005	<2	<2	<5	46	500	900	420	2	1	0.27	0.083	<2	<5	34
6227	3/1/2005	12	14	17	110	13000	13000	210	0.4	52	0.34	0.16	18	33	120
6231	3/15/2005	17	3.4	19	54	500	500	280	4.4	40	0.46	0.19	6.9	61	82
6335	5/3/2005	12	<2	<5	31	8000	13000	320	3.5	25	0.27	0.18	<2	7.1	32
6337	5/10/2005	50	5.1	<5	25	1300	2300	150	4.2	230	2.6	0.87	5.4	5.6	81
6360	5/24/2005	8.8	9.3	<5	60	160000	160000	120	1.8	11	0.73	0.12	13	12	61
6398	5/31/2005	9.4	<2	<5	23	50000	50000	310	3.9	16	0.73	0.69	<2	<5	20
6441	6/7/2005	<2	2.9	<5	67	13000	13000	200	4.5	<2.5	0.24	0.048	5.2	<5	26
6443	6/14/2005	45	2.7	<5	37	30000	160000	400	3	140	9.2	1.2	100	460	890
6504	6/21/2005	35	2.3	<5	31	50000	90000	380	9.7	260	18	1.4	150	440	690
6506	6/28/2005	6.2	3.5	<5	37	22000	160000	300	2.2	7.5	0.63	0.068	3.9	<5	20
6534	7/6/2005	3.7	5	<5	38	5000	8000	170	1.6	3.4	0.32	0.091	6.3	<5	34
6614	7/12/2005	76	2.8	<5	59	900	30000	310	3.2	260	0.65	0.049	20	43	220
6618	7/19/2005	3.4	2.4	<5	35	3000	3000	300	3.2	200	<0.1	0.46	11	56	120
6622	7/26/2005	<2	4.8	<5	43	>160000	>160000	370	2.9	42	0.24	0.25	11	23	48
6625	8/9/2005	3.7	6.4	<5	49	30000	>160000	180	1.2	2.5	0.59	0.1	7.9	8.5	55
6628	8/16/2005	73	20	<5	43	50000	50000	380	3	390	3.2	1.4	66	280	390
6633	8/23/2005	7	3.7	<5	23	5000	17000	280	2.8	140	1.9	0.56	22	94	120
6636	8/30/2005	<2	3	<5	33	300	14000	290	2.3	34	1	0.17	11	20	43
6682	9/20/2005	60	2.2	<5	57	30000	30000	170	9	140	1	0.32	46	100	340
6684	10/4/2005	95	2.1	<5	24	30000	50000	320	2.1	760	21	3.4	250	660	1200
6690	10/12/2005	<2	4.4	<5	25	500	90000	250	2.9	10	0.07	0.049	7.2	7	33

6692	10/18/2005	30	2.4	<5	21	30000	90000	350	4.5	240	4	0.78	49	150	330
6869	11/1/2005	5.2	2	<5	46	1400	5000	160	2.9	33	0.68	0.17	310	23	100
6912	11/8/2005	<2	<2	<5	35	50000	160000	230	2.6	34	0.2	0.076	3.6	8.7	40
6914	11/15/2005	3	2.7	<5	42	11000	17000	250	2.1	38	1.9	0.45	11	27	77
7049	12/20/2005	<2	<2	<5	29	300	300	270	2.6	3	0.15	0.14	<2	<5	<20

Lanvale Grab After

Event #	End Date	BOD5	DisCu	DisPb	DisZn	E. coli	Fec Col	Hardness	NO2-NO3	SS	TKN	TP	TotCu	TotPb	TotZn
Units		mg/L	µg/L	µg/L	µg/L	MPN/100 ml	MPN/100 ml	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
7052	1/4/2006	<2	<2	<5	20	400	400	200	2.4	7	<0.1	0.055	2.7	<5	10
7057	1/18/2006	9.8	4.8	<5	63	3000	3000	110	0.43	110	1.5	0.13	15	74	140
7109	1/31/2006	16	12	<5	62	30000	30000	120	0.99	43	1.8	0.3	19	47	110
7111	2/15/2006	4.8	5.7	<5	60	22000	22000	250	1.8	19	0.32	0.25	16	21	74
7152	2/28/2006	<2	3.4	7.2	39	5000	5000	200	3.1	10	0.22	0.059	3.1	7.2	54
7157	3/14/2006	8.2	5.3	<5	53	300	300	200	2.4	150	1.2	0.62	50	150	310
7241	3/28/2006	130	29	9.9	110	2000	23000	1100	7.4	8400	49	13	71	110	210
7284	4/25/2006	8	3.1	<5	53	50000	50000	380	2.9	36	1.9	0.48	10	31	74
7329	5/9/2006	120	12	<5	38	80000	240000	630	4	1500	5.1	1.8	290	1500	2000
7396	5/23/2006	50	2.5	<5	58	9000	9000	560	2.6	60	3.6	0.31	29	39	99
7399	6/6/2006	13	2	<5	41	9000	50000	340	1.8	60	2.4	0.36	11	73	110
7471	6/20/2006	28	16	<5	87	30000	50000	380	1	36	2.9	0.27	21	32	130
7543	7/5/2006	2	3.9	9.2	33	700	5000	310	3.1	7	1.6	0.062	5	<5	27
7588	7/18/2006	16	4.3	<5	43	2400	16000	400	2.9	180	3.1	0.88	470	430	360
7647	8/1/2006	<2	3.6	<5	20	1300	3000	200	3	17	0.4	0.1	18	13	26
7704	8/15/2006	32	2.1	<5	37	50000	110000	250	1.3	53	0.42	0.14	11	66	69
7909	8/29/2006	7.7	<2	<5	27	1300	5000	120	1.2	2.5	0.18	0.055	<2	6.7	10
7942	9/12/2006	5.8	<2	<5	30	5000	80000	330	2.2	33	0.17	0.08	9.1	45	58
7963	9/26/2006	<2	2.9	<5	20	3000	9000	230	1.9	3.5	0.35	0.059	2.4	<5	20
8036	10/13/2006	3.5	2.4	<5	21	300	300	320	2.3	20	0.4	0.12	6	22	32
8039	10/24/2006	2.6	2.6	<5	10	20	40	220	3.6	1.2	0.55	0.055	2.9	<5	<20
8175	11/9/2006	<2	3.6	<5	28	210	500	250	2.1	22	0.84	0.15	4.8	13	28
8195	11/21/2006	<2	<2	<5	10	230	300	290	2.9	12	0.15	0.077	3.8	10	24
8236	12/5/2006	<2	5	<5	49	<20	500	210	1.9	11	<0.1	0.033	2.3	<5	10
8283	1/18/2007	<2	<2	<5	10	230	230	220	2.1	21	0.38	0.091	8	21	44
8286	1/30/2007	10	9.6	<5	38	50000	50000	190	2.2	32	0.12	0.057	12	44	77
8362	3/13/2007	<2	2.4	<5	<20	80	80	180	3	4.5	0.09	0.041	3.3	<5	20
8443	3/27/2007	<2	<2	<5	<20	40	40	250	2.5	87	0.4	0.062	24	20	28
8479	4/10/2007	12	<2	<5	<20	3000	3000	240	2.5	150	0.36	0.063	6	22	73
8529	5/8/2007	26	7.6	<5	20	110000	110000	220	1.4	25	1.9	0.18	10	8.9	27

8538	5/22/2007	13	2	<5	40	2400	2400	140	1.6	3.2	0.78	0.095	2.6	<5	40
8541	6/5/2007	<2	2.7	<5	20	50000	50000	270	1.6	63	0.41	0.093	9.1	34	59
8625	6/19/2007	7.3	7.3	<5	20	340	1300	190	1.8	7	0.14	0.062	2.6	5.4	21
8632	7/3/2007	25	15	<5	57	900000	900000	320	1.9	190	1.9	0.26	65	130	300